Proceedings of the

V Simposio de Residuos Agropecuarios y Agroindustriales
IX Internacional Symposium on Agricultural and Agroindustrial Waste Management

November 4-7, 2025

Mar Del Plata | Argentina

Brazilian Society of Agricultural and Agroindustrial Waste Management - Sbera

Brazilian Agricultural Research Corporation
Embrapa Swine and Poultry
Ministry of Agriculture, Livestock and Food Supply

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PRESENTATION AND EDITORIAL COMMENTS

For the first time, the V Simposio de Residuos Agropecuarios y Agroindustriales and the IX International Symposium of Agricultural and Agroindustrial Waste Management (SIGERA) were held jointly as a single integrated event organized by the Instituto Nacional de Tecnología Agropecuaria (INTA) and the Sociedade Brasileira de Especialistas em Resíduos das Produções Agropecuárias e Agroindustriais (SBERA). By bringing together regional and international communities under one framework, the joint agenda aimed to strengthen scientific cooperation, foster technological innovation, and advance coordinated strategies for sustainable agricultural and agroindustrial waste management.

The organization of this symposium was made possible through the support of more than 30 collaborating institutions, 18 sponsors, and over 20 volunteers, whose dedication ensured the high quality of the event. Over four days of intensive exchange, the symposium gathered more than 340 participants from 11 countries and featured 274 scientific and technical contributions, along with 56 keynote lectures and expert talks. We would like to specially thank the Natural Resources Program and the Added Value Program of INTA. These contributions reflect the latest advances and the ongoing trajectory in the pursuit of sustainable solutions for agricultural and agroindustrial systems.

The abstracts compiled in this volume are organized into four major topics:

Waste management and treatment technologies: This topic includes advances in anaerobic digestion, biogas production, nutrient recovery, composting optimization, digestate post-treatment, thermochemical conversion processes, and innovative approaches to solid and liquid waste management in livestock, dairy, aquaculture, and agroindustrial systems.

Waste valorization strategies: This topic highlights the transformation of residues into value-added products such as biochar, compost and charcoal pellets, bioproducts derived from agroindustrial by-products, enzymatic and microbial processes, lignocellulosic biomass conversion, recovery of functional compounds, development of biofertilizers and organomineral fertilizers, and circular applications within production chains including potato, brewing, fisheries, dairy, fruit, and horticultural systems.

Environmental impact and sustainability: Contributions in this topic include nutrient balance assessments, greenhouse gas emissions, antimicrobial resistance in agroecosystems, monitoring of contaminants in soil and groundwater, life cycle assessment, water quality evaluation, and bioremediation strategies using microorganisms, microalgae, and phytoremediation approaches.

Circular economy and regulatory frameworks: In this topic, contributions explore business models, institutional and governance challenges, public policy instruments, certification schemes, food loss and waste reduction strategies, and case studies integrating circular economy principles into regional development.

A distinctive component of the event was the Dynamic Field Exhibition held at the INTA Balcarce Experimental Agricultural Station. This activity extended the scientific discussions into real operational settings, where technologies such as composting systems, pelletizing processes, and field application equipment were demonstrated in action. Producers, technical advisors, researchers, and private sector representatives engaged directly around practical challenges and scalable solutions, reinforcing the role of the symposium as a platform that connects science, industry, and the productive sector.

We firmly believe that advancing sustainable agricultural and agroindustrial waste management demands collective effort, scientific excellence, and sustained long-term commitment. The outcomes of the V Simposio de Residuos Agropecuarios y Agroindustriales – IX SIGERA 2025 edition provide a strong foundation for academia, policymakers, industry leaders, and producers to deepen collaboration, bridge research and practice, and accelerate the transition toward circular and regenerative production systems at regional and global scales.

We hope that this publication will serve not only as a record of the research presented, but also as a platform for continued collaboration, interdisciplinary dialogue, and innovation.

Elena Okada
Fabiane Goldshmidt Antes
Organizing committee

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WASTE MANAGEMENT AND TREATMENT

IMPACT OF ACIDIC, ALKALINE, AND PHYSICAL PRETREATMENTS ON THE ANAEROBIC DIGESTION OF CORN SCREENING RESIDUE DERIVED FROM THE BIOETHANOL INDUSTRY

Francisco Tomás Badin, María José Galván, Diego Acevedo, Pablo Fiorito, Analía Becker

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Anaerobic digestion is an effective technology for the energetic valorization of agro-industrial residues, enabling the conversion of organic matter into biogas. In this context, corn screening residue (CSR), a by-product of the bioethanol industry (Galvan et al., 2020), represents a promising substrate due to its starch content and other fermentable compounds. However, its lignocellulosic structure can hinder biodegradation, limiting process efficiency (Zhao et al., 2019). This study evaluated biogas production from CSR as a sole substrate, both untreated and subjected to physicochemical pretreatments. Untreated CSR was also compared with a physically pretreated sample in which particle size was reduced through milling. Acid and alkaline hydrolysis were applied to the milled CSR to enhance the availability of fermentable sugars. The alkaline pretreatment involved two pH levels (8.0 and 11.5) and three hydrolysis durations (12, 24, and 48 hours). For acid hydrolysis, two temperatures (65 and 85 °C), two durations (2 and 4 hours), and two acid concentrations (0.1 and 0.2% v/v) were tested. Anaerobic digestion assays were carried out under mesophilic conditions, and pig slurry was used as inoculum in all cases. Biogas production potential (BPP) for each sample was measured using volumetric displacement. The results showed that untreated CSR had a slower kinetic profile but yielded a higher cumulative biogas production. In contrast, hydrolyzed substrates exhibited a faster initial biogas production rate, attributed to the release of easily degradable sugars (Karthikeyan et al., 2024). However, this also led to rapid accumulation of volatile fatty acids (VFA), causing a sharp drop in pH and system inhibition, significantly reducing total biogas output (Beschkov et al., 2025). Moreover, unmilled CSR produced less biogas compared to its milled counterpart. These findings suggest that although chemical pretreatments can accelerate the initial biodegradation of CSR, they may also induce unfavorable conditions affecting process stability. Therefore, their application requires careful management, including strategies such as pH control or co-digestion with substrates that provide buffering capacity to mitigate acidification. Additionally, the results highlight that reducing CSR particle size enhances biogas production and improves substrate homogeneity. This work provides valuable insights into the limitations and potential of using CSR in anaerobic digestion, supporting its energetic valorization within a circular economy framework for the bioethanol industry.

Keywords: biogas; agro-industrial wastes; bioethanol; hydrolysis; corn.

WASTE IN TEXTILE AND APPAREL INDUSTRIES: CLEANER PRODUCTION TECHNOLOGIES FOR THE SECTOR

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The textile and apparel industries have a significant role in the Brazilian economy and they are also among the largest generators of solid waste. Cleaner Production (CP) is an environmental management strategy, that proves particularly effective in sectors characterized by high waste generation, such as textile and apparel industries. This study aimed to identify CP actions applicable to the management of textile solid waste. A Systematic Literature Review (SLR) was conducted in the CAPES Journal Portal using the descriptors "textile waste" and "cleaner production." From the 72 articles identified, 21 were selected based on their thematic relevance and presentation of applied results. The selected studies were analyzed regarding waste typologies, applied methodologies and technologies, challenges, and implemented outcomes. The research highlights mechanical recycling as the predominant strategy. Chemical recycling is also a highlight, especially for synthetic waste such as polyester, although its greater complexity. Upcycling emerges as an innovative and accessible alternative, facilitating the repurposing of waste into novel products including artisanal clothing and accessories. Additional identified strategies include zero-waste techniques, reverse logistics, the utilization of modeling and nesting software (CAD/CAM), circular design, and the application of regulatory instruments as Extended Producer Responsibility (EPR). The identified actions represent viable and replicable alternatives for management of textile and apparel waste, with the potential to mitigate environmental impacts, enhance resource value, and guide public policies towards sustainable consumption and production.

Keywords: systematic literature review; textile waste; circular design; sustainable consumption and production; zero-waste techniques; reverse logistics.

USE OF BANANA PEELS TO OBTAIN PRODUCTS WITH ADDED VALUE

Vitória Dassoler Longo, Nair Mirely Freire Pinheiro Silveira, Felipe Devens Bitencourt, Vitória Eduarda Wrublewski da Costa, Marcelli Powzum Amorim, Loisleini Fontoura Saldanha, Larissa Capeletti Romani, Gabriel Henrique Klein, Helen Treichel

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The increasing disposal of agro-industrial waste has encouraged extensive research into the valorization of this biomass. Among the most cultivated fruits is the banana (Musa sp.), with an annual production of over 150 million tons, approximately 35% of which is comprised of peels, yielding a substantial quantity of waste. One viable approach for valorizing this biomass is the production of biofuels and high-value-added compounds. In this context, the present study aimed to utilize banana peels to enhance the production of fermentable sugars and bioethanol, as well as to extract and quantify D-limonene, a compound with significant industrial applications. Initially, the banana peels were dried in a forced-air oven at 40 °C, ground to a particle size of 20 mesh, and stored at -20 °C. The extraction of D-limonene was performed using the Soxhlet method, with 8 g of peel and 200 mL of hexane (matrix: solvent ratio of 1:25) for 4 h at the boiling point of the solvent (68 °C). The resulting fraction was concentrated using a rotary evaporator (100 °C, 120 RPM), resuspended in 50 mL of hexane, and stored at -80 °C until further analysis. Optimization of sugar production was conducted using a Central Composite Design (CCD, 2^3), evaluating the effects of biomass load, sulfuric acid (H_2SO_4) concentration (for pretreatment), and cellulase enzyme concentration (for hydrolysis). The responses measured were total reducing sugars (after hydrolysis) and ethanol production (after fermentation). For the D-limonene extraction, 0.56 mg/g of dry matter was recovered, highlighting the potential of this biomass for use in integrated biorefineries. For sugar production, the best results were achieved with 15 g of biomass, 10% sulfuric acid, and 50 FPU/g of cellulase, yielding 11.88 g/L of sugars. Among the variables tested, only the enzyme concentration was significant, as confirmed by the statistical model ($p < 0.05$; $R^2 = 97.64\%$). Despite the high sugar release, ethanol production was relatively low (1.37 g/L), attributed to the accumulation of citric acid (9.05 g/L), a potential fermentation inhibitor. This highlights the importance of incorporating detoxification steps into future studies. Overall, the process optimization demonstrated high sugar yields with lower acid usage, offering economic and environmental benefits. Additionally, the recovery of D-limonene highlights the promise of a comprehensive biomass utilization strategy that integrates both its energy and chemical applications.

Keywords: d-limonene; agro-industrial waste; fermentable sugars.

FERMENTATION OF TRICHODERMA KONINGIOPSIS IN AIRLIFT BIOREACTOR FOR BIOCOMPOSITE PRODUCTION

Marcelli Powzum Amorim, Vitória Dassoler Longo, Loisleini Fontoura Saldanha, Nair Mirely Freire Pinheiro Silveira, Larissa Capeletti Romani, Vinicius Woitysiak, Altemir Mossi, Helen Treichel

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Wastewater treatment using microalgae has emerged as a sustainable and efficient alternative to conventional methods, distinguishing itself due to its capacity for pollutant removal and biotechnological potential. Microalgae accumulate biomass rich in industrially relevant compounds, such as enzymes. The objective of this work was to produce a fungal biocomposite through fermentation in an Airlift bioreactor using microalgae derived from wastewater treatment, while also investigating the impact of enzymatic activities on biocomposite production. The microalgae were cultivated at 28 °C under an average light intensity of 914.48 μmol m^{-2} s^{-1}, with a shading screen blocking 50% of natural light radiation to prevent photo-inhibition and promote microalgal diversity. Cultivation was carried out in a transparent 50 L tank containing anaerobically pre-treated sewage from a UASB reactor and 5 L of inoculum from native microalgae in sanitary wastewater obtained from the Candeia/Bauru-SP effluent treatment plant. The fungus Trichoderma koningiopsis was cultivated on potato dextrose agar medium, subcultured, and stored in a BOD incubator at 28 °C for 7 days. Fermentation was conducted in a sterile 3 L Airlift bioreactor. A total of 11.06 g of microalgae were added along with 16 mL of antifoam and distilled water, reaching a final volume of 2 L. The system was inoculated with 10^6 spores/mL of fungal suspension, and fermentation proceeded for 72 h at 28 °C, with 20 mL samples collected every 24 h for enzymatic analysis. After fermentation, the liquid was filtered, centrifuged, and stored for further analysis. Several environmentally and technologically relevant enzymes were quantified for their activity, including cellulase, amylase, peroxidase, laccase, lipase, protease, catalase, ascorbate peroxidase, superoxide dismutase, and tannase. Enzymes such as catalase and laccase showed no activity at any time point. Protease exhibited an initial activity of 119.44 U/mL at time zero, which declined over time. Lipase displayed low activity (0.90 U/mL at time zero) and became inactive by 48 h. Superoxide dismutase showed an initial activity of 11.01 U/mL, decreasing throughout fermentation. Cellulase had low initial activity (0.061 U/mL) but peaked at 24 h (0.969 U/mL), declining to zero by 48 h. This result was expected, as fungi of the Trichoderma genus are known to be efficient cellulase producers. Amylase reached its peak activity (60.83 U/mL) at 48 h, while ascorbate peroxidase followed a similar trend, peaking at 2.9 U/mL. Peroxidase also peaked at 48 h, with an activity of 3.05 U/mL. This study demonstrated the feasibility of producing a fungal biocomposite through the fermentation of microalgae cultivated in sanitary wastewater using Trichoderma koningiopsis in an Airlift bioreactor. The presence of cellulase confirms the fungus's efficiency in biomass degradation, while the activity of amylase and peroxidase suggests potential applications in biotechnological and environmental processes. These results reinforce the potential of microalgae as a sustainable raw material for biocomposite production, integrating wastewater treatment with the generation of value-added products.

Keywords: enzymes; microalgae; biotechnological; sustainable.

FERMENTATION OF *CHLORELLA* SP. WITH *WICKERHAMOMYCES* SP. AIMING AT THE PRODUCTION OF ENVIRONMENTALLY RELEVANT BIOCOMPOSITES

Vitória Dassoler Longo, Loisleini Fontoura Saldanha, Marcelli Powzum Amorim, Larissa Capeletti Romani, Helen Treichel

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Each year, bioethanol has gained increasing prominence, driven by pressure and the need to seek sustainable alternatives to fossil fuels. In this context, microalgae have become increasingly relevant, as they are composed of carbohydrates that, when broken down, release fermentable sugars, making ethanol production a viable option. This study aimed to optimize the production of third-generation ethanol from microalgal biomass. The enzyme used was from the brand Prodooze, widely used by brewers, with an enzymatic activity of 202.7 U/mL. Initially, the biomass was subjected to a pretreatment step using 100 mL of 0.2 M sodium phosphate buffer (pH 5.5) in 250 mL Erlenmeyer flasks. The flasks were frozen at -80 °C for 24 hours, then kept at 4°C for an additional 24 hours and finally placed in a thermostatic water bath at 100 °C for 10 minutes to achieve gelatinization and break down the carbohydrate chains. After pretreatment, the hydrolysis of the biomass was evaluated using a Central Composite Rotational Design (CCRD), considering the biomass and amylase enzyme amounts as variables. The biomass was filtered, and the specific amounts of amylase were added according to the experimental design. The experiments were conducted with agitation at 50 °C and 150 RPM for 1 h, during which the concentration of total reducing sugars was determined using the 3,5-dinitrosalicylic acid method. After hydrolysis, the pH was adjusted with acetic acid to a range of 4.5 to 5, and the fermentation process was initiated using the yeast Wickerhamomyces sp. The experiments were maintained under agitation for 48 hours at 30 °C and 120 RPM, with samples taken at 0, 12, 24, and 48 hours to determine the total reducing sugars and ethanol concentration. Ethanol was determined through distillation using a bench-scale distiller and subsequently analyzed spectrophotometrically with potassium dichromate. The results demonstrated the potential of microalgal biomass for producing third-generation ethanol, offering a low-cost alternative with significant potential to mitigate the environmental impacts caused by the intensive use of fossil fuels.

Keywords: microalgae; yeasts; sugars; ethanol; enzymes.

PURIFICATION METHODS FOR ENZYMES DERIVED FROM WASTE

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Enzymes are considered a valuable product; the size of this market is expected to reach USD 11.2 billion by 2029. Enzymes can be produced through the fermentation of various types of waste, and numerous studies in literature have successfully employed fermentation-produced enzymes for different industrial purposes or effluent degradation. To fully understand the relationship between an enzyme's structure and function, it is necessary to study its characteristics after purification. Purification involves separating and isolating specific enzymes to allow detailed research on their properties. Most techniques are expensive, time-consuming, and involve a multistep protocol, resulting in high costs. In this context, this research aims to provide a review of low-cost purification methods for enzymes obtained from waste. Precipitation has been widely used in enzyme extraction, leveraging the different solubilities of molecules in various solvents to isolate and purify these molecules within a mixture. Aqueous two-phase systems (ATPS) are a type of liquid-liquid extraction widely employed. The system consists of two compounds dissolved in an aqueous medium, which, at concentrations above a certain threshold, undergo liquid-liquid demixing. The implementation of this method does not require expensive equipment or reagents and has proven promising, demonstrating applicability in various enzyme purifications. The three-phase partitioning (TPP) system is a versatile method that combines extraction, separation, and purification processes. Three phases are typically formed by adding a certain amount of inorganic salt and an organic solvent to the crude extract, with enzymes accumulating in the intermediate phase. Studies have explored the combined use of TPP with ultrasound or microwave irradiation methods to increase purification yield. In conclusion, although the field of enzyme purification is equipped with numerous technologies, low-cost techniques remain scarce. It is not consistent to use expensive methods for purifying enzymes obtained from waste, where the goal is to reduce costs and make the process more sustainable. Despite advancements in systems, many still rely on basic separation techniques. It is essential to focus on studies that enhance the efficiency of techniques aligned with sustainable principles, aiming to properly manage waste and turn it into an important source of high-value-added enzymes, which can later be applied for various purposes.

Keywords: precipitation; aqueous two-phase systems; three-phase partitioning; low cost.

FEEDSTOCK AND PYROLYSIS TEMPERATURE SHAPE BIOCHAR PERFORMANCE IN ACIDIFIED AND CONTAMINATED SOILS

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Biochar is a carbon-rich material obtained through the pyrolysis of biomass under limited oxygen conditions, increasingly explored as a sustainable amendment for degraded soils. Its properties—and thus its agronomic and environmental performance—depend strongly on both the feedstock used and the pyrolysis temperature, making these variables critical when designing biochar-based soil management approaches. In this study, four types of biochar were produced from combining two types of residual plant biomass—discarded culms of the bamboo Guadua chacoensis (Rojas Acosta) Londoño & P.M. Peterson and pruning waste from Olea europaea L. (olive tree)—at two pyrolysis temperatures: 350 and 700 °C. All four biochar exhibited alkaline pH, with values increasing alongside pyrolysis temperature. The olive-derived biochar at 700 °C (BO700) showed the highest pH (9.66), specific surface area (284.76 $m^2\,g^{-1}$), and ash content (20.76%). Bamboo biochar at 700 °C (BB700), although lower in those parameters, recorded the highest EC (32.09 $\mu S\,cm^{-1}$). CEC varied with both temperature and feedstock: bamboo biochar showed a decreasing trend with increasing temperature (from 11.56 to 9.89 cmolc kg^{-1}), while olive biochar exhibited the opposite trend, reaching 20.38 cmolc kg^{-1} at 700 °C. Two acidified soils were amended—one agricultural (pH 4.86) and one contaminated with heavy metals (pH 5.48)— applying all four biochar at 5% (w/w). All biochar increased soil pH toward neutrality in both soils, with BO700 producing the highest pH values: 8.12 in the agricultural soil and 7.21 in the contaminated one. These results highlight the liming potential of biochar and its capacity to ameliorate soil acidity. To assess plant response, Lolium multiflorum Lam., a fast-growing forage species, was used as a bioindicator in a growth assay conducted under controlled conditions. Notably, in the agricultural soil, BO700 significantly reduced biomass yield—over 70% lower than other treatments—possibly due to phytotoxicity or salt stress. In the contaminated soil, no differences were detected in aerial biomass. These findings highlight the critical role of both feedstock type and pyrolysis temperature in shaping the physicochemical properties and functional performance of biochar. Also, underscore the importance of optimizing pyrolysis conditions and selecting appropriate feedstocks to maximize biochar benefits while avoiding undesirable side effects. The conversion of residual biomass into biochar not only improves soil properties and supports plant growth under specific conditions but also represents a viable circular economy strategy. By transforming organic waste into a valuable soil amendment, this approach contributes to sustainable land use, environmental impact mitigation, and more resilient agroecosystems.

Keywords: biochar; circular economy; plant growth; soil amendment.

USE OF FRUIT MIXED WASTE TO OBTAIN VALUE-ADDED BIOCOMPOUNDS

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A significant portion of food intended for human consumption is wasted throughout the production chain, highlighting the need for viable technologies to repurpose this waste. In this context, the present study employed a combination of fruit peels (pineapple, banana, lemon, orange, and mango), which are rich in various biocompounds, to extract D-limonene and produce bioethanol from fermentable sugars. Initially, the biomass was oven-dried, ground, and characterized based on its moisture content. D-limonene extraction was carried out using a Soxhlet apparatus with 1 g of fruit biomass and 25 mL of hexane for 4 hours. The resulting extract was purified using a rotary evaporator and subsequently resuspended in 50 mL of hexane. During the hydrolysis stage, the biomass was washed with distilled water in a Dubnoff bath to remove soluble sugars, then filtered and oven-dried. The solid fraction of the biomass was used for the production of fermentable sugars, with process optimization performed using a Central Composite Rotational Design (CCRD), evaluating the mass of fruit peels and the concentration of commercial cellulase as variables. Following hydrolysis optimization, bioethanol was produced by alcoholic fermentation of the sugar-rich hydrolysates using Wickerhamomyces sp. in an orbital shaker. Samples were collected at 0, 12, 24, and 48 hours to monitor sugar consumption, ethanol production, and the formation of organic acids. Total reducing sugars were quantified using the 3,5-dinitrosalicylic acid (DNS) method. Glucose, cellobiose, arabinose, fructose, ethanol, citric acid, and acetic acid were quantified by HPLC-RID, while GC-MS quantified D-limonene. A D-limonene yield of 6.41 mg/g was obtained. The optimization of the hydrolysis stage enabled a reduction in enzyme usage, and ethanol production achieved a glucose-to-ethanol conversion efficiency of 96.87% within 12 hours of fermentation, resulting in 7.14 g/L of ethanol. These results demonstrate that optimizing the hydrolysis process enables the generation of a satisfactory amount of fermentable sugars and, consequently, ethanol. Additionally, the extraction of D-limonene provides further valorization of fruit biomass through the recovery of a high-value biocompound.

Keywords: d-limonene; fermentable sugars; soxhlet; enzymatic hydrolysis; ccrd.

PHENOLIC COMPOUNDS FROM MIXED FRUIT WASTE: OPTIMIZATION OF ULTRASOUND-ASSISTED EXTRACTION

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The global expansion of fruit production and processing generates a substantial amount of waste annually. One way to repurpose this agro-industrial waste is by obtaining value-added products such as phenolic compounds, which are essential antioxidant agents. In this context, the present study aimed to optimize the extraction of total phenolic compounds (TPC) from a fruit mix residue composed of pineapple, banana, orange, lemon, and mango peels. Initially, the fruit peels were oven-dried, ground, and their moisture content determined. The effects of the biomass-to-solvent ratio, ethanol concentration, and ultrasound power on the TPC and antioxidant activity (AA) of the fruit mix extract were evaluated using a Central Composite Rotational Design (CCRD). Extraction kinetics were also assessed at 5, 10, 15, and 20 minutes. TPC quantification was performed using the Folin–Ciocalteu spectrophotometric method, while AA was measured through the DPPH free radical scavenging assay. The highest TPC concentration obtained was 12.34 mg GAE/g of dry biomass, achieved using a biomass-to-solvent ratio of 1:47, a 50% ethanol concentration, and 50% ultrasound power, with an extraction time of 10 minutes. The results obtained so far demonstrate the potential of utilizing fruit mix residue for extracting phenolic compounds, contributing to waste valorization and the development of value-added products of industrial relevance.

Keywords: waste; value-added compounds; antioxidant compounds; gallic acid; ccrd.

VALORIZATION OF PECAN NUTSHELL AS AGRO-INDUSTRIAL RESIDUE BY SUPERCRITICAL FLUID EXTRACTION OF ANTIOXIDANTS COMPOUNDS

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Valorization of byproducts from the agri-food industry has attracted growing interest particularly given the sector's growing demand for natural compounds with functional properties that enhance food quality. Pecan nutshells, typically considered industrial waste, are known to contain a variety of phenolic compounds with notable antioxidant activity, presenting an opportunity for their incorporation into food formulations. To capitalize on this potential, it is essential to develop laboratory-scale extraction methods that minimize degradation and preserve the bioactivity of these compounds, facilitating future industrial scale-up.

Supercritical fluid extraction (SFE) is an advanced, environmentally friendly technique for recovering bioactive compounds, that involves the use of a gas above their critical temperature and pressure. Among these, supercritical carbon dioxide (CO_2) is particularly advantageous due to its relatively low critical point (31 °C, 74 bar). Given the non-polar nature of CO_2, the solubility and selectivity for polar compounds such as polyphenols can be effectively enhanced by introducing co-solvents like ethanol.

The objective of this work was to extract polyphenols from the pecan nutshells (PNS) using supercritical CO_2 as solvent and ethanol as co-solvent, and to evaluate the antioxidant activity of the resulting extracts.

PNS obtained from the Delta region of Buenos Aires province were milled and divided into two fractions. One portion was subjected to acid hydrolysis with hydrochloric acid (yielding PNSH) to facilitate the release of bound phenolic compounds and thereby increase the total phenolic content (TPC), while the other portion (PNS) was processed directly.

The extraction processes were performed using a high-pressure unit (model HPU500, Eurotechnica GmbH, Germany). The setup included a solvent reservoir, cooling bath, heating elements, valves, a pump, and an extraction vessel. CO_2 (Gamasol, 99.5%) was employed as solvent, and ethanol was used as co-solvent. In each experiment, approximately 50 g of nutshell was impregnated with 25 mL of ethanol, contained with filter paper and loaded into the extractor vessel. The $scCO_2$ was pumped into the sample until pressure reached 40 MPa. The temperature was set at 40°C for each extraction process.

The results revealed total phenolic contents of 280.0 and 88.6 mg gallic acid equivalents (GAE) per gram of nutshell for PNSH and PNS, respectively. Antioxidant activity, assessed by the Oxygen Radical Absorbance Capacity (ORAC) assay, yielded values of 31.6 and 18.0 µM Trolox equivalents (TE) for PNSH and PNS, respectively. Additionally, the Ferric Reducing Antioxidant Power (FRAP) assay demonstrated values of 1002.8 and 176.0 µM TE for PNSH and PNS, respectively. These results demonstrate the effectiveness of hydrolysis in enhancing polyphenol release and antioxidant potential.

Conventional extraction using 80% acetone yielded only 0.3 and 0.2 mg GAE/g nutshell for PNSH and PNS, respectively. In contrast, the use of $scCO_2$ and ethanol achieved substantially higher recoveries of polyphenols with antioxidant activity. Specifically, PNSH extracts exhibited elevated TPC, ORAC, and FRAP values compared to PNS, demonstrating that the hydrolysis pretreatment effectively facilitated the release of polyphenolic compounds.

These results highlight the potential of pecan nutshells as a rich source of natural antioxidants for applications in food and cosmetic products.

Keywords: supercritical fluid; pecan nutshell; antioxidant compounds; agro-industrial residue.

IMPROVEMENT OF BIO-OIL PROPERTIES FROM CATALYTIC PYROLYSIS OF DRIED DISTILLER'S GRAINS WITH SOLUBLES (DDGS) USING ZSM-5 ZEOLITE

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This work presents the influence of a catalyst (H-ZSM-5 zeolite) on the physicochemical properties of bio-oil obtained from the pyrolysis of dried distiller's grains with solubles (DDGS), a lignocellulosic by-product from the corn bioethanol industry. The aim of the study is to improve the bio-oil quality by reducing its oxygen content and enhancing the yield towards compounds with a higher energy potential. The biomass was supplied by a company located in Córdoba, Argentina, and was washed with distillate water, dried at 80 °C in static furnace for 24h. Afterwards, it was grounded and screened through sieves to obtain a particle size of 0.5 mm. The pyrolysis reaction was carried out in a fixed-bed glass tubular reactor (23 mm I.D., 290 mm length) under nitrogen flow (20 ml/min), at a temperature of 550 °C for 10 minutes at atmospheric pressure. A biomass to catalyst mass ratio of 2:1 was used. The H-ZSM-5 catalyst was synthesized via hydrothermal method, showing crystalline structure confirmed by X-ray diffraction, a BET surface area of 383 m^2/g, and a total acidity of 93.36 μmol/g determined by pyridine-FTIR technique. The products of thermal and catalytic pyrolysis were compared through mass balance to evaluate phases yields and, by gas chromatography–mass spectrometry (GC-MS) for the liquid phase. Under catalytic conditions, a slight decrease in biochar yield and a relative increase in biogas production wereobserved, attributed to higher cracking and molecular fragmentation of the biomass. Regarding the bio-oil, although phase yields were similar between thermal and catalytic pyrolysis, this last showed a substantial improvement in bio-oil quality. A significant reduction in oxygenated compounds (70.80% vs. 43.90%) such as phenols, acids, and alcohols were achieved, with an increase in hydrocarbon content (10.70% vs. 20.90%), particularly toluene, xylenes, and ethylbenzene. This improvement is attributed to the catalytic mechanism proposed by several authors, involving a sequence of dehydration, deoxygenation, decarboxylation, and aromatization reactions promoted by the acid sites of the H-ZSM-5 zeolite. The acid sites facilitate the transformation of oxygenated intermediates into aromatics within the zeolite channels, maximizing deoxygenation while minimizing coke formation. The enhanced composition also positively affects the higher heating value (HHV) of the bio-oil, which was comparable to commercial bioethanol, and leads to the generation of stable products with promising fuel applications. This approach represents a sustainable and efficient route for the energetic valorization of agro-industrial residues.

Keywords: pyrolysis; biomass; catalysis; bio-oil; zeolites.

PROTEIN CONSERVATION IN BREWER'S SPENT BARLEY GRAINS DURING THE EXTRUSION-DRYING AND PELLETING PROCESS

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In Argentina, 1.3 million hectares of malting barley are cultivated annually, yet the reuse of brewer's spent grain (BSG) as animal feed remains very limited. Although BSG is a highly valuable by-product, comparable to alfalfa with a protein content of 19%, its main limitation is the high moisture content (75%) and a very short window for utilization. High transportation costs, fermentation, and mold growth can be avoided by drying the BSG after beer production, thereby increasing its availability as livestock feed. If the protein is preserved, it should not increase the nitrogen mineral forms. In drum dryers, moisture must first be reduced mechanically through extrusion. For this purpose, Industrias Montecor (Montebuey, Argentina) designed an extruder-dryer as part of the FONTAR-018 project. The objective of this study was to assess protein preservation during the extrusion, drying, and pelleting process of BSG. The study was conducted at Wesley Brewery (Bariloche, Argentina). Composite samples were taken from the initial BSG, after extrusion, and after drying. Protein content is the Total Kjeldahl nitrogen (Nt) multiplied by the conversion factor of 6.25. Nt was determined in duplicate, and inorganic nitrogen (Ni; ammonium and nitrate) was measured in triplicate. The dryer was calibrated to 90 °C at the end of the drum dryer, near the burner. The same parameters were also measured in the BSG leachate from the extruder and in BSG pellets. The output flow rate from the extruder and the maximum yield of dried material (kg h^{-1}) from the dryer were also determined. Average Nt (%) values were: initial: 3.2, extruded: 3.0, dried: 3.7, pellets: 3.1, and leachate: 0.16, corresponding to 20, 18.8, 23.1, 19.4, and 1% protein content, respectively. Average Ni (ppm) values were: initial: 24, extruded: 37, dried: 41, pellets: 64, and leachate: 35. No decrease in Nt was observed throughout the extrusion, drying, and pelleting process. Similarly, no significant increase in Ni was detected. These findings strongly suggest that Nt (and thus protein) was preserved during the extrusion, drying, and pelleting process, without exceeding 90 °C at the end of the dryer, where no material scorching was observed. Moisture content after extruding was 65%, preventing sticking inside the drum dryer. The leachate flow rate was determined to be 27 liters $hour^{-1}$, with a maximum dried BSG yield of 75 kg $hour^{-1}$, yielding a ratio of 0.36 L leachate kg^{-1} BSG. Considering a Nt concentration of 0.16% in the leachate, this corresponds to a nitrogen loss of 0.58 g kg^{-1} of BSG, or about 1.5% of the Nt in the dried BSG. The results suggest that protein is preserved during processing, and nitrogen losses in the extract are not significant.

Keywords: by-products; brewing industry; nitrogen.

VALORIZATION OF LEAFY VEGETABLE WASTE THROUGH ANAEROBIC DIGESTION FOR BIOGAS PRODUCTION

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In the context of the ongoing energy transition toward renewable sources, anaerobic digestion (AD) of organic waste represents a viable technological pathway for biogas production. In Mar del Plata, a company specializing in fruit and vegetable processing generates approximately 2.5 tons of leafy vegetable waste per day between June and October, coinciding with an increase in liquefied petroleum gas consumption for thermal processes such as blanching. To assess the technical feasibility of using this waste as an energy resource, an AD trial was conducted using a substrate composed of spinach (50%), broccoli (35%), and onion (15%).

At the INTI Mar del Plata laboratories, the substrate was characterized by determining total solids (TS), volatile solids (VS), carbon, nitrogen, phosphorus content, pH, and the carbon-to-nitrogen (C/N) ratio. The AD trial was conducted in a 50-liter semi-continuously operated biodigester with temperature control (35 ± 2 °C), mixing, and recirculation. An online monitoring system equipped with Raspberry sensors recorded ambient temperature, reactor temperature, biogas volume, and heater temperature every 10 minutes. The feeding was progressively carried out over a 45-day period. Key variables were monitored throughout the process: pH, VFA/TAC ratio, alkalinity, volatile fatty acids (VFAs), biogas composition, and digestate quality.

Additionally, a Biochemical Methane Potential (BMP) test was performed using the AMPTS II system at the INTI Miguelete Technological Park laboratory, employing Inoculum-to-Substrate Ratios (ISR) of 2 and 4 gVS_i/gVS_s at 37 °C.

Initial substrate characterization showed a TS content of 12.9%, a VS/TS ratio of 76.9%, and a pH of 5.8. After stabilization, the digester liquor exhibited parameters consistent with anaerobic conditions: pH 7.68, VFA/TAC ratio of 0.14, and VFA/TA ratio of 0.29, indicating good system stability.

During the experiment, a maximum organic loading rate (OLR) of 3.7 g VS/L·day was achieved without signs of inhibition. The average methane yield was 194 L CH_4/kg VS, with a peak methane concentration of 64% in the biogas. Elevated levels of hydrogen sulfide were detected (up to 1300 ppm), which may present technical challenges at an industrial scale. Biogas production per kilogram of fresh feedstock reached 41.4 L/kg. The BMP test confirmed the methanogenic potential of the substrate, with an average yield of 283 L CH_4/kg VS, showing no significant differences between the ISR values tested.

The evaluated residues are suitable for valorization through anaerobic digestion, demonstrating good operational stability, an appropriate C/N ratio, and no limitations under increased organic loading. Methane yields were within competitive ranges reported in the literature (Dhanalakshmi et al., 2015; Yan et al., 2017; INTI-GTZ, 2017). However, the high hydrogen sulfide content will require appropriate treatment for removal. While the overall process performance was satisfactory, the limited seasonal availability of this waste and its relatively low contribution to overall energy demand (~15%) restrict its use as a standalone biogas source. Co-digestion with carbon-rich residues or alternative valorization schemes is recommended.

Keywords: anaerobic digestion; biogas production; biomethane potential; leafy vegetable waste.

ENHANCING SWINE CARCASS COMPOSTING: EFFECTS OF MECHANICAL TURNING ON PROCESS DYNAMICS AND END-PRODUCT QUALITY

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The intensification of animal production, particularly in pig farming, presents major challenges for waste management, with the disposal of carcasses being one of the most critical issues. Traditional methods such as burial or incineration are increasingly being questioned due to their environmental and sanitary impacts. Against this backdrop, carcass composting emerges as a sustainable alternative, capable of transforming organic remains into a valuable resource through controlled microbial activity. This study examined the impact of mechanical turning on the efficiency of swine carcass composting and the quality of the product. The trial was conducted over seven weeks on a pig farm in San Antonio de Areco (Buenos Aires, Argentina) using a completely randomised design with two treatments: mechanically turned piles (T) and static piles (C). A windrow turner machine (Turner 280, EcoManagment®) was used for treatment T. Internal temperatures were monitored at depths of 20 and 60 cm. Additionally, the final compost was subjected to descriptive physicochemical analyses (BOD, density, pH, total nitrogen, organic matter, organic carbon, C:N ratio and nitrates) and microbiological analyses (coliforms and Salmonella sp. detection). Statistical analysis was performed using the student version of Infostat software (2020), applying ANOVA and Tukey's test ($\alpha = 0.05$) to compare the two treatments. The results showed that turning had a significant impact on thermal dynamics. Turned piles reached thermophilic temperatures (>60 °C) more quickly and maintained them for longer in the early weeks (e.g. week 1: 49.87 ± 2.46 °C vs. 41.20 ± 1.76 °C; $p = 0.0017$), demonstrating faster stabilisation and reduced internal thermal variability (mean CV <20%). By contrast, static piles had lower, more variable temperatures and potentially developed anaerobic zones. In terms of compost quality, the turned treatment exhibited higher BOD (11,808 mg O_2/L), organic matter content (56.1%) and a higher C:N ratio (10.01), indicating greater biological activity. However, it also had higher levels of coliforms (26,000 CFU vs. 4,600 CFU in the control group). Both treatments tested negative for *Salmonella* sp., meeting basic biosecurity standards. While the hypothesis was only partially confirmed, mechanical turning improved thermal efficiency, but not all compost quality parameters. The findings support its use as an effective technology to accelerate decomposition, improve process uniformity and promote more sustainable waste management in intensive pig production systems. Nevertheless, the final compost quality assessment was insufficient to fully characterise the process of evolution. This study provides valuable empirical evidence in support of the implementation of sustainable carcass composting practices and paves the way for future research aimed at optimising techniques and improving compost outcomes.

Keywords: biosecurity; circular economy; microorganisms; environmental management.

CHARACTERIZATION OF MICROBIAL COMMUNITIES IN ANAEROBIC DIGESTION SYSTEMS: EFFECT OF CARBON-BASED ADDITIVES AND AMMONIUM TOLERANCE

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Anaerobic digestion (AD) is a biological process that decomposes organic matter in the absence of oxygen, producing biogas, primarily methane. Ammonium (NH_4^+), derived from the substrate or from the mineralization of organic compounds, can inhibit methane production at high concentrations due to the sensitivity of the microbial communities involved, especially methanogenic archaea. Carbon-based additives can mitigate this effect by adsorbing NH_4^+, decreasing its concentration in the system.

The objective of this study was to evaluate the effect of activated carbon (AC) and almond shell biochar (B) as additives to improve performance, process stability, and microbial community structure in AD systems under potentially inhibitory NH_4^+ conditions. Three treatments were assessed: control (no additive), B (4% w/w), and AC (4% w/w), using semi-continuous bioreactors with an effective volume of 1.165 L. Each reactor was fed with laying hen manure diluted to 10%, at a volumetric organic loading of 3 gST/L.d (three times per week) for 110 days. The average ammonium concentration in the substrate was 4478 mg/L.

Before each feeding, biogas production was measured using the manometric method, and its composition was analysed weekly by gas chromatography. Physicochemical parameters in the digestate were monitored throughout the process. Microbial communities were characterized at the beginning and end of the trial by high-throughput sequencing of the V3-V4 region of the 16S rRNA gene to assess changes associated with NH_4^+ concentration and additive use.

No signs of process inhibition were observed in any of the treatments during the trial. Biogas production, methane content, physicochemical parameters, and the overall microbial community composition did not differ significantly between treatments. This suggests that the NH_4^+ concentration reached (7000-7500 mg/L) did not generate inhibition, which may explain the lack of differences between additive and control treatments.

However, differences in microbial composition were observed at the beginning of the trial. The control reactor exhibited higher diversity and dominance of Methanobacterium and Methanospirillum, whereas the AC and B treatments showed lower diversity, with a predominance of Methanosaeta (~90%). By the end of the trial, microbial communities converged toward a similar structure in all treatments, dominated by Methanosarcina and, to a lesser extent, Methanoculleus. Methanospirillum was detected at low levels in both additive treatments, and Methanimicrococcus appeared exclusively in the AC treatment.

These results indicated that, although the additives did not impact overall process performance or dominated taxa, they did influence microbial community structure, likely through selective adsorption mechanisms or the creation of microhabitats on porous surfaces. The final dominance of Methanosarcina in all treatments reflects a typical adaptation of stable AD systems. This archaeon, tolerant to high levels of ammonium and volatile fatty acids, outcompeted more sensitive genera, promoting the establishment of adapted communities to the system's conditions. The final convergence observed underscored the adaptive capacity to moderate environmental stress and highlights the role of Methanosarcina in maintaining long-term function in AD systems.

Keywords: anaerobic digestion; 16s rrna gene sequencing; ammonium tolerance; methanosarcina.

CARBON-BASED ADDITIVES IN PIG DIGESTATE COMPOSTING: IMPACTS ON MICROBIAL COMMUNITY STRUCTURE, FUNCTIONALITY, AND COMPOST QUALITY

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The management of anaerobic digestates represents a growing challenge for large-scale biogas plants. Separating the solid and liquid fractions offers advantages, allowing the use of the liquid fraction as a biofertilizer and the solid as a soil amendment. Given the physicochemical and microbiological characteristics of the solid fraction, composting is a viable strategy for its stabilization and sanitation. The incorporation of additives with sorption capacity may enhance the quality of the final compost and modulate the microbial communities involved in the process.

This study evaluated the impact of zeolite (Z) and spent activated carbon (AC) -the latter previously used for biogas H_2S filtration- on the composting process of the solid fraction of pig digestate (PD). Three treatments were assessed: control (100% PD), AC (95% PD + 5% AC), and Z (95% PD + 5% Z), each with three biological replicates. Temperature and moisture of the composting piles were monitored to determine three sampling points: T1 (initial phase), T2 (end of thermophilic stage), and T3 (maturation). At each time, physicochemical and biological variables were determined, and microbial community structure was analysed by high-throughput sequencing of the V3-V4 region of the 16S rRNA gene. Functional prediction of microbial communities was also performed to explore their metabolic potential and associations with physicochemical properties, and effects of the additives throughout the composting process and in the final compost.

Microbial communities were dominated by the phyla Firmicutes and Proteobacteria, with a progressive reduction in Firmicutes and an increase in Bacteroidota, Actinobacteriota, and Gemmatimonadota over time. These shifts were accompanied by an increase in the community richness, evenness, and diversity. Correlation analyses revealed that organic matter (OM) and ammonium (NH_4^+) modulated microbial communities at T1, while dry matter (DM), soluble phosphorus, nitrate (NO_3^-), and electrical conductivity (EC) played a more influential role at T3.

At the treatment level, the AC treatment showed a higher abundance of Patescibacteria, while Chloroflexi, Acidobacteriota, and NB1-j were more prevalent in the Z treatment. Functional profiles indicated a greater abundance of genes associated with the oxidation of reduced sulphur compounds in the AC treatment, possibly due to residual H2S adsorbed during its prior use. In contrast, the control treatment exhibited an increase in genes linked to denitrification and dissimilatory nitrate reduction during T2 and T3, potentially implying nitrogen losses.

These findings suggest, especially in Z treatment, a positive effect on compost maturation and stabilization of recalcitrant organic matter. Additionally, reusing AC generated within the biogas plant represents a sustainable circular economy strategy for managing internal residues. Overall, the inclusion of additives modulated both the structure and functionality of microbial communities during composting, promoting more complex microbial networks and creating favourable conditions for obtaining higher-quality compost.

Keywords: pig digestate; composting; carbon-based additives; microbial community structure.

DARK FERMENTATION FOR H2 PRODUCTION USING AGRICULTURAL DIGESTATE AS A STRATEGY FOR PH CONTROL AND MICROBIAL REINOCULATION

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Dark fermentation has emerged as a promising route for hydrogen production from organic waste, particularly due to its potential integration with anaerobic digestion systems. Although promising, this process still faces challenges, especially regarding the achievement of continuous output on a larger scale. To ensure stability and efficiency in hydrogen production, it is essential to control parameters such as hydraulic retention time (HRT), solids retention time (SRT), and pH. In this context, this study investigated the use of digestate derived from a CSTR fed with cattle manure as a strategy for reinoculation and pH control in an acidogenic reactor aimed at biohydrogen production. The reactor, with a working volume of 12 L, was inoculated with 7 L of digestate and 5 L of swine manure. The digestate was previously alkalinized (pH 10) with 1 mol L^{-1} NaOH for selective inhibition of methanogenic microorganisms, followed by neutralization with 0.5 mol L^{-1} HCl to reach pH 6. This step aimed to ensure a fermentative environment dominated by acidogenic and hydrogen-producing bacteria. The substrate used was sucrose, applied at an organic loading rate (OLR) of 20 g_{VS} L^{-1} d^{-1}, simulating a highly fermentable substrate. The pH was automatically controlled within the range of 5.8–6.2 by adding alkalinized digestate whenever the reactor pH dropped, using a peristaltic pump and a digital pH controller. In addition to acting as a buffering agent, the digestate was continuously reintroduced into the system as a strategy for renewing the active microbiota, contributing to the maintenance of an adapted and functional microbial community throughout the operation. The reactor was operated for 120 consecutive hours. During the initial stages (first 60 hours), oscillatory behavior was observed in gas production and hydrogen concentration, attributed to adjustments in feed flow. The best performance was obtained with feeding divided into 24 daily cycles, with flow rates of 15 mL per cycle, resulting in a cumulative H_2 production of 30 L within 20 hours. These results indicate that the digestate from the CSTR fed with cattle manure was effective as an inoculant and pH regulator, preventing inhibition of hydrogen production. Furthermore, the digestate generated in the acidogenic reactor can be used in the methanogenic stage, since dark fermentation promotes substrate hydrolysis and acidification, increasing its bioavailability and favoring subsequent biogas production. Further studies are recommended to optimize operational parameters and determine the technical and economic feasibility of this configuration.

Keywords: Bio-hythane, Acidogenic, pH control, microbial reinoculation, agricultural waste.

HOUSEHOLD GREYWATER TREATMENT AND REUSE FOR IRRIGATION: A PILOT PROJECT USING CONSTRUCTED WETLANDS IN MENDOZA'S DRYLANDS

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The growing global scarcity of freshwater—exacerbated by climate change, declining precipitation, and increased pollution of surface water bodies—demands the implementation of effective water management strategies. In the metropolitan area of Mendoza, Argentina, domestic potable water consumption reaches approximately 487 liters per capita per day, far exceeding the World Health Organization's recommendations. This situation is particularly critical in arid regions, where access to water supply networks is limited. In this context, the safe use of household greywater emerges as a viable alternative to reduce potable water demand and promote more efficient use of the resource.

This project, initiated in 2024, involved the design, construction, and commissioning of three household-scale greywater treatment systems based on horizontal subsurface flow constructed wetlands in Lavalle, an arid region in Mendoza. The objectives of the project were: (i) to reduce potable water consumption through the reuse of treated greywater; (ii) to assess system performance in terms of effluent quality and quantity; and (iii) to promote sustainable water management practices in resource-constrained communities.

Each treatment system consists of two main components: a primary settling unit (decanting tank) and a subsurface flow wetland (biofilter). The settling unit provides physical separation of fats and suspended solids via flotation and sedimentation, using 50-liter plastic containers. The wetland component is composed of a filtering medium made of inert gravel (washed crushed stone) housed within a sealed bed, which supports both emergent macrophyte growth and the development of microbial biofilms responsible for biological treatment processes.

The selected plant species exhibit morphological and physiological adaptations to saturated conditions, such as the presence of aerenchyma tissue, which facilitates oxygen transport to the rhizosphere. Key species include Typha sp., Scirpus sp., Phragmites australis, Zantedeschia sp., and Equisetum arvense. The systems operate via gravity flow, taking advantage of the natural slope of the terrain, and are designed to treat approximately 100 liters of greywater per day per household.

Routine maintenance is required to ensure long-term functionality, including cleaning of the settling tanks and seasonal pruning of vegetation to prevent clogging of the filter bed and maintain treatment efficiency. To date, three systems have been installed, with a monitoring and evaluation phase underway. This will include physicochemical and microbiological analyses of influent and effluent water to assess treatment performance.

The treated effluent is intended for the irrigation of surrounding trees and vegetation, with low levels of organic matter, pathogens, and residual chemical compounds. This initiative contributes to enhancing water resilience in vulnerable communities and reinforces sustainable practices in the decentralized management of domestic wastewater.

Keywords: biofilter; nature-based solutions; subsurface wetlands.

CONSTRUCTED WETLAND FOR THE TREATMENT OF MIXED EFFLUENTS AT INTA MENDOZA: DESIGN, PROGRESS, AND PROSPECTS

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Mendoza is facing a critical decline in water availability, marked by a sustained reduction in the discharge of its main rivers. Simultaneously, the generation of urban, industrial, and agro-industrial wastewater has increased significantly, often lacking appropriate treatment prior to final discharge. In this context, decentralized wastewater treatment represents a key strategy for water conservation and resource recovery, mitigating environmental impacts and promoting the safe reuse of treated effluents. Nature-based Solutions (NbS), such as constructed wetlands (CWs), integrate physical, chemical, and biological processes for wastewater treatment, leveraging the synergistic action of macrophytes, microbial communities, and filtering substrates. These systems are characterized by low energy consumption, reduced operational costs, and high adaptability, offering a sustainable alternative for wastewater treatment in both urban and rural settings. Moreover, by enabling the reuse of treated effluent for irrigation, CWs contribute to closing nutrient and water cycles, in line with circular economy principles and integrated water resources management.

Within this framework, INTA Mendoza launched a project in 2024 aimed at the design, construction, and evaluation of a horizontal subsurface flow constructed wetland to treat more than 1,500 m^3/year of mixed effluents generated by an experimental winery, laboratories and sanitation facilities, serving approximately 50 people. The system goal is to treat a mixture of residential and industrial wastewater, with subsequent reuse as an irrigation resource in an experimental Malbec vineyard. The objectives of the project are to: (i) generate evidence and technical knowledge on the performance of CWs in the treatment of mixed-origin effluents; (ii) develop and validate environmentally sustainable treatment technologies; (iii) assess the reuse of treated effluent in a Malbec vineyard in terms of soil physicochemical and microbiological properties, vine physiological responses, and potential impacts on oenological quality and ecosystem biodiversity; and (iv) promote the adoption of bioremediation-based technologies in liquid waste management. During the first year, significant progress was achieved: coordination with key stakeholders (public and private), technical visits to existing CWs in the region, site selection, baseline surveys of local fauna and microfauna, and system design. The 90 m^2 horizontal subsurface flow wetland is expected to treat approximately 4,000 liters of effluent per day and will include plant species adapted to local conditions such as Typha sp., Phragmites australis, and Cyperus alternifolius, along with ornamental species including *Canna* sp., *Iris* sp., *Zantedeschia* sp., and *Hedychium coronarium*. All species are currently being evaluated in small-scale pilot systems operating on-site. The treated effluent will be reused to irrigate a 1,000 m^2 plot of a 30-year-old Malbec vineyard (Vitis vinifera L.), trained on vertical shoot positioning trellises and irrigated via a drip system. The effects of reuse will be monitored through the evaluation of Soil physical, chemical, and microbiological parameters, as well as the vegetative development of vines and wine composition. This initiative is envisioned as a replicable model for residential areas, public institutions, educational centers, and agro-industrial facilities, integrating wastewater treatment, water reuse, and ecological restoration.

Keywords: bioremediation; industrial effluents; nature-based solutions; sewage effluents; water reuse.

VALORIZATION OF AGRO-INDUSTRIAL WASTE: PRETREATMENT AND CHEMICAL COMPOSITION ANALYSIS FOR BIOTECHNOLOGICAL APPLICATIONS

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The conversion of agricultural and agro-industrial residues into sustainable biomass for bioenergy production and valuable chemicals compounds contribute to greenhouse gas emissions mitigation and promotes the valorization of waste. Due to their recalcitrance, pretreatments are necessary to increase the accessibility of cellulose and hemicellulose to hydrolytic enzymes. In this study, two physico-chemical pretreatments were applied to grape pomace (GP) and Sorghum bicolor bagasse (SB). The physical pretreatment involved grinding biomass to a particle size of 2 mm, followed by chemical pretreatments. The chemical methods comprised an alkaline pretreatment using 2N potassium hydroxide (KOH) (hereafter referred as pKOH) and a hot water pretreatment at 90 °C (hereafter referred to as pH_2Oc). SB was subjected exclusively to alkaline pretreatment (SB-pKOH), whereas GP received both alkaline (GP-pKOH) and hot water pretreatment (GP-pH_2Oc). Total polysaccharide and monosaccharide compositions of pretreated biomass were analyzed using the following methods: (1) the Dubois assay for total carbohydrate quantification, (2) complete acid hydrolysis with 0.5M trifluoroacetic acid (TFA) for monosaccharide composition analysis, (3) thin-layer chromatography (TLC), and (4) high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD) for the composition and characterization of mono- and oligosaccharides, using arabinose, galactose, glucose, and xylose standards with external calibration curves. Hemicellulosic fractions were characterized by proton (1H) and carbon (13C) using a nuclear magnetic resonance (NMR) spectroscopy (Bruker 400 MHz). For 1H NMR analysis, samples were dissolved in deuterium oxide (D_2O). For 13C NMR, spectra were referenced to the solvent signal of deuterated methanol (CD_3OD). The spectra were referenced to D_2O and CD_3OD for 1H and 13C, respectively. SB-pKOH contained 90% of total carbohydrates. Monosaccharide analysis revealed a composition predominantly of xylose, with minor amounts of arabinose, galactose, and glucose in molar ratios of 1:0.12:0.072:0.0013, respectively. The anomeric proton signals correspond to xylose, arabinose, and galactose, while anomeric carbons signals confirmed the presence of xylose as a major component. In addition, the pretreated SB (SB-pKOH) was subjected to enzymatic hydrolysis using the recombinant bifunctional xylanase Xyl10E, which showed specific activity, confirming the accessibility of hemicellulosic substrates. On the other hand, GP-pKOH and GP-pH_2Oc contained 41% and 37% total carbohydrates, respectively. Monosaccharide analysis revealed the presence of xylose, arabinose, glucose, galactose, and rhamnose in molar ratios of 1:0.18:0.17:0.14:0.07 in GP-pKOH, and 1:0.71:0.66:0.53:0.30 in GP-pH_2Oc. NMR analysis showed complex polysaccharide profiles without a predominant hemicellulosic fraction, consistent with the total carbohydrate content. Furthermore, 1H-NMR spectra revealed greater structural complexity in GP-pH_2Oc compared to GP-pKOH. The sugar composition was consistent across all analytical methods. For GP, the alkaline pretreatment (pKOH) predominantly released xylose, while hot water pretreatment (pH_2Oc) yielded a more complex monosaccharide profile, a factor that may influence the design of future enzymatic hydrolysis strategies.

Keywords: agro-industrial waste; pretreatments; composition characterization.

MOLECULAR DYNAMICS OF THE ADSORPTION OF POLYPHENOLS FROM RED QUEBRACHO TANNIN ON MCM-41: PRELIMINARY STUDIES OF SYSTEMS FOR REVALORIZATION AND WATER TREATMENT

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In industrial processes involving the production of natural products with high polyphenol (PP) content, it is common for not all produced batches to meet sector standards and specifications. Aiming to reduce costs and minimize losses, different revalorization strategies are now being explored. There is, for example, growing interest in developing encapsulated polyphenolic extracts with potential applications in sectors such as agriculture. Materials like zeolites and mesoporous solids have been reported as good carriers for these bioactive compounds, opening new opportunities to add value to products that would otherwise be discarded. Its application can also be considered in effluent management, since selective adsorption using these materials constitutes an efficient option for the removal of PPs from wastewater. This technology helps in purifing the water and can also recover valuable compounds, close cycles and promoting more sustainable production. By using Molecular Dynamics (MD), the scope of this work is to understand and compare the adsorption mechanisms of two dimeric PPs —leucofisetinidin-(4β→8)-catechin (PN) and an ionic sulfited derivative (PSI)— present in red “chaqueno” quebracho tannin onto mesoporous silica materials (MS), specifically MCM-41. The solid material was represented by a model channel 30 Å in diameter and 116 Å in length. Each PP was manually placed at the center of the mesopore channel, the system was solvated and then optimized using AmberTools. Ten replicas of each of the two polyphenol-mesopore systems were simulated via MD using OpenMM, with trajectories analyzed by VMD (Visual Molecular Dynamics) and cpptraj. From these 10 replicas, polyphenol adsorption energies were calculated using the MM-GBSA approximation, along with the diffusion coefficient (D) of the PFs within the mesopore. Further molecular interaction analyses were performed within the framework of the reduced density gradient (RDG) using NCIPLOT (Non-Covalent Interaction Plot) software. To this end, two replicas of the systems were explored: one with the longest distance of the PP from the surface and the other with the shortest. Preliminary results reveal distinct differences in the interaction of natural and ionic sulfited polyphenols with the MCM-41 mesoporous surface. While PN shows slightly higher affinity and more stable hydrogen bonds, PSI establishes a greater number of less stable interactions. These observations suggest PN is an optimal candidate for efficient and prolonged separation processes, given its potentially higher adsorption energy and lower diffusion coefficient. Conversely, PSI interactions indicate easier controlled release, projecting less stabilized adsorption energy and a higher diffusion coefficient, which could be highly valuable for applications like agricultural biostimulants. These findings lay the groundwork for the selective design of adsorption/desorption systems tailored to specific applications.

Keywords: adsorption; polyphenols; mesoporous materials; molecular dynamics.

FROM WASTE TO INGREDIENT: MODELING OF CONVECTIVE DRYING AND NUTRITIONAL CHARACTERIZATION OF CARROT AND APPLE BAGASSE

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The bagasse generated by the fruit and vegetable processing industry constitutes a by-product rich in compounds of nutritional and functional interest. Its dehydration through convective techniques emerges as a viable strategy to stabilize this highly perishable matrix, promoting its recovery within valorization and circular economy approaches. The aim of this work was to evaluate the valorization potential of carrot and green apple bagasse through convective dehydration, analyzing drying kinetics and nutritional composition as key criteria for its use as a functional ingredient. Carrot and green apple bagasse from a cold-press detox juice industry were studied. Sub-samples of 50 g from three different production batches were ground and dehydrated by convective drying at 50, 60, and 70 °C (air velocity: 0.6 m/s) until constant weight was reached. Drying kinetics were modeled using the Weibull equation, and energy consumption was estimated. Nutritional composition (moisture, protein, lipid, and ash content) was determined according to AOAC standards. Carbohydrates were calculated by difference. Water activity was also measured in the dehydrated samples. Convective dehydration significantly reduced the moisture content in all samples (final values: 3.20–5.01%), achieving water activity levels below 0.24, which contribute to product stabilization. The Weibull model successfully described the drying behavior, with R^2 values above 0.98 in all conditions. At 50 and 60 °C, the drying times were the same for both bagasse (6.5 h and 5.5 h, respectively), and similar for 70 °C (5 h for green apple and 4.5 h for carrot bagasses), which would enable their dehydration simultaneously, making energy expenditure more efficient. The scale parameter λ was inversely related to the drying rate, decreasing as temperature increased, while the shape parameter k (>1) indicated an initial acceleration phase in moisture loss. Energy consumption in carrot bagasse ranged from 14.84 to 18.42 kWh and remained relatively stable in green apple bagasse (14.84-16.58 kWh). Nutritional analysis revealed a concentration of macronutrients after dehydration. In carrot bagasse, protein content increased from 0.99% (fresh) to 5.06–6.62% (dried), and in green apples bagasse, from 0.69% to 3.15%. Lipid content also increases, reaching up to 4.16% in dried green apples. Ash content increased from 1.2% to 7.28% in carrots and from 0.4% to 1.67% in green apples. Carbohydrates became the predominant component in dried samples, reaching over 87% in green apples and 80% in carrots, suggesting high energy and fiber potential. Overall, convective drying at 60–70 °C proved effective in enhancing the nutritional profile and stability of carrot and green apple bagasse. The increase in protein, lipid, and carbohydrate content supports its potential use as a functional ingredient in food formulations. Moreover, the integration of drying modeling and nutritional evaluation provides a comprehensive tool for the valorization of agro-industrial residues. These results highlight the relevance of selecting appropriate drying conditions to optimize both processing efficiency and the functional quality of the final ingredient.

Keywords: by-products; dehydration; revalorization; functional ingredients.

PHOSPHORUS RECOVERY FROM POULTRY MANURE AFTER WET EXTRACTION USING COMMERCIAL OR ORGANIC RESIDUES ACIDS

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Phosphorus (P) is an essential macronutrient with no substitute. Given the limited global reserves of P and its complex dynamics in soils, it is critical to develop advanced technologies for the treatment of organic animal wastes. Specifically, for poultry manure, an advanced technology must be capable of minimizing the environmental issues associated with P accumulation from direct land application of poultry manure and focused on the valorization of the waste by recovering P before manure land application. A main objective of the technology is to generate P-rich materials that are easy to handle and apply, like commercial fertilizers, with lower transportation costs than untreated manure. To this end, three laboratory-scale experiments were conducted to gather the necessary data for scaling up the technology to pilot level based on the Quick Wash method for P extraction and recovery. After sampling, physicochemical characterization of poultry manure included measurements of dry matter content, pH, electrical conductivity, carbon, and total macronutrient concentrations (N, P, Ca, Mg, K and Na). Based on these results, the first laboratory phase was designed and executed to optimize the P extraction and recovery process from the manure. In Experiment 1, the manure was acidified to determine the optimal pH for P extraction using sulfuric and oxalic acids. As part of a waste valorization approach, alternative acidification procedures were tested using grape pomace from wine production and vinasse from sugarcane ethanol production. These agricultural residues have slightly acidic pH, containing sugars that can produce lactic acid via fermentation by naturally occurring yeasts, contributing to the acidification process. In Experiment 2, P was recovered as a precipitate through the addition of alkaline agents. For the precipitation of P, calcium hydroxide ($Ca(OH)_2$) and magnesium chloride ($MgCl_2$) were used. The results of Experiment 1 showed that poultry manure could be successfully acidified and extracted using both commercial acids and those from organic residues. The results in Experiment 2 showed the P precipitation yield varied depending on the acidifying material used and the final pH achieved during precipitation. Phosphorus concentration in the precipitates ranged from 0.87% to 4.3% P across the different acid-base combinations. In Experiment 3, the most effective acid/residue and alkali combinations were tested at a larger batch scale. Using sulfuric acid, the P concentration in the precipitate was 3.2% (with both $Ca(OH)_2$ and $MgCl_2$). With oxalic acid, P concentrations were 3.3% and 3.5%, respectively, for $Ca(OH)_2$ and $MgCl_2$. For the organic residues, vinasse yielded a precipitate with 1.3% P, while grape pomace yielded 2.5% P, both precipitated with $Ca(OH)_2$. To enhance phosphorus solubilization, a small volume of sulfuric acid was added to the mixture of grape pomace and poultry manure. This treatment resulted in an increase in phosphorus concentration to 3.3%. In conclusion, it is feasible to use organic residues as alternative acidifying agents, which reduces the use and handling of commercial acids, but the extraction efficiency is lower with the organic residues' acids. Pilot-scale implementation is currently underway to evaluate extraction time, dosage, and material ratios.

Keywords: p recovery; poultry manure; grape pomace.

FROM PURIFICATION TO ENERGY: BIOGAS AND BIOMETHANE PRODUCTION FROM SCHOENOPLECTUS AMERICANUS AFTER PHYTOREMEDIATION OF DOMESTIC WASTEWATER

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The management of macrophyte biomass in large-scale wastewater treatment wetlands is a significant challenge. Its harvesting is key to maintaining system efficiency, preventing bed saturation, ensuring proper water flow, and taking advantage of the greater nutrient absorption capacity during the active plant growth phase. It is also essential to prevent the biomass from decomposing within the system, as its decomposition increases the biochemical oxygen demand (BOD), compromising the quality of the treated wastewater. In this regard, anaerobic digestion (AD) emerges as a promising strategy to counter the global energy crisis and promote the use of renewable energy. This biotechnological process uses bioreactors with methanogenic microorganisms that transform organic matter into biogas, a clean energy source. The use of native plant species is a significant advantage due to their adaptation to local conditions for use in treatment wetlands and the subsequent use of biomass in AD processes, supporting a sustainable approach. The efficiency of AD is evaluated using the theoretical biomethanogenic potential (TBMP), which estimates the maximum possible methane production considering the complete degradation of organic matter, and the experimental potential (BMP), which reflects the actual production observed under laboratory conditions and is influenced by various experimental factors. Comparing these values is key to optimizing the process, adjusting pretreatments, and improving biogas production. In this study, the biomethanogenic potential (BMP) of S. americanus biomass was evaluated after the phytoremediation of domestic wastewater and 50 days of AD. A total TBMP of 267 mL CH_4/g VS and a specific EBMP of 146 mL CH_4/g VS were obtained, indicating that this biomass is a viable option for biogas and biomethane production. Additionally, the biodegradability index (BI) was estimated, with a value of 55%, revealing the fraction of organic matter susceptible to conversion into biogas during the process; in this case, the obtained value indicated intermediate biodegradability. The difference between TBMP and EBMP suggested that degradation was not optimal under the experimental conditions. The presence of complex fibers, especially lignin, may have affected the process, as lignin reinforces plant structures and is difficult to break down using conventional biological methods. To improve efficiency, it would be appropriate to implement physical pretreatments such as grinding, chemical pretreatments like alkaline treatment, or biological methods such as enzymatic treatment, aimed at breaking down lignin and facilitating the degradation of organic matter. Implementing these pretreatments at an experimental level would optimize methane production and narrow the gap with the theoretical value, enhancing the economic and technical feasibility of utilizing macrophyte biomass as a substrate in AD processes, thereby contributing to more effective wetland management and the sustainable generation of renewable energy.

Keywords: biogas; biomethane; schoenoplectus; phytoremediation; energy.

PILOT SCALE OZONATION OF LANDFILL LEACHATE: POLLUTANT REMOVAL AND ENVIRONMENTAL PERSPECTIVES

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Landfill leachate is a complex and highly toxic effluent marked by high organic load, elevated electrical conductivity, appreciable ammonium and dissolved salts, intense color and pathogenic microorganisms, which can cause serious risks to receiving waters and public health when untreated. On the other hand, conventional activated sludge treatment processes typically generate large volumes of sludge, increasing disposal costs and worsening the situation of saturated landfills. The aim of the present pilot scale study was to assess the effectiveness of catalytic ozonation as an alternative leachate treatment capable of lowering organic load, eliminating color and pathogens, and eliminating sludge production. Five batches of 300 liters of landfill leachate, collected at different times, were ozonated for 0 and 1.0 h in a reactor equipped with an ozone generator delivering 20 g O_3 h^{-1}; samples taken before and after treatment and analyzed for physicochemical and microbiological water quality parameters. Untreated leachate showed pH 7.9, biochemical oxygen demand (BOD_5) 1220 mg L^{-1}, chemical oxygen demand (COD) 2390 mg L^{-1}, turbidity 70 nephelometric turbidity units (NTU), ammoniacal nitrogen (NH_4 N) 799 mg L^{-1} and a high microbial load. After 1 h of ozonation, pH decreases to 8.2; BOD_5, COD and color were reduced by 70 %, 30 % and 90 %, respectively, and turbidity declined to 48 NTU. Ammoniacal nitrogen decreased by 60 %, while final nitrate nitrogen (NO_3 N) averaged 7.0 mg L^{-1}. Total coliforms decreased from 10^6 to 10 most probable number per 100 mL, with the same residual count for Escherichia coli and complete elimination of Salmonella spp. Helminth viable eggs were not detected in the raw leachate. Sodium content, sodium adsorption ratio (SAR) and electrical conductivity remained high and essentially unchanged—about 1500 mg L^{-1}, 22 and 21.7 mS cm^{-1}, respectively, indicating unsuitability for agricultural reuse. Although residual salinity and COD still exceed discharge standards for direct release to water bodies, catalytic ozonation showed strong oxidative capacity, degraded biodegradable fractions without generating sludge and thus emerges as a promising step within integrated leachate treatment schemes guided by circular economy principles and more sustainable environmental management.

Keywords: municipal solid waste; leachate; advanced oxidation; organic load removal; disinfection.

GREEN MANAGEMENT OF FISH WASTE BY FERMENTATION AND ENZYMATIC HYDROLYSIS

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Bioconversion represents a sustainable strategy for managing fish processing residues by transforming waste into valuable products such as animal feed. Processes such as fermentation and enzymatic hydrolysis provide environmentally friendly alternatives to conventional disposal methods, such as landfilling and incineration. In this study, fish waste derived from the slaughter of Piaractus mesopotamicus (pacu) was subjected to two biotechnological treatments: (i) fermentation using yeasts isolated from the artisanal brewing industry (24 h at 25 °C), and (ii) enzymatic hydrolysis employing enzymes recovered from shrimp (Pleoticus muelleri) waste (6 h at 25 °C). The resulting products were evaluated in terms of proximate composition, amino acid profile, antioxidant capacity, microbiological safety, and shelf life. The experimental treatments included: P (raw material); fermentation: F-P0 (raw material + yeast, initial time) and F-P24 (raw material fermented for 24 h); enzymatic hydrolysis: E-P0 (raw material + enzymes, initial time) and E-P6 (raw material hydrolyzed for 6 h). Both fermented and enzymatically treated pacu waste showed increased protein content (44.2% and 56.8%, respectively) compared to the untreated raw material (33.2%), along with reduced ash content. Lysine and leucine were the predominant essential amino acids in all treatments. Enzyme-treated samples exhibited significantly higher antioxidant activity. Mesophilic bacterial counts remained below 1×10^2 CFU/g across all treatments, and coliforms were absent, indicating satisfactory microbiological quality. Evaluation of the shelf life of fermented and hydrolyzed products after six months of storage at room temperature demonstrated that the products maintained adequate microbiological quality, with mesophilic bacteria and, yeast and mold counts within acceptable limits, and no detection of Salmonella spp., E. coli, S. aureus, Clostridium spp., coliforms, or Enterobacteriaceae, thereby confirming their shelf life and ensuring microbiological safety without the need for refrigeration. In conclusion, both yeast fermentation and enzymatic hydrolysis significantly improved key quality parameters and represent effective biotechnological strategies for the sustainable valorization of fish processing waste. These approaches contribute to the circular economy by enabling the reuse of pacu processing residues while reducing environmental impact.

Keywords: piaractus mesopotamicus; fermentation; enzymes; by-product valorization; circular economy.

ESTIMATION OF ANAEROBIC DIGESTION DEGRADABILITY USING NIR SPECTROSCOPY IN SORGHUM PLANT

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Anaerobic digestion is an effective technology for treating agro-industrial waste, more than half of which consists of organic matter. This process not only mitigates the potential environmental pollution caused by such residues but also enables the generation of bioenergy through the production of combustible gas (biogas). Sorghum (Sorghum bicolor L. Moench) is not a waste product per se, but a strategic co-substrate that can enhance the efficiency of anaerobic digestion systems, especially those treating agro-industrial or livestock residues with low carbon content. Measuring the methane production potential provides valuable insight into whether anaerobic treatment of a given residue could be viable for biogas generation. These tests typically involve long analysis periods (ranging from 30 to 100 days) and require intensive monitoring. Spectroscopic techniques offer rapid, cost-effective, and non-destructive alternatives, enabling the simultaneous determination of multiple parameters. This study aims to evaluate the application of UV-visible and near-infrared (NIR) spectroscopy for determining degradability parameters in sorghum plants. A total of 150 samples representing whole plant and different plant fractions (leaf, stem, and panicle) from 44 distinct genotypes—grown under irrigated and rainfed conditions across three locations in Buenos Aires Province—were analyzed. Some samples also underwent post-harvest treatment (ensiling). For both reference biogas production analysis and reflectance spectroscopy, samples were dried and finely ground. Spectroscopic measurements were conducted using a FOSS DS-2500 device (spectral range 400–2500 nm), and data analysis was performed using Win-ISI software. Calibration and external validation sets (20% of the samples) were randomly selected to estimate three parameters: biomethane potential (BMP), adjusted theoretical methane yield (Bmax), and biogas production rate (k). The results were optimal for predicting BMP and k, with the technique showing potential for quantitative applications (RSQ2-BMP: 0,920; R2cv-BMP: 0,76; RSQ2-K: 0,860; R2cv-K: 0,722). In contrast, the estimation of Bmax showed lower predictive capacity, especially in the validation set (RSQ2-Bmax: 0,923; R2cv-Bmax: 0,452). These findings support the use of combined NIR and UV-visible spectroscopy as a reliable tool for estimating methane production in sorghum-derived residues subjected to anaerobic digestion.

Keywords: sorghum; nir; anaerobic digestion; biogas; methane.

TREATMENT AND VALORISATION OF METAL-CONTAMINATED WINERY SLUDGE FOR SUSTAINABLE REUSE IN VINEYARDS

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The wine industry generates significant amounts of organic solid residues, primarily composed of grape pomace, which include skins, seeds, vine leaves and stalks. In the Penedès region (Catalonia, Spain), part of these residues is valorised through the extraction of subproducts like seed oil, ethanol and tartaric salts. However, the remaining biomass is typically subjected to anaerobic digestion, producing thousands of tons of sludge annually. The destination options for this sludge are landfill, incineration, or its use in soils as fertilisers due to the huge amount of nutrients (i.e.: N, P, K) and organic matter (>50%) that contains. Incineration and landfill disposal are controversial due to secondary contamination effects and logistics unviability. Despite its potential as a soil amendment, it contains elevated concentrations of copper (Cu) and zinc (Zn) - reaching up to 230 $mg.kg^{-1}$ and 100 $mg.kg^{-1}$- due to the use of fungicides in viticulture. These levels exceed legal European thresholds established for land application, preventing its direct use as a fertilizer. This work focused on the remediation of winery sludge to enable its safe and sustainable reuse in the vineyards. Different acid leaching treatments were evaluated to reduce metal concentration in the bioavailable phases of the sludge. Kinetics leaching of Cu and Zn was studied with 0.5 $mol.L^{-1}$ at room temperature, reaching the maximum extraction after 30 minutes. Removal efficiencies achieved were up to 95% for Cu and 99% for Zn under under optimized and pH-adjusted conditions. The impact of these treatments on the stability of organic matter was also assessed, to ensure that the treated sludge maintains its fertiliser value. In a subsequent step, the metal-rich leachates obtained from the extraction process were investigated for metal recovery. Different methodologies were tested: ionic exchange through commercial resins obtained from Purolite® and adsorption experiments through synthesised alumina microspheres. The use of commercial resins specifically designed for Cu adsorption proved to be laborious and time-consuming, mainly due to the low Cu concentrations in the leachates (~6-11 ppm Cu). This approach may not be convenient unless a prior pre-concentration step, such as evaporation, is implemented. In contrast, the alumina microspheres showed 80% adsorption in synthetic solutions and 49% in real leachates solutions, a decrease attributed to competition with Fe ions present; also, a subsequent separation step, such as centrifugation or nanofiltration, is needed to recover the adsorbent. Future studies should consider the implementation of a previous step of Fe precipitation to avoid ion competition, along with the immobilization of alumina particles onto a fixed support to facilitate its use in continuous flow systems. These results demonstrate that the remediation and partial recovery of metals from winery sludge is technically feasible and also aligns with the principles of circular economy and sustainable agriculture, contributing to the development of integrated waste management strategies in agro-industrial productions.

Keywords: winery waste; heavy metal; sludge remediation; circular economy; viticulture.

STRUVITE PRODUCTION IN DIGESTATE WITH HIGH Ca/Mg RATIO

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Struvite ($MgNH_4PO_4{\cdot}6H_2O$) precipitation is a promising technology for phosphorus recovery. Its stoichiometric composition, with equimolar concentrations of nitrogen (N), phosphorus (P), and magnesium (Mg), renders it a potentially marketable product for the fertilizer industry due to its slow-release characteristics and its role as a supplementary source of P, N, and Mg. The crystallization of struvite involves nucleation and crystal growth processes, which are influenced by physicochemical parameters such as pH, molar ratios, temperature, mixing intensity, and the presence of interfering ions. Among these, calcium (Ca) concentration in wastewater has been identified as a critical inhibitory factor. The presence of Ca ions during struvite formation negatively affects the morphological and crystalline properties of the resulting precipitate. In this context, the present study investigated the struvite precipitation from digestate with high Ca/Mg molar ratio. The digestate was collected from a biodigester of swine manure in a pig farm (Videira, Santa Catarina State, Brazil). Batch experiments were conducted in cylindrical reactors with an effective volume of 1 L. Digestate acidification was carried out using 4 mol L^{-1} sulfuric acid to enhance P-phosphate (PO_4^{3-}-P) availability. After solid–liquid separation, either 0.3 or 0.6 g of magnesium oxide (MgO) was added to the supernatant and mixed for 10 min (reaction time). Crystallization experiments were conducted at pH values of 8.5 and 9.5 under stirring speeds of 90 rpm. After the reaction time, samples were transferred to Imhoff cones for sedimentation over 24 h. Supernatant analyses included measurements of Mg, ammonia (NH_4^+-N), total phosphorus (Ptotal), PO_4^{3-}-P, and Ca. Analytical determinations were performed according to methods described by the American Public Health Association (APHA 2012) and AOAC 975.03 from the Association of Official Analytical Chemists (AOAC 1995). After acidification, concentrations of Ptotal, PO_4^{3-}-P, Ca, Mg and NH_4^+-N in the digestate were 1245, 1056, 2287, 887 and 1301 mg L^{-1}, respectively. This composition corresponds to a Ca/Mg molar ratio of 1.6:1. Ptotal removal ranged from 82 to 85% under pH 8.5 and 9.5, respectively. PO_4^{3-}-P removal higher than 99% was observed under all tested conditions. NH_4^+-N removal rates varied between 22 and 23%, while Mg concentrations remained relatively constant due to the external addition of MgO during the crystallization process. Calcium removal exhibited significant variation, with 26% at pH 8.5 and 72% at pH 9.5, suggesting a strong influence of pH on the precipitation of Ca-containing compounds. This difference may be attributed to competitive interactions between Ca^{2+} and Mg^{2+} during struvite formation, where, under high Ca/Mg molar ratios, preferential precipitation of calcium phosphate can inhibit struvite nucleation and crystal growth at higher pH values. Thus, for effluents rich in Ca, the production of struvite at lower pH seems to avoid the production of $Ca_3(PO)_2$, favoring the nutrient recovery via struvite precipitation.

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Keyword: crystallization, fertilizer, competitive ion

INFLUENCE OF TEMPERATURE ON NITROGEN REMOVAL EFFICIENCY IN A DEAMMONIFICATION REACTOR

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Deammonification is a promising biological process for autotrophic nitrogen removal, particularly in effluents with high ammonium concentrations and low carbon-to-nitrogen (C/N) ratios, such as those derived from anaerobic digestion. However, its efficiency is highly dependent on operational parameters, with temperature being a critical factor due to its direct influence on the metabolism of key microorganisms, such as AOB (ammonia-oxidizing bacteria) and AnAOB (anaerobic ammonium-oxidizing bacteria). This study aimed to investigate the influence of temperature on nitrogen removal efficiency. A laboratory-scale Nitrammox® reactor (8 L) was inoculated with nitrifying sludge obtained from a nitrification pond, which is part of the Swine Wastewater Treatment System (SISTRATES®), using 15% (v/v) of the reactor's working volume. The reactor was operated at 35 °C for the first 30 days, after which it was maintained at room temperature, ranging from 16.1 to 28.7 °C (without control). Throughout the entire operation, the reactor was continuously aerated (DO<0.1 mgO2 L-1), feeding, and recirculation (2×Qin). Air was supplied by an air pump (A230, Big Air) connected to an air diffuser. Supply of air was controlled by a rotameter (Gilmont, GF-9260). During the experimental period, reactor temperature and nitrogen removal efficiency (NRE, %) were monitored. The NRE showed a strong correlation with the medium temperature, highlighting the fundamental role of this operational variable. The results showed that in the first 30 days of reactor operation at controlled temperature (35.5 ± 0.9 ºC) the NRE of 74.9 ± 18.1%. However, with the temperature decline to a range of 24.1 ± 2.8 ºC from 31 days of operation onward, there was a sharp drop in efficiency, with values of 41.5 ± 8.7%. Under extreme conditions (<20 ºC) between days 38 and 40 of operation, the NRE further dropped to 33.7 ± 8.3%. These findings indicate a substantial reduction in metabolic activity at lower temperatures, consistent with the expected behavior of anammox processes, whose optimal operational range lies between 30 and 35 °C. The performance decline can be attributed to decreased enzymatic activity and slower growth rates of autotrophic microorganisms. This metabolic impairment leads to reduced expression of genes involved in the anammox pathway, hinders substrate transport across cell membranes, and consequently compromises overall system performance. Continuous monitoring and a comprehensive understanding of thermal dynamics are essential for the successful operation of autotrophic nitrogen removal systems such as deammonification. These results emphasize the importance of thermal regulation in deammonification reactors, particularly in regions with significant temperature fluctuations. Therefore, strategies such as thermal insulation or controlled heating should be implemented to ensure process stability.

Keywords: anammox; partial nitritation; nitrogen; swine digestate.

STABILIZATION OF BLACK SOLDIER FLY LARVAL FRASS THROUGH VERMICOMPOSTING WITH CATTLE MANURE: AGRICULTURAL AND CHEMICAL ASSESSMENT

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Frass, a nutrient-rich byproduct generated from the large-scale rearing of Hermetia illucens (black soldier fly), represents a promising input for sustainable agriculture. This residue, composed of larval excreta, undigested feed, and associated microorganisms, is rich in organic matter and macronutrients, including nitrogen (N), phosphorus (P), and potassium (K). However, its direct application is limited by biological instability, elevated salinity, and phytotoxicity, which may impair plant development and soil quality. Overcoming these limitations is essential for advancing circular economy strategies in agro-industrial waste valorization. This study evaluated vermicomposting as a low-cost, scalable strategy to stabilize frass and enhance its agronomic potential. Frass was co-processed with cattle manure in varying proportions (0%, 25%, 50%, 75%, and 100%) to determine the optimal blending ratios for producing mature, nutrient-rich, and phytotoxin-free vermicompost. Analyses included physicochemical parameters, germination index (GI), cation exchange capacity (CEC), and Fourier transform infrared spectroscopy (FTIR) to assess the transformation and humification of organic matter. The 50:50 frass-to-manure mixture (T50) showed the best performance, with high organic matter (48.4%) and total organic carbon (28.1%), favorable pH (6.56), moderate EC (5.83 mS cm^{-1}), balanced C:N (8.54) and C:P (39.5) ratios, robust CEC (48.05 cmol kg^{-1}), and a GI of 104.4%, classifying it as non-phytotoxic and suitable for agricultural use. In contrast, 100% frass (T100) led to excessive salinity (EC = 11.64 mS cm^{-1}), acidic pH (6.07), and reduced GI (38.8%), highlighting the importance of co-composting. FTIR and principal component analysis confirmed significant chemical changes and humification in intermediate mixtures (T25–T75), including the formation of stable aromatic compounds. Earthworm survival and reproduction (Eudrilus eugeniae) were also higher in T50 and T75, while T100 proved detrimental to worm activity. Vermicomposting with manure, particularly at the 50:50 ratio, is an effective strategy for stabilizing frass and producing high-quality organic fertilizer. This approach enhances nutrient recycling, reduces environmental risks, and aligns sustainable agriculture and bioeconomy goals.

Keywords: hermetia illucens; vermicomposting; circular economy; organic fertilizer; agricultural waste; ftir.

RE-VALORIZATION OF CITRUS WASTE: PECTIN EXTRACTION USING MICROWAVE-ASSISTED METHODS

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Significant volumes of orange peel are generated as waste in food companies and natural juice producers. Added to this is the large amount of waste generated throughout the citrus fruit marketing chain. These by-products represent a biomass of interest due to their abundance, constant availability, and chemical richness, which allows them to be valorized to obtain high value-added compounds, such as pectin, under a “zero waste” approach that promotes the circular economy and reduces environmental impact. Pectins are complex natural heteropolysaccharides found mainly in citrus and apple peels. They are used as gelling and stabilizing additives in products such as jams and yogurts. Currently, pectin is not produced nationally, and its demand is met through imports. The objective of this study was to evaluate the yield and chemical characteristics of pectin extracted from orange peels using two methods: one aqueous (E1) and one acidic (E2), both with microwave-assisted heating. The discarded peels were dried at 70 °C, ground, and sieved (500 µm). Twenty grams of peel were used per extraction with a solid-liquid ratio of 1:20. The mixture was heated in a microwave at 400 W for 10 minutes and filtered while hot. The pectin was precipitated by adding twice the volume of 80% ethanol and left to cool for 24 h. It was then filtered, washed with ethanol, and dried at 60 °C. In method E2, the pH was previously adjusted to 2.4 with HCl. Three extractions were performed per treatment. Characterization was performed by conductometric titration using 0.1 N NaOH, before and after deesterification. The equivalent weight (PE), degree of esterification (GE), and anhydrogalacturonic acid content (%AAG) were calculated, parameters that allow the proportion of free and esterified carboxyl groups and the purity of the polysaccharide to be evaluated. The results showed significant differences between the two methods ($p < 0.05$). The yield was higher in E2 (19.07 ± 1.42%) than in E1 (9.69 ± 2.93%). The PE was higher in E1 (1209.42 ± 133.58 mg/meq), indicating a lower amount of free carboxyl groups. GE was also higher in E2 (69.83 ± 2.27%) than in E1 (63.13 ± 1.34%), placing both samples in the high methoxyl pectin category (GE > 50%). In terms of %AAG, E2 had a significantly higher value (70.16 ± 4.62%) than E1 (39.73 ± 3.11%). Only the pectin extracted by the acid method exceeded the 65% threshold required by the Argentine Food Code, meeting the requirements for food use. Microwave acid extraction was more efficient in terms of yield, purity, and functionality of the pectin. These results validate the potential of citrus waste as a sustainable source of quality pectin. However, the treatment of the acid waste generated must be considered to ensure the sustainability of the process.

Keywords: pectin; food additive; orange peel; microwave-assisted extraction; circular economy.

SAMPLING METHODOLOGY FOR THE PHYSICAL-CHEMICAL AND MICROBIOLOGICAL CHARACTERIZATION OF STACKED POULTRY LITTER

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The agronomic reuse of poultry litter (PL) is essential for nutrient recycling in agricultural production systems. However, prior to field application, sanitation treatments such as stack heating—is required to reduce the load of pathogenic microorganisms. To evaluate the effectiveness of such treatments and to characterize the physical-chemical properties of PL, a representative sampling method is critical. This study aimed to determine an appropriate sampling strategy for stacked PL to simultaneously assess the presence of undesirable microorganisms and its agronomic value as a soil amendment and fertilizer. A static stacking process was conducted using raw PL from a commercial farm located in the core broiler production region of Entre Ríos, Argentina. The process lasted 30 days, with piles averaging 1.2 m in height. An initial sampling of raw PL was performed immediately after pile formation. Composite samples were obtained, each comprising 15 subsamples collected at different depths and locations within the pile. At the end of the stacking period, additional composite samples were taken from three specific layers: surface (10 cm depth), center (40–50 cm depth), and a mixed sample combining equal parts of material from the surface and the center. Samples were analyzed for the following physical-chemical parameters: organic matter, total nitrogen, organic nitrogen, ammoniacal nitrogen, nitrate, phosphorus, potassium, calcium, magnesium, sulfur, sodium, iron, copper, manganese, zinc, electrical conductivity, pH, and moisture. In addition, the presence of Salmonella spp., enterobacteria, Campylobacter spp., sulfite-reducing Clostridia, total coliforms, and fecal coliforms were determined. To assess whether mixed sampling adequately represents the pile's overall composition, the results from the mixed samples were compared with the average values of the surface and center samples. No significant differences were detected for physical-chemical parameters, indicating that mixed sampling provides a representative assessment of the pile's overall physical-chemical properties.

Similarly, no significant differences were observed in microbial counts between mixed and average surface/center samples for most microorganisms. However, the levels of Campylobacter spp., enterobacteria, and total coliforms differed between center samples and mixed samples, suggesting that sampling from the center is more sensitive for detecting microbial changes associated with the sanitation process. In conclusion, for physical-chemical characterization, composite samples may be collected either from the center or through mixed sampling from surface and center layers. However, for microbiological analyses, sampling exclusively from the facility is recommended, as it provides greater sensitivity for detecting treatment effects by being more representative of the total volume of the chicken litter. Therefore, center sampling is advised to enable simultaneous physical-chemical and microbiological evaluations using a single sample.

Keywords: chicken litter; pathogenic microorganisms; sanitation treatment.

MONITORING OF METHANOGENIC COMMUNITIES VIA QPCR IN ANAEROBIC DIGESTERS UNDER AMMONIA STRESS

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The optimization of anaerobic digestion in Continuos Stirred Tank Reactors (CSTRs) treating substrates with high nitrogen concentrations is a challenge, due to the frequent inhibition of the process by ammonia. Mitigating such operational instabilities requires tools that enable rapid and quantitative assessment of microbial dynamics. In this context, quantitative real-time PCR (qPCR) represents an effective process monitoring alternative, mainly due to its high sensitivity and specificity. Accordingly, this study evaluated the applicability of qPCR to quantify and monitor methanogenic taxon known to predominate in anaerobic digestion (Methanosarcinales, Methanomicrobiales, and Methanosaetaceae) in CSTRs operated under ammonia stress. Three sludge samples were collected at different operational periods from a bench-scale CSTR subjected to metabolic inhibition induced by urea supplementation. Total genomic DNA was extracted from 0.25 g of concentrated sludge using the DNeasy PowerSoil Pro Kit (Qiagen). DNA quality was assessed by spectrophotometry (BioDrop, Biochrom Ltd., Cambridge, United Kingdom), ensuring adequate purity and concentration. Quantification was performed on a real-time PCR thermocycler (7500, Applied Biosystems, Thermo Fisher Scientific, USA) using SYBR Green detection and specific primers (Yu et al., 2005). The specificity of amplifications was confirmed by melting curve analysis of the products. The analysis was based on the ΔCt method, calculated as the difference between the Ct of the target gene and that of a conserved 16S rRNA gene sequence present in organisms of the Archaea domain, allowing estimation of the relative abundance of methanogenic groups in relation to the total archaeal population. The method demonstrated high analytical performance, with consistent and reproducible relative quantification of the three target groups across all samples analyzed. A persistent dominance of Methanosarcinales was observed, with no statistically significant differences between samples. On the other hand, Methanomicrobiales showed a reduction: the mean ΔCt increased from 6.749 (sample A) to 9.738 (B) ($p<0.05$). The difference between B and C (ΔCt 8.798) was not significant, suggesting a lack of population recovery. For Methanosaetaceae, the mean values were 4.030 (A), 6.081 (B), and 4.721 (C) ($p<0.05$), indicating a fluctuation in environmental stressor levels. The differentiation between resilient and sensitive groups, as detected by qPCR, reinforces the potential of the technique as a functional indicator for technical-operational management of biodigesters. Therefore, it is concluded that the qPCR assay constitutes a robust and accurate methodology. Its satisfactory performance in monitoring microbial communities in anaerobic digesters supports its applicability to complex environmental matrices and may consolidate its use as a strategic tool for diagnosis, control, and optimization of bioprocesses.

Acknowledgment: CNPq

Keywords: quantitative pcr; microbial monitoring; anaerobic digestion; biodigester; ammonia.

DEVELOPMENT OF TREATMENT TECHNOLOGIES FOR EFFLUENTS GENERATED FROM SEED INOCULATION, CURING, AND INDUSTRIAL COLORING

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Following the expansion of agriculture and livestock farming in Uruguay, seeds have evolved from being mere reproductive elements to becoming technological packages. The seed treatment process is essential and takes place in industrial facilities where seeds are coated with agrochemicals, dyes, and pigments. This process generates wastewater with high chemical stability, intense coloration, and elevated ecotoxicity, originating from the washing of machinery, containers, and leftover mixtures. Currently, these effluents are not subject to any treatment. In the first stage of this work, a nationwide survey was carried out in collaboration with the seed sector to assess the current state of production and effluent management, including physicochemical characterization. The main production areas, treated volumes, and current management practices were identified. These effluents show high concentrations of pesticides, chemical oxygen demand (COD), intense color, Total Suspended Solids (TSS), and heavy metals. These characteristics hinder their treatment through conventional biological technologies, so a combined treatment approach is proposed, consisting of coagulation-flocculation as a primary stage, followed by biofiltration using beds filled with recycled materials. In this context, the efficiency of the coagulation-flocculation process as a primary treatment was evaluated by comparing the performance of three chemical coagulants (aluminum sulfate, ferric chloride hexahydrate, and polyaluminum chloride – PAC) and a natural coagulant derived from Gleditsia triacanthos (black locust), an invasive plant species in the region. A jar test procedure was applied using representative composite samples. The analyzed parameters included total solids TS, TSS, COD, turbidity, true color, sludge volume generated, and heavy metal concentrations (Cu, Zn, Cd, Ni, Pb, and Cr). The percentage removal of each parameter was calculated, and a sustainability matrix integrating environmental, economic, and social criteria was developed. All four coagulants showed over 90% efficiency in turbidity and TSS removal and over 75% in COD removal. PAC and the plant extract showed better performance in the removal of true color and copper, although the black locust extract generated the lowest sludge volume. Considering both technical efficiency and sustainability indicators, the natural coagulant proved to be the most suitable alternative for this type of effluent. Currently, the biofiltration process is being studied through the implementation of a lab-scale system. The system's performance will be assessed based on pesticide removal and reduction of the ecotoxicity of the treated effluents. Additionally, the microbial communities developed in the biofilters will be analyzed to understand the mechanisms involved in pesticide removal.

Keywords: pesticides; biofilters; coagulants.

DESIGN PROPOSAL FOR A SOLID WASTE COLLECTION VESSEL IN THE PORT OF MAR DEL PLATA

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The Port of Mar del Plata, one of Argentina's key maritime hubs, faces increasing challenges associated with floating solid waste. This waste originates from industrial port operations and urban runoff discharged directly into the harbor through the stormwater system. It accumulates in critical areas of the port basin, where it poses risks to marine life, hinders port logistics, and degrades water quality. In response to this issue, we present the design of a specialized vessel developed to collect floating solid waste from the surface of the water in a clean, efficient, and sustainable manner. Our solution is a twin-hull (catamaran) vessel, engineered to operate in the narrow, high-traffic zones of the port with minimal disruption. The catamaran configuration improves transverse stability and provides a wide, unobstructed working area on deck. The hulls follow a prismatic geometry, which, while not hydrodynamically optimal, offers substantial advantages in terms of construction simplicity, cost, and compatibility with local shipbuilding capacity. Given the vessel's slow speed and protected operating environment, the trade-off in resistance is negligible. The waste collection mechanism is a retractable steel basket mounted on a forward gantry. Operated by an electric winch, the basket is lowered to capture floating debris and then hoisted to empty its contents into large, removable collection bags placed on deck. Once full, the bags are swapped out and the cycle repeats. This method allows for efficient, low-effort waste handling compatible with daily operations. Propulsion is fully electric, provided by two outboard motors powered by rechargeable batteries, with solar panels assisting in charging auxiliary systems. This emission-free configuration not only reduces the vessel's environmental footprint, but also ensures silent operation, which is particularly beneficial in a port that is home to sensitive marine species. All onboard systems—including lighting and communication equipment—are integrated into a single energy platform designed for an 8-hour shift. The vessel has been designed to match the specific environmental and logistical constraints of Mar del Plata's port. Its compact size and responsive control systems allow it to maneuver safely around fishing vessels, service boats, and recreational traffic. Construction and maintenance have been optimized for local infrastructure and technical capabilities, supporting scalability and replication in similar settings. The proposed catamaran offers a practical and scalable solution to the growing problem of floating waste in port environments. Its design combines sustainability, operational efficiency, and structural simplicity. The vessel's ease of construction, electric propulsion, and effective waste retrieval system make it particularly suited to high-traffic, confined waters such as those found in Mar del Plata. This makes it a compelling model for implementation in similar urban ports worldwide.

Keywords: port waste management; floating solid waste; naval architecture; sustainable technologies; waste collection vessels.

B-GLUCANS AS A VALORIZATION ALTERNATIVE FOR RESIDUAL BREWER'S YEAST BIOMASS

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Beer is one of the most widely consumed beverages globally, and increasing consumer demand continues to drive growth in its production. In 2023, beer consumption in Argentina reached approximately 40 liters per capita per year, and the market is expected to grow at an estimated annual rate of 1.8%. During the brewing process, the second most abundant by-product is spent yeast, as approximately 10% of the wort carbohydrates are converted into yeast biomass. Currently, brewer's yeast is mainly used in animal feed due to its high nutritional value. However, this biomass is also a sustainable and cost-effective source of bioactive compounds, particularly β-glucans. These polysaccharides, structural components of the Saccharomyces cerevisiae cell wall, are well known for their immunomodulatory, antioxidant, hypocholesterolemic, and prebiotic properties. This makes their extraction a promising strategy for obtaining high-value-added products. In this context and motivated by the increasing consumer demand for healthier eating habits and the inclusion of functional foods in the diet, we aimed to develop an alternative method for producing a β-glucan-rich extract from residual brewer's yeast. Biomass pretreatment was carried out to remove hop-derived acids and residual beer compounds. Then, a thermal treatment was applied to the sample to activate endogenous enzymes, promoting cell autolysis and partial solubilization of the matrix. This was followed by an enzymatic hydrolysis using Bromelain, a proteolytic enzyme, performed at constant pH. The process aimed to optimize operating conditions like temperature, reaction time and enzyme concentration relative to total solid for efficient extraction of β-glucans. The β-glucan content was quantified using a specific analytical kit: Megazyme Enzymatic Yeast β-Glucan Assay Kit (K-YBGL)." The extract with the highest β-glucan content was nutritionally characterized in terms of fiber, protein, fat, and ash content. In addition, several technological properties were evaluated, including solubility, moisture content, water absorption, water holding capacity (WHC), water binding capacity (WBC), swelling capacity (SC), oil holding capacity (OHC), and glucose adsorption capacity (GAC). This work represents an initial stage in the development of sustainable processes for obtaining functional ingredients from brewery industry by-products.

Keywords: ß-glucans; brewer's yeast; enzymatic hydrolysis; functional ingredients; high-value-added.

USE OF WINE RESIDUES FOR METHANE PRODUCTION

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Several agro-industrial sectors seek to reduce the environmental impact of their waste to ensure environmental sustainability and the growth of their economic activities. Meanwhile, the search for clean and renewable energy to replace fossil fuels has been gaining momentum worldwide. Waste-based biogas generation technologies are a safe renewable energy alternative with low greenhouse gas emissions. This anaerobic digestion process is carried out by microbial consortia that decompose organic matter in a sequence of phases, generating not only methane but also a set of other compounds with economic value. methane, specifically, is widely used to generate thermal and vehicular electricity. Winemaking waste, such as bagasse, seeds, and twigs, is rich in organic matter, making it a suitable substrate for anaerobic digestion, providing nutrients for microorganisms in the production of methane and other products. Therefore, the objective of this study was to evaluate the biochemical methane potential (BMP) from grape pomace in batch tests. To this end, analyses of total solids (TS) and volatile solids (VS) of the substrate (grape) and inoculum, a standardized and environmentally friendly animal waste, were initially performed. The inoculum-to-substrate ratio (ISR) used in the tests was determined according to the VS concentration of the substrate and reactor inoculum. The tests were performed at ratios of 3:1 and 2:1, at a pH of 7.3. Control tests using only inoculum and microcrystalline cellulose were also performed. BMP tests were performed in 250 mL reactors connected to eudiometer tubes and maintained at 37 °C. The volume of methane produced was measured daily by the displacement of the sealing liquid in the eudiometer tube. The assay that presented the best methane production results was grape residue (2:1) with 261.92 mLNCH4/gSV, followed by the 3:1 concentration with 210.12 mLNCH4/gSV. While the control, inoculum only, produced only 36.40 mLNCH4/gSV. These results are consistent with those described in the literature, where a lower RIS (2:1) favors the anaerobic digestion of lignocellulosic residues. Thus, winemaking residues proved to be efficient substrates for methane production and can be used on wineries, thus avoiding discharge into the environment and the release of greenhouse gases.

Keywords: grape; methane; biomass; anaerobic digestion.

METATAXONOMY OF A MICROBIAL CONSORTIUM ACTING IN TWO-STAGE ANAEROBIC DIGESTION USING RESIDUAL GLYCEROL

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Anaerobic digestion (AD) is a biological process widely used for the treatment of organic waste and the production of biogas. In this process, microorganisms convert the substrate into energy and other products. Bacteria form volatile fatty acids (VFAs), while methanogenic archaea use these metabolites to generate methane (CH_4). However, the efficiency of AD can be compromised by physical and chemical factors that lead to the accumulation of VFAs and a reduction in pH. Increased acid concentration inhibits archaea activity, interrupting CH_4 production. As an alternative, the separation of AD into two stages: acidogenic and methanogenic is proposed. The acidogenic stage aims to produce hydrogen (H_2) and VFA, while the methanogenic stage aims to generate CH_4.On the other hand, Brazil is the world's third-largest producer of biodiesel, and residual glycerol is generated during its processing. Although this byproduct has applications in the pharmaceutical industry, it can also be used for energy generation. Therefore, the objective of this study was to investigate the microbial community involved in methane production through two-stage anaerobic digestion, using residual glycerol as the main substrate. In the acidogenic stage, isolated cultures of Bacillus amyloliquefaciens were used in 600 mL flasks containing medium containing 3% residual glycerol (pH 6.0), under agitation at 37 °C for 72 hours. After this period, H_2 production, substrate consumption, and the metabolites generated, such as VFA and alcohols, were analyzed. In the methanogenic stage, acidogenic broth was used as a substrate for CH_4 production and acclimated inoculum. The tests were conducted in 200 mL reactors connected to eudiometric tubes, filled with sealing liquid, and maintained at 37 °C under a nitrogen atmosphere. The inoculum-to-substrate ratio (ISR) of 2:1 was evaluated. In the control assay, the same procedure was used, but with medium containing only 3% glycerol medium. The microbial community was characterized by 16S rRNA gene amplification and sequencing on the Oxford Nanopore platform. Initial and final samples from the control and two-stage AD assays (ISR 2:1) were selected for metataxonomic analysis. In the acidogenic stage, B. amyloliquefaciens produced 20.7 mmol H_2/L, with 28% substrate consumption, resulting in a yield of 0.34 mmol H_2/mol of glycerol. Among the soluble metabolites, acetic acid (168 mg/L) and ethanol (1.6 g/L) stood out. In the control assay, CH_4 production was only 51 mL. With the acidogenic broth, CH_4 production at a 2:1 ratio was tenfold higher (600 mL), with 70% of the remaining VFA consumed. Taxonomic analysis of the methanogenic stage revealed the predominance of the phyla Bacillota, Pseudomonadota, Thermodesulfobacteriota, and archaea of the phylum Euryarchaeota. Archaeal diversity and the presence of Methanobacterium (H_2 consumer) and Methanothrix (VFA consumer) were associated with improved methanogenic performance. Thus, two-stage AD proved to be an efficient strategy for utilizing residual glycerol, representing a promising alternative for managing this waste and producing renewable energy.

Keywords: hydrogen; methane; industrial waste; volatile fatty acids.

SUBSURFACE HORIZONTAL FLOW WETLAND AS AN ALTERNATIVE FOR THE POST-TREATMENT OF PORCINE DIGESTATE

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Digestate from small- and medium-scale biodigesters in Argentina presents some limitations and restrictions for its agricultural application, including: large storage areas, high nutrient dilution, nutrient loss due to leaching or volatilization, inadequate application infrastructure, high application costs, and non-compliance with environmental regulations. In this context, there is a need to find appropriate alternatives for the post-treatment of digestate. Among these, constructed artificial wetlands are one of the most recommended and recognized non-conventional technologies for water purification and are proposed as an efficient alternative in the removal of residual organic matter, reduction of salt content, toxic substances and pathogenic microorganisms. Following the Environmental Protection Agency (EPA) methodology, three pilot-scale subsurface flow wetlands, each 2 meters long, 1 meter wide, and 0,4 meters deep, were designed and constructed using large river rocks and 3-5 cm gravel as fill material and Typha Domingensis as the plant species, with a planting density of 4 plants per m^2. Pig digestate was extracted from a 25 m^3 tubular plug-flow plastic digester operated under psychrophilic conditions. Following a 4-week acclimatization phase, a 70-day trial was conducted with a total of 10 monitoring sessions to evaluate the removal efficiency of organic matter, nutrients, potentially toxic elements, and pathogens from the digestate inlet and the treated digestate outlet after passing through the wetland. The results showed high efficiency in removing chemical oxygen demand (91-98%), total solids (54-81%), volatile solids (80-94%), total nitrogen (65-90%), ammonium nitrogen (62-91%), and total phosphorus (60-86%). Regarding pathogens and heavy metals, the permitted discharge levels for surface water bodies required by Law 5965/58 of the Province of Buenos Aires (Resol. 336/03) were met, with removal rates ranging from 60-90% and 55-100%, respectively. The wetlands designed as a post-treatment system for pig digestate proved to be efficient technology for removing organic matter, potentially toxic elements, and pathogens. This also enables the production of a significant amount of biomass (harvested Typha) that can be utilized through anaerobic co-digestion with pig slurry effluent. The combined implementation of a vertical wetland or biofilter and a horizontal subsurface flow wetland would further improve all the parameters evaluated, while reducing occlusion, improving hydraulic flow, and consequently the lifespan of the entire system.

Keywords: pig digestate-wetland-typha domingensis.

REVALORIZATION OF DISCARDED PEARS: OPTIMIZATION OF DRYING CONDITIONS WITH OSMOTIC PRETREATMENT

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Within the framework of a sustainable food production system, ensuring food security and nutrition without compromising the natural resources of future generations is key. In this context, the recovery of agri-food waste takes on a central role. Dehydration of fruit, particularly agro-industrial waste, is presented as an effective strategy for preserving food, reducing post-harvest losses, and facilitating storage and distribution. This study evaluated the isothermal drying process of pears subjected to osmotic pretreatment to optimize operating conditions to obtain a quality product. The raw material used consisted of fruit discarded due to defects in color, shape, size, or mechanical damage, thus promoting the comprehensive use of resources and reducing waste in the agri-food chain. The pears were washed, destemmed, and cut into 2 ± 0.1 mm slices. The osmotic pretreatment and drying experiments were conducted according to a Box-Behnken design model. The independent variables evaluated were the concentration of the osmotic sucrose solution (25, 40, and 55 °Brix), drying time (30, 135, and 240 minutes), and drying temperature (60, 70, and 80 °C). The dependent variables were % yield (dehydrated pear weight/fresh pear weight ratio), color variation (ΔE), water activity (aw), and titratable acidity. Second-order polynomial models were fitted to the results, considering linear and quadratic effects and interactions, including only statistically significant terms with explanatory capacity. The quality of the fit was evaluated using the standard error of the estimate (S) and the adjusted coefficient of determination (R^2 between 0.58 and 0.9). Process optimization was subsequently applied, maximizing yield percentage and minimizing ΔE, aw, and titratable acidity using response surfaces. The optimal values determined were: osmotic solution concentration of 38.3 °Brix, immersion time of 131.8 minutes, and drying temperature of 72.3 °C. Under these conditions, a yield of 27.6% was obtained, a ΔE of 16.2 (ratio of dehydrated pear color to fresh pear color), an acidity of 0.16 malic acid equivalents, and an aw of 0.39, values suitable for product preservation. The combination of osmotic pretreatment with controlled isothermal drying is presented as a viable and eco-efficient technological alternative for the reuse of discarded pears. This approach aligns with the principles of sustainability and the circular economy, enabling the production of a dehydrated product with commercial potential, reducing post-harvest losses, and strengthening value-added chains in producing regions.

Keywords: osmotic pretreatment; drying; pear; optimization; sustainability.

SUSTAINABLE VALORIZATION OF AGRO-INDUSTRIAL WASTES VIA FAST AND SOLAR PYROLYSIS: MACHINE LEARNING PREDICTION OF BIOCHAR YIELD

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The sustainable management of agro-industrial waste through thermochemical processes plays a central role in the transition toward circular and low-carbon energy systems. This study presents the development of predictive models based on machine learning to estimate biochar yield obtained from fast and solar pyrolysis of diverse agro-industrial biomasses. Biochar, a carbon-rich solid with applications in soil improvement, carbon sequestration, and pollution remediation, represents a high-value product in biomass valorization. A key innovation of this work lies in the integration of experimental data from fast and solar pyrolysis processes. The latter is an emerging technology that uses concentrated solar energy to provide rapid heating rates with minimal external energy input. This inclusion broadens the dataset and extends the range of operational conditions, improving model robustness and relevance across multiple pyrolysis configurations. To ensure model interpretability, essential for industrial implementation and process optimization, this study employs Ordinary Least Squares (OLS), Random Sample Consensus (RANSAC), and polynomial Ridge regression, rather than complex "black-box" algorithms. These linear and regularized regression models offer transparent insights into the contribution of each input variable, which is critical for guiding experimental strategies and reactor design. Input features include elemental composition (C, H, O, N, S), proximate analysis (moisture, volatile matter, fixed carbon, and ash), pyrolysis temperature, and heating rate. An exploratory data analysis (EDA) was performed to assess variable distributions, identify outliers, and evaluate correlations, ensuring data integrity before model training. The best-performing model, a RANSAC-based linear regression, achieved a coefficient of determination (R^2) of 0.94 and a mean squared error (MSE) of 5.6 in predicting biochar yield, highlighting the model's accuracy after appropriate outlier removal. Analysis of model coefficients revealed that higher volatile matter, carbon, and hydrogen content negatively correlate with biochar yield, as these components tend to vaporize during pyrolysis, favoring the formation of non-solid products. In contrast, ash content shows a positive influence, as inorganic material tends to remain in the solid phase. Additionally, moisture content was found to promote biochar formation, likely due to its effect in moderating the pyrolysis temperature and reducing the extent of thermal decomposition. This study demonstrates the feasibility of using interpretable regression models, coupled with robust data preprocessing techniques, to accurately predict biochar yields across varying feedstocks and pyrolysis conditions, including solar-driven systems. The findings provide valuable insights for the design of efficient and sustainable biomass valorization pathways and support the integration of data-driven approaches in circular economy frameworks.

Keywords: solar pyrolysis; biochar; machine learning; agro-industrial waste.

USE OF SUNFLOWER HUSKS AS A HYDROCARBON SORBENT: STANDARDIZATION OF A SORPTION ANALYSIS AND TESTING PROTOCOL

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Sunflower oil production generates a large amount of husk waste, whose final disposal poses an environmental challenge. Our research line explores the use of sunflower husks as a sorbent for hydrocarbons (HC) in the treatment of contaminated effluents, aiming to develop value-added products from this agricultural residue. This work presents the development and optimization of a method to analyze sorption capacity using exhausted engine oil as a model sorbate. The methodology was based on ASTM F726-12 and the recommendations proposed by Bazargan et al. (2015). The ASTM procedure involves immersing 4 g of sorbent material in the hydrocarbon for 15 minutes or 24 hours, followed by draining for 15 to 120 seconds prior to weighing. However, this method presents inconsistencies; therefore, the approach of Bazargan et al. was followed, which recommends optimizing several parameters to quantify only the oil strongly bound to the sorbent. Four types of containers with different pore sizes were evaluated. The sorbent mass in each test was limited to the maximum amount that could be held by the smallest container. Sorption capacity was determined gravimetrically. A one-way random effects ANOVA was performed to assess the influence of the container and estimate the proportion of variance attributable to this factor. The analysis indicated that containers introduce systematic bias in the measurement of sorption capacity, making their standardization essential to ensure reproducibility and accuracy. The container that yielded the best results was a nonwoven polypropylene (NPP) sack, which enabled effective drainage of unsorbed oil and was suitable for both whole and ground husks. To ensure complete dripping, the husk-free area was gently scraped with tweezers after the initial dripping had ceased, repeating the process until no further retained oil was observed. Using the optimized method, the effect of particle diameter (Dp) on sorption capacity was evaluated, testing whole husks and ground fractions between 0.5–0.297 mm and below 0.297 mm. A significant increase in sorption capacity was observed as Dp decreased. Additionally, a 15% w/w sulfuric acid treatment was applied to both whole and ground husks, resulting in a further increase in sorption compared to untreated material. Finally, the specific surface area (SSA) was estimated using methylene blue sorption tests. SSA also increased with decreasing Dp, which may explain the improved hydrocarbon sorption performance. This protocol optimization enables the evaluation of different treatments on sunflower husks for their use in hydrocarbon removal.

Keywords: sunflower hulls; hydrocarbons; sorption.

VALORIZATION OF AQUACULTURE BYPRODUCTS THROUGH ENZYMATIC HYDROLYSIS: PRODUCTION OF PEPTIDES WITH ANTIOXIDANT AND ACE-INHIBITORY ACTIVITY

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The valorization of aquaculture byproducts is a key strategy to promote sustainable food systems, reduce waste generation, and develop high-value functional ingredients. This study investigated the effect of various commercial food-grade proteolytic enzymes on blue tilapia (Oreochromis aureus) heads to produce protein hydrolysates with antioxidant and angiotensin-converting enzyme (ACE) inhibitory activities, with potential applications in functional foods and nutraceuticals. The enzymes used were Papain (PA), Protamex (PR), Neutrase/ Flavourzyme (NF), and Alcalase/Flavourzyme (AF), along with a control without enzyme addition (C). Hydrolysis was conducted at pH 6.5–7.5 (according to each enzyme's optimal range) and 55 °C for 180 minutes. The degree of hydrolysis (DH) was determined using the ortho-phthaldialdehyde (OPA) method. Antioxidant capacity was assessed using ABTS and ORAC assays, while ACE inhibition was quantified by HPLC using the hippuryl-histidyl-leucine (HHL) substrate. Protein hydrolysates (PHs) obtained with the different enzymes showed significant differences in the evaluated parameters (ANOVA, $p < 0.05$). The hydrolysate produced with AF exhibited the highest DH (55 ± 5%), followed by NF (32 ± 3%), PR (14 ± 1%), PA (4 ± 1%), and C (4 ± 1%). Regarding antioxidant capacity (ABTS), PHs from AF showed the highest radical scavenging activity (44 ± 3%), followed by NF (34 ± 2%), PR (19 ± 1%), PA (16 ± 1%), and C (12 ± 1%). The ORAC assay confirmed this trend: PHs from AF exhibited the highest activity (78.9 ± 1.5% at 0.5 mg/mL), followed by NF (71.5 ± 0.04%), PR (59.7 ± 1.7%), PA (56.3 ± 7.1%), and C (54.9 ± 0.3%). In terms of ACE inhibition, hydrolysis with AF was the most effective (59 ± 10% at 5 mg/mL), followed by NF (34 ± 7%), PA (18 ± 5%), PR (17 ± 3%), and C (12 ± 2%). At lower concentrations, PHs from AF maintained relevant inhibition levels (31 ± 1% at 0.5 mg/mL and 16 ± 8% at 0.05 mg/mL), demonstrating functional efficacy and stability across a broad dosage range. Although no direct linear correlation was observed between DH and the evaluated bioactivities, hydrolysis with AF combined a high DH with the greatest generation of functional compounds, suggesting a more efficient and targeted release of bioactive peptides. Overall, the results indicate that enzymatic hydrolysis of tilapia heads is a viable approach for producing functional ingredients with antioxidant and antihypertensive properties, adding value to aquaculture byproducts within a circular economy and sustainability framework.

Keywords: aquaculture byproducts; enzymatic hydrolysis; bioactive peptides; antioxidant capacity; ace inhibition.

EFFICIENCY STUDY OF GAS PERMEABLE MEMBRANES FOR VOLATILE FATTY ACIDS RECOVERY FROM LIQUID EFFLUENTS

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Hydrogen production through dark fermentation has emerged as a promising biotechnological route for converting agro-industrial waste into bioenergy. However, this process faces significant operational challenges, especially in continuous systems, such as the accumulation of volatile fatty acids (VFAs), which can inhibit microbiological activity and compromise the efficiency of H_2 production. On the other hand, VFAs are high-value compounds, widely used as precursors in the chemical industry and as intermediates in biofuel and biopolymer production chains. In this context, their selective removal during the fermentation process may represent a strategy to mitigate the inhibitory effects and also to enable the recovery of these acids as valuable byproducts. This work investigated the recovery of VFAs – acetic acid, propionic acid, and butyric acid – from a liquid synthetic effluent through the mass transfer rate (j) in an alkaline solution (0.5 mol L^{-1} NaOH) under mesophilic conditions (37 °C), using gas-permeable contact membranes. Two laboratory scale experiments were conducted using a synthetic acid solution (5 g L^{-1} of each VFA) in 2.25 L cilindric reator maintained in external contact with the membrane. The alkaline solution was recirculated internally to the membranes using peristaltic pumps, with specific flow rates for each configuration. Two different configurations were evaluated: the first experiment used a tubular ePTFE membrane (8 mm × 7 mm, with a wall thickness of 0.5 mm and an area of 0.0125 m²), submerged in 2.25 L of synthetic acid solution (5 g L^{-1} of each VFA), with internal recirculation of the alkaline solution at a flow rate of 250 mL min^{-1} by a peristaltic pump; and the second experiment used a polypropylene (PP) hollow fiber membrane module, with an area of 0.1 m² and a thickness of 0.2 mm, in which the synthetic acidic solution (5 g L^{-1} of each VFA) and the alkaline solution were recirculated in counterflow at 250 mL min-1 and 290 mL min^{-1}, respectively. Both experiments lasted 6 hours. The tubular membrane showed an average recovery of 154.54 mgVFA h-1 (R^2 = 0.99), obtaining a mass transfer rate (j) of 12.87 g $m^{-2}.h^{-1}$, while for the hollow fiber membrane an average recovery of 544.28 mgVFA h^{-1} (R^2 = 0.98) and a mass transfer rate of 5.44 g $m^{-2}.h^{-1}$ was obtained. Despite the higher total recovery of the hollow fiber membrane, the tubular membrane had a transfer rate almost 2.5 times higher, possibly due to its complete immersion in the feed solution, which increased the contact area with the VFAs. The promising results obtained encourage the application os the proposed system to real effluents and evaluate the mass transfer rate for implementing this acid removal/recovery system as a control in biohydrogen production.

Keywords: volatile fatty acids; biorefinery; nutrient recovery; dark fermentation; anaerobic digestion.

DEM-DRIVEN DESIGN OF COMPOST TURNERS FOR AGRO-INDUSTRIAL WASTE VALORIZATION: SIMULATING PARTICLE-MACHINE INTERACTIONS TO ENHANCE EFFICIENCY

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Composting plays an essential role in the treatment and valorization of agricultural and agro-industrial residues, helping to improve sustainable waste management and soil quality. In this context, mechanical turning of compost is key for promoting aeration, achieving uniform temperatures, and speeding up biodegradation. However, understanding exactly how the machinery interacts with compost material remains challenging but crucial to optimize both process and equipment. In our work, we applied the Discrete Element Method (DEM) to simulate the interaction between a compost turner and a triangular compost pile during the thermophilic maturation phase. DEM is well suited for this application because it allows us to represent the complex behavior of granular materials, including how particles interact with each other and with the equipment. This is something that traditional continuum models often fail to capture. Our main goal was to test whether the model could realistically reproduce the dynamic behaviors seen during turning, such as compaction, material flow changes, and particle dispersion inside the pile. To model compost, we incorporated typical properties of thermophilic compost such as moisture, cohesion and density. To model particle shape we represented compost particles as clumps of spheres. For particle interactions, we used a Hertz–Mindlin contact model combined with the JKR adhesion theory, which accounts for moisture-driven cohesion effects.

We simulated two rotor designs: one with paddles arranged along the entire rotor length following a helical pattern, and another where the paddles at the rotor ends were replaced with solid helical flights. Comparing these helped us explore how small geometric changes influence compost flow, providing a practical test of the model's sensitivity. While our focus was primarily on validating DEM for compost turning, these insights into rotor geometry may also guide equipment improvements. The simulations revealed flow patterns, including areas where compost tends to accumulate, voids form, and material recirculates, which are relevant for understanding and improving turning efficiency. We believe these findings can help reduce the need for costly physical tests and speed up the design process. Overall, our study shows that DEM can be a powerful tool to support sustainable organic waste management in agro-industrial settings. We hope that by improving the modeling of mechanical compost treatment, this work will contribute to better process control and more effective valorization of residues.

Keywords: discrete element method (dem); compost turning; agro-industrial waste management; numerical simulation; cohesive granular materials.

METHODS FOR THE RECOVERY OF HIGH-GRADE PHOSPHATES FROM LIVESTOCK WASTES

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Desirable characteristics of phosphorus (P) recovery technologies include the production of new materials with high-grade and predictable phosphate concentration, the ability to be used directly without requiring further industrial processing beyond the recovery process and providing other ecosystem benefits such as protection and restoration of water quality. Livestock effluents contain high amounts of inorganic carbon (carbonate) that produces interference for precipitating high-grade phosphates using phosphorus-precipitating compounds, calcium, and magnesium. Acidification before adding the phosphorus-precipitating compounds enhances phosphorus recovery by solubilizing phosphorus and destroying the interfering compounds. Without P solubilization, a smaller amount of the total P is available for recovery as a concentrated phosphate. Without carbonate destruction, the alkaline earth metal compound (Ca and Mg precipitating agent) reacts first with the carbonate, before reacting with the phosphate, resulting in inefficient phosphate precipitation and the production of low-grade phosphate products that are undesirable. Over the past twenty years, five different methods have been developed for enhanced phosphate recovery from wastes by removing the inhibitory effect of inorganic carbon and increasing phosphorus dissolution, resulting in effective phosphorus recovery from various manure and municipal waste streams. 1) One method uses biological nitrification of ammonia to produce the necessary acidity at the farm by microorganisms before P precipitation (US Patent 6,893,567); 2) another method developed for poultry wastes and municipal sludges uses chemical acidification: it adds mineral or organic acids to acidify the organic waste before the P precipitation step with lime (US Pat. 8,673,046); 3) in another method, the organic acids are produced in-situ through rapid fermentation using acid precursors (sugary wastes) (US Pat. 10,710,937); 4) another method uses physical acidification: it adds the P precipitating compounds to the wastewater after the carbonate alkalinity and ammonia are substantially reduced using gas-permeable membranes that recovers the ammonia in a second product (US Pat. 9,926,213); 5) the most recent method developed uses electrochemistry to enhance the P recovery from livestock wastewater (US Pat. App. 18/808,123). In all these methods, high-grade phosphate fertilizers have been produced from livestock and municipal waste, with a quality like commercial superphosphates.

Keywords: phosphorus recovery; resource recovery; high-grade phosphates; circular economy.

PILOT MONITORING SYSTEM FOR ANAEROBIC DIGESTION AND BIOGAS CHARACTERIZATION

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Anaerobic digestion represents an efficient technological alternative for organic waste treatment, promoting biogas production as a renewable energy source and reducing environmental impact. To ensure proper reactor operation and optimize performance, it is essential to have tools that allow recording and controlling key process variables, as well as evaluating the quality of the generated gas. This work presents a pilot system designed to perform measurements during the digestion process, of both the operating conditions and the quantity and quality of the biogas produced. The system enables the recording of parameters such as pH, temperature, electrical conductivity, redox potential, and dissolved oxygen. It includes a data acquisition subsystem connected to a mini-PC with a touchscreen as HMI. It works with a distributed architecture based on Atmega microcontrollers (RISC), which act as dedicated processing units. Communication with sensors is managed through an API developed in C++, using serial protocols with structured data exchange. Each sensor operates on an independent channel, with dynamic configuration and specific reading interfaces (READ) for each transducer. The acquired data is stored with time traceability, ensuring measurement integrity and continuity. The communication protocol allows remote configuration of sampling parameters, calibrations, and verification of data quality through checksum algorithms.

A module for measuring the methane content in biogas was also developed, based on a sensor housed in a specially designed chamber manufactured using 3D printing, and with sealed connections for the gas line. Gas tightness was guaranteed with internal epoxy coating and pneumatic fittings. To protect the sensor from water vapor and hydrogen sulfide, a sampling system was developed to allow the introduction and removal of the gas under controlled conditions. The system includes open-source hardware and software components, 3D-printed parts, and standard medical supplies such as Luer-type components, which facilitates accessibility and replicability. Using motorized three-way valves and syringe pumps, the device can control the biogas flow into the sensor chamber and its subsequent purging with fresh air after each measurement. The system was tested in a pilot plant treating industrial waste, particularly from the meat processing sector. Different waste fractions were analyzed, with the co-digestion of green and red waste standing out due to their high biogas generation potential. During system operation, the process variables were recorded, and methane measurements showed a good correlation with those obtained through gas chromatography (GC-2014, SHIMADZU) and a portable biogas analyzer (BIOGAS 5000), confirming the reliability of the developed system. This work demonstrates the feasibility of implementing accessible, versatile, and cost-effective measurement devices. The modular design and the integration of accessible components allow the combination of measurement quality and scalability, making it a valuable tool for both research and application in real treatment plants.

Keywords: methane measurement; process monitoring; sensor integration; industrial wastes; co-digestion.

CO-DIGESTION OF PIG MANURE WITH PEANUT SHELLS: METHANE YIELD IMPROVEMENT AND KINETIC MODELLING

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In the last 22 years, pig production in Argentina has increased, along with greater intensification, resulting in concentrated effluents with high organic load. Stabilization of these effluents is essential prior to environmental discharge. Anaerobic digestion (AD) is a widely recognized method to treat pig manure (PM), producing renewable energy and a digestate with potential agronomic use. However, high ammonium levels in PM can inhibit the AD process. Co-digestion is a cost-effective strategy to mitigate this issue by balancing nutrients and diluting inhibitors. To implement this approach, it is crucial to identify locally available co-substrates with low nitrogen, high carbon content, and year-round availability must be identified. In this context, peanut shells (PS), a by-product generated during the blanching step of peanut processing, have potential as a co-substrate in the AD of PM. The objective of this study was to evaluate the potential of PS as a co-substrate to optimize the anaerobic digestion of pig manure. A biochemical methane potential (BMP) test was conducted using the Automatic Methane Potential Test System (AMPTS® II), with an inoculum-to-substrate (I/S) ratio of 2 gVS/gVS. Four treatments were evaluated, in addition to a blank containing only inoculum (I) and a control (cellulose + I). The treatments were: PM100: PM + I; PM97.5: I + PM 97.5% (w/w) + PS 2.5% (w/w); PM92.5: I + PM 92.5% (w/w) + PS 7.5% (w/w); and PM77.5: I + PM 77.5% (w/w) + PS 22.5% (w/w). All treatments were conducted in triplicate. Net methane production was estimated by subtracting the methane produced in the blank. Using the experimental data, four kinetic models (First-order, Fitzhugh, Cone, and Modified Gompertz) were applied to describe the anaerobic process and estimate methane production parameters from PM in co-digestion with varying proportions of PS. Calculations were performed using an Excel macro (VBA). Based on the coefficient of Determination (R^2) and the root mean square error (RMSE), the Cone model provided the best fit. This model describes cumulative methane production M(t) as a nonlinear function of time. The results showed that PS addition enhanced the cumulative methane production potential ($M\infty$). Specifically, methane yield increased by 35.6% between the treatment without PS and the treatment with the highest PS proportion (237 L/gVS; 277 L/gVS; 333 L/gVS; and 368, L/gVS for PM100, PM97.5, PM92.5, and PM77.5, respectively). On the other hand, the methane production rate constant (k) decreased with increasing PS content (PM100: 0.35 d^{-1}; PM97.5: 0.6 d^{-1}; PM92.5: 0.31 d^{-1}; and PM77.5: 0.28 d^{-1}). A similar behavior was observed for the shape parameter n, where higher addition of PS led to a decrease in its value compared to PM100. In this context, the Cone model associates lower n values with less accessible or more difficult to assimilate substrates. In conclusion, the addition of PS positively influenced methane production, suggesting this co-substrate could represent a viable strategy for large-scale PM treatment. Furthermore, these strategies facilitate integration of additional waste streams, contributing to reduced environmental impact and fostering circular economy approaches.

Keywords: pig manure; peanut shells; biochemical methane potential; kinetic modeling; co-digestion.

IMPLEMENTATION OF AN INTEGRATED BIODIGESTER AND CONSTRUCTED WETLAND MODULE FOR DECENTRALIZED SEWAGE TREATMENT IN THE MARÉ COMPLEX, RIO DE JANEIRO

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Urban sanitation is fundamental to public health and the well-being of any region. However, in the Maré Complex, less than 1% of the sewage generated is directed to treatment plants, resulting in the direct discharge of untreated effluents into Guanabara Bay. This situation exacerbates pollution, compromises residents' quality of life, and hinders the sustainable development of the community. In response to this scenario, the present project proposes the implementation of an integrated Biodigester and Wetland module, aiming to treat domestic effluents in a decentralized and sustainable manner, while also generating data to enable replication in other vulnerable territories. The adopted methodology involved the design, construction, and implementation of a prototype system adapted to the local conditions of Maré. The process was divided into three main stages: Planning and procurement: Selection of the intervention site (Evanildo Alves Canal, Parque Maré), system layout design, acquisition of materials, and site preparation; System construction: Installation of a pump for effluent collection, equalization tank, grease trap, anaerobic biodigester, sludge chamber, monitoring boxes, and a wetland system composed of phytoremediating aquatic plants (Costus spiralis, Xanthosoma sagittifolium, Vetiver grass); and Monitoring and analysis: Over a three-month period, water samples were collected at different points in the system for physicochemical and microbiological analysis, following recognized laboratory protocols. Community engagement was promoted through educational activities and local participation in the implementation and maintenance of the prototype. The prototype demonstrated high removal efficiencies, achieving up to 95% reduction in Chemical Oxygen Demand (COD) and 70% in Biochemical Oxygen Demand over 5 days (BOD5), indicating significant reduction of organic load in the treated effluent. The resulting water showed potential for reuse in activities such as garden irrigation, street cleaning, and toilet flushing, including in community schools. The implementation cost, approximately R$ 8,000, demonstrates economic feasibility for replication in other communities areas, especially considering low maintenance requirements and the use of accessible materials. Continuous monitoring and community mobilization also strengthened local ownership of technology and increased awareness regarding sanitation and environmental health. This experience demonstrates that integrating biodigesters with wetlands is a viable, low-cost, and highly efficient alternative for decentralized sewage treatment in vulnerable territories such as Maré. The system contributes to reducing water pollution, improving residents' quality of life, and can be replicated in other communities with similar characteristics. Furthermore, the project reinforces the importance of community participation and data collection to support public policies aimed at universalizing basic sanitation in Brazilian communities.

Keywords: urban sanitation; biodigester; constructed wetland; water reuse.

SMALL-SCALE BIOGAS DIGESTER FOR RURAL RENEWABLE ENERGY, GHG EMISSION CONTROL, AND DAIRY WASTE MANAGEMENT

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In rural areas, livestock waste poses numerous challenges including environmental pollution, and risks to public and animal health, and controlling it requires improved technologies for waste management. These technological solutions are only feasible in developing countries and rural communities if the cost is affordable, and technology is simple. Small-size biogas plants could provide an alternative option for livestock waste treatment and for renewable energy production because these biogas plants also produce methane, which is a source of renewable energy. However, if this biogas is not trapped then this biogas is emitted into atmosphere, and it can cause potential issues related to greenhouse gas (GHG) emissions. Further, studies from China, and India showed that these biogas plants are proven to provide improved sanitation and reduces the health risks caused by livestock waste. While anaerobic process inside bio digester is natural and complex, the designing of biogas plants could be relatively simple, however, improved understanding of the technology, and its potential benefits is needed. In this research, the goal was to synthesis information on small-size dairy digesters (i.e., biogas plants) and their applications in disadvantaged and underdeveloped regions. Further, we elaborated the potential challenges in the implementation of these technologies. We anticipate that the information provided here will help in educating biogas technology to agricultural communities, next-generation work force in the technologies, which has numerous application in rural regions.

Keywords: biogas plants; rural energy; waste treatment; renewable energy; dairy farms.

EVALUATION OF CARCASS COMPOSTING IN SWINE FARMS: PILOT EXPERIENCE IN ARRECIFES (BUENOS AIRES, ARGENTINA)

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Proper management of carcasses on pig farms remains a challenge in many production systems. In response, the “Valorizing Waste” team, composed of pig farmers from Arrecifes and technicians from INTA, set out in 2025 to address this issue. Composting represents a potential alternative for managing pig farm mortalities; however, there is currently limited information on the process’s requirements and overall effectiveness. The aim of this study was to initiate an evaluation of the feasibility of this approach. To reach the objective, an open-air pile measuring 10 m long, 2 m wide, and 1.5 m high was set up on a pig farm. The process began on April 16, and over a 15-day period, 32 carcasses totaling 1,200 kg were incorporated. Each was subjected to an abdominal incision and limb separation. As a carbon source, 1,120 kg of sorghum hay were used; in addition, 1,800 kg of corn silage were applied to cover the pile. Temperature was periodically measured at three different points along the pile. On day 40, once the decomposition of the carcasses allowed, the first turning was performed. On day 51, samples were collected for material characterization. Three days after setting up, the average temperature rose above 50 °C. The maximum temperature recorded was 61.4 °C on day 24. Although the average pile temperature remained above 45 °C during most of the monitored days, microbiological analyses revealed fecal coliform levels of 26,500 MPN/g DM, exceeding the national regulatory limit (<1,000 MPN/g DM). On day 51, the compost showed an alkaline pH (8.3) and high electrical conductivity (9.34 dS/m). It also had a high organic matter content (62%) and total Kjeldahl nitrogen (3.2%). CO_2 production reached 1,354.5 mg CO_2/kg OM/h, far exceeding the stability threshold (<120 mg CO_2/kg OM/h), indicating that the material had not yet reached the desired stability. The ammonium content (1,352 mg N–NH_4^+/kg) also exceeded the recommended threshold (<400 mg N–NH_4^+/kg), and the low lettuce seed germination index (11%, below the required minimum of 60%) indicates that the material is still immature and may exhibit phytotoxic effects. The moisture content (64%) indicates the need for pile turning to enhance drying, ensure material homogenization, and achieve complete sanitization through elevated temperatures. Although fifty-one days of composting were not sufficient to meet the parameters established by current regulations, the process is considered to be progressing appropriately and represents a viable strategy for the treatment of swine carcasses. The farm has adopted the system and continues the staggered construction of open-air piles. Further research is needed to develop strategies to reduce the use of carbon-rich materials, exploring alternative biomass sources, and adjusting practices to improve the efficiency of the composting process.

Keywords: residues; mortality; composting; temperature; farmers.

EFFECT OF PYROLYSIS TEMPERATURE ON YIELD AND CARBON CONTENT OF BIOCHAR PRODUCED FROM TWO GRASSES GROWN IN CADMIUM-POLLUTED OXISOL

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Soil and water contamination by cadmium (Cd) is a serious environmental concern, as Cd is readily absorbed by plants and can enter the food chain. Phytoremediation is a promising strategy to reduce Cd concentrations in the environment, and its effectiveness can be enhanced through the strategic use of biochar produced from contaminated plant biomass. High-biomass species, such as grasses, are capable of uptaking and accumulating metals from polluted soils. When subjected to pyrolysis, these metals become largely sequestered within the carbonaceous matrix of the resulting biochar, but it depends on resulting carbon content. In this study, we evaluated the influence of pyrolysis temperature (500 and 800 °C) on the yield and carbon content of biochar derived from the biomass of two grass species—Pennisetum glaucum cv. Purpureum Schum and Panicum maximum cv. Mombaça—grown in an Oxisol moderately contaminated with Cd (7.5 mg kg^{-1} soil). Pyrolysis at 800 °C significantly reduced the biochar yield from P. glaucum, but as expected, resulted in the highest carbon contents, especially for this species. At 500 °C, both P. glaucum and P. maximum produced higher biochar yields; however, the biochar from P. glaucum still exhibited higher carbon content than that from P. maximum. This finding is particularly relevant, as higher carbon content is typically linked to greater chemical stability and the formation of a porous structure enriched with surface functional groups. These characteristics enhance the biochar's ability to interact with metal ions, promoting their immobilization and, consequently, reducing their toxic effects on plants and soil microorganisms. Our findings highlight the potential of using high-biomass grasses, particularly P. glaucum, not only for Cd phytoremediation but also for generating biochar with favorable properties for environmental recovery. Despite the lower biochar yield at 800 °C, the significant increase in carbon content - especially in P. glaucum - reinforces the value of higher pyrolysis temperatures when the goal is to obtain a more chemically stable and functionally active material. These results suggest that optimizing pyrolysis conditions according to the biomass source is essential to maximize the efficiency of Cd immobilization. Therefore, combining phytoremediation with tailored biochar production represents a viable and sustainable strategy for mitigating Cd pollution in tropical soils.

Keywords: circular phytoremediation; environmental sustainability; poaceae; soil pollution.

INTEGRATION OF ANAEROBIC DIGESTION AND COMPOSTING: A CASE STUDY

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This research focused on the exploration and projection of a combined system integrating anaerobic digestion and composting. The premise is that by merging both processes, it becomes possible to harness their respective strengths, achieving greater efficiency in waste valorization, while reducing operational time, the volume required in digesters, and the surface area needed for composting. Theoretical advantages of an integrated system include the elimination of potential pathogens in the digestate—by irrigating compost piles during the thermophilic phase—and the use of biogas to dry the compost. Additionally, the warm air existing the dryer can be used to heat the feed into the digester, maintaining mesophilic conditions. Compost pile leachate can also serve to dilute the waste destined for digestion. The study was conducted by the composting company TRESOR, located in Montevideo, which processes agro-industrial waste in open-air piles and operates a compost dryer powered by propane. This fuel is proposed to be replaced by biogas, which could be produced from the anaerobic digestion of a portion of the waste. The analysis focused on the waste typically composted by TRESOR. Based on the estimated biomethanation potential, the study selected primary sludge from a dairy industry, to evaluate its treatment via anaerobic digestion. Later, fruit and vegetable market waste was incorporated for co-digestion, aiming to reduce ammonia concentrations and mitigate inhibition risks in the digester. A 3-liter stirred digester was used, inoculated with a mixture of sludge from an IC-type anaerobic reactor and anaerobic lagoon sludge. The system was fed once daily from Monday to Friday, operated at 35°C, and subjected to increasing organic loads. In parallel, the suitability of the resulting digestate for composting was assessed through respirometric techniques, which provide insight into its contribution to the bio-oxidative phase. The monitored digester parameters included total solids (TS), volatile solids (VS), chemical oxygen demand (COD) in influent and effluent, pH, temperature, soluble COD, ammoniacal nitrogen, volatile fatty acids, bicarbonate alkalinity in the digestate, biogas flow rate, and methane content. A stable performance was achieved with a 15-day hydraulic retention time, an organic loading rate of 4 kgVS/(m^3·d), and a biogas production of 3.0 L/d per liter of reactor. At an industrial scale, implementing a 200 m^3 digester would allow the release of 0.78 hectares within the composting area. The operating parameters of the rotary drum sludge dryer were evaluated, determining an energy consumption of 373 kW to dry 4 m^3 of compost from 68% to 50% dry basis. Under these conditions, the dryer releases an air stream of 4,300 m^3/h at 120 °C, suitable for heating the digester feed to up to 40 °C. From the site-wide water balance and leachate characterization, it was determined that the leachate is suitable for diluting the digester feed. Respirometric analysis indicated that the digestate retains sufficient organic load to help sustain the thermophilic phase of composting when applied to the compost piles. In conclusion, the integration of anaerobic digestion into this composting facility would enable a significant improvement in both its capacity and environmental performance.

Keywords: co-digestion; biogas; composting; rotary dryer.

BIOGAS SAMPLE STABILITY IN DIFFERENT CONTAINERS

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The analysis of anaerobic digesters biogas' composition is necessary to determine its quality, including the methane content to determine its calorific potential, as well as its impurities for use in several burners. In small rural or demonstration digesters, biogas analyzers are often not available on-site due to their high cost. Therefore, it is necessary to take a biogas sample and send it to a laboratory for analysis. In Argentina, specialized laboratories with the capacity to analyze biogas samples are scarce and not available in all provinces. This leads to samples being sent by mail, typically taking 3-7 days to arrive to destination. This situation led us to evaluate the stability of samples taken in Tedlar bags and other sampling tools. We sampled the same biogas in Tedlar bags, and three other systems reported in scientific publications for biogas storage: urine bags, inflatable balls and syringes with three-way valves closed to prevent biogas escape. The samples were then analyzed daily using CO_2 absorption by 1 N NaOH. With the Tedlar bag, the CO_2 concentration varied significantly ($p > 0.5$) on the seventh day compared to previous days. This situation occurred on the third and first day for the inflatable ball and urine bag, respectively. The syringes showed highly dispersed results, with loss of stored biogas volume prior to sampling. These results show that even the Tedlar bags, specially designed for gas sampling, are permeable to CO_2 after a certain period, and that urine bags are not a reliable method for biogas storage. It is essential to ensure that the sample shipment never exceeds 7 days.

Keywords: biogas; sampling; stability.

EXPLORATORY AND CAUSAL ANALYSIS OF OPERATIONAL VARIABLES IN AN ANAEROBIC DIGESTION PLANT TREATING AGRO-INDUSTRIAL WASTE

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Anaerobic digestion systems are a sustainable technology for the energy recovery of organic waste through biogas production, contributing simultaneously to waste management and renewable energy generation. However, the efficient operation of these plants faces significant challenges associated with high organic loads and the compositional variability of substrates, especially when processing heterogeneous agro-industrial waste. This operational complexity demands the development of advanced monitoring and control strategies based on multivariate analysis of operational data. This work proposes an exploratory and causal analysis strategy of operational variables in an anaerobic digestion plant treating agro-industrial waste, aimed at identifying significant relationships and relevant time lags between key process parameters. These insights can serve as a foundation for the development of predictive models to optimize system performance. Time series data were collected daily from January 2022 to December 2024. The monitored variables included feeding indicators (volumetric flow rate [m³], organic load [kg COD], alkalinity/volatile acidity ratio - ALFA), operating parameters (internal temperature, pH), and biogas characteristics (volume consumed, CH_4 and H_2S concentrations). Additionally, daily ambient temperature was included as an exogenous variable, sourced from the National Meteorological Service. Computational analysis was conducted using Python and libraries specialized in data processing and time series analysis. Preprocessing steps included uniform data type conversion, removal of variables with more than 40% missing values, outlier detection, and replacement using the z-score method (threshold = 3) and mean-based point imputation. A smoothed moving average of 7 and 14 days was also applied to facilitate visual pattern recognition. However, no distinctive patterns were observed. Spearman correlation analysis revealed significant nonlinear associations between operational variables. Notable findings included direct correlations between pH and ALFA ($\rho = 0.62$), ambient temperature and acetic acid concentration ($\rho = 0.45$), and negative correlations between ALFA and volatile fatty acids ($\rho = -0.55$), consistent with expected biological phenomena such as acidification and its impact on process stability. To assess the directionality of these relationships, Granger causality tests were applied, exploring lags of up to 10 days. Results showed that acetic acid concentration anticipates changes in ALFA (lag = 10), pH (lag = 1), and organic load (lag = 6), reflecting the acidogenic phase of the process. Internal temperature proved to be predictive of pH (lag = 1), volumetric load (lag = 1), and, notably, biogas production with a lag of 3 days. Meanwhile, ambient temperature showed predictive influence on biogas consumption (lag = 6) and acid-base balance (pH and ALFA) with lags ranging from 1 to 6 days. These findings highlight complex temporal relationships among variables governing the bioprocess dynamics, suggesting that systematic lag analysis can support the development of predictive control strategies and adaptive operation. In this context, the implementation of automated data acquisition systems enabling continuous, accurate, and traceable monitoring is emphasized as a solid foundation for applying artificial intelligence and hybrid modeling techniques aimed at optimizing biogas production.

Keywords: anaerobic digestion; multivariate analysis; agro-industrial waste; time series analysis; operational monitoring.

EVALUATION OF THE OPERATION OF CONTINUOUSLY STIRRED TANK REACTORS (CSTR) FOR THE ANAEROBIC CO-DIGESTION OF BROILER LITTER AND LAYING HENG MANURE

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Poultry production in Uruguay is concentrated in the southern region of the country, where egg and broiler production generate 26% of agro-industrial waste. The main residues produced in poultry farms are broiler litter (BL) and laying hen manure (LHM), reaching 81,000 and 3,300 tonTS/year, respectively (Benzano et al., 2016). Although the solids wastes have been used as fertilizer in the region, the excessive application and lack of prior stabilization generated the overload of nutrients in the water basin where the poultry production is concentrated. In this context, the valorization of BL and LHM through anaerobic digestion (AD) is proposed to produce biogas and digestate. The research strategy consists of evaluating the technological, economic, and environmental feasibility of implementing centralized anaerobic co-digestion (CoAD) projects using these residues. In order to assess maximum energy production, the Biochemical Methane Potential (BMP) of BL, LHM, and their mixture at the nationally generated ratio (24:1 in TS) was evaluated. To evaluate the technology in full-scale centralized plants, the performance of AD was studied in reactors operated under continuous flow conditions. Specifically, six continuous stirred-tank reactors with 2 L of effective volume (BRS Bioprocess Control) were fed over 176 days with BL, LHM, and the BL:LHM mixture (24:1). The aim was to determine the operating conditions that yield the highest methane (CH_4) production with minimal reactor volume. Reactors were operated at a constant Hydraulic Retention Time (HRT) of 20 days with a progressive increase in Organic Loading Rate (OLR). Process monitoring included biogas volume measurement and digestate analysis of pH, TS, VS, FOS/TAC, and NH_4^+. Three steady states were established corresponding to OLRs of 1, 2, and 3 kgVS/m³·d, where the CH_4 concentrations, the digestate characterization (COD, TP, TN, volatile fatty acids, macro- and micronutrients), pathogen, antibiotic resistance, and microbial community composition were also determined. Throughout the assay, pH (6.94 - 7.94), FOS/TAC (< 0.3), NH_4^+ (200 - 1151 mgN-NH_4^+/L), and NH_3 (52 - 74 mgN-NH_3/L), were in the reported ranges for these type of processes (Mezes et al., 2011; Dai et al., 2016; Guebitz et al., 2015; Yenigün and Demirel, 2013). Maximum methane yields (YCH_4) were obtained at OLR = 1 kgVS/m³·d (BL: 106 $NLCH_4$/kgVS, LHM: 229 $NLCH_4$/kgVS, BL:LHM: 103 $NLCH_4$/kgVS), which decreased as the load increased to 2 kgVS/m³·d (BL and LHM: 23%, BL:LHM: 17%). When the OLR was raised to 3 kgVS/m³·d, RCH_4 remained similar in the LHM reactors (184 $NLCH_4$/kgVS), while those containing BL and BL:LHM progressively ceased CH_4 production after day 100. It is presumed that the poor degradation of BL, evidenced by the accumulation of solids in the reactors at the end of the assay, led to a 40% reduction in effective reaction volume, thereby reducing HRT and increasing OLR. As a result, the maximum RCH_4 for LHM was 88% of its BMP, while for BL and BL:LHM it was considerably lower than these BMP results (28% and 37%, respectively).

Keywords: poultry farm wastes; anaerobic co-digestion; BMP; CSTR.

EFFICIENT CONVERSION OF GLYCEROL TO ETHANOL IN ELECTRO-SYNTROPHIC BACTERIAL CO-CULTURES

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World excess of glycerol, the main by-product of biodiesel industry, is causing traditional production and refinement industry of glycerol to shut down while novel applications for this, now abundant, carbon source are needed. The discovery in 2006 that Escherichia coli is capable of fermenting glycerol with the subsequent production of several by-products, including ethanol, a source of clean fuels with proven less environmental impact than conventional fossil fuels, may offer a solution. During fermentation of glycerol, H2 is also produced and if not removed it inhibits the fermentation process. Specifics pH, temperature and medium composition conditions are also required. Our hypothesis is that growing E. coli together with Geobacter sulfurreducens will promote and improve the production of bio-ethanol since the latter is capable of oxidizing H2 generated by E. coli in its respiratory metabolism. Coupling this co-cultures to an electrochemical system provides an endless source of electron acceptor for Geobacter respiration process and favors its application. We put our hypothesis to test by designing a set of experiments where electrochemical co-culture systems were developed. The co-cultures grew in an H-cell type electrochemical cell, with agitation at 37 ºC and pH of 6,3 externally maintained during fermentation. The experiments had a duration of two weeks, through the first week Geobacter electroactive biofilms were developed with acetate as carbon and electron source. During the second week medium was replaced with specific fermentative one containing glycerol 108 mM (10 g/l) as unique carbon source and inoculated with E. coli. From this moment the system was maintained without gas injection so that H2 produced during fermentation would accumulate and samples were taken daily for fermentation development analysis. In this work we present results for two differentiated reactors. After E. coli inoculation current production (i.e. Electrons derived from Geobacter metabolism) raised to a maximum of 2,98 ± 0,32 mA during the first 30 hs of co-culture. This result indicates that Geobacter was metabolically active during co-cultures conditions. E. coli growth curve, on the other hand, follows a similar behavior in all reactors, reaching a OD600nm of 0.9 by the end of the experiments. Co-cultures named C1 had a 80.8% glycerol consumption with an ethanol production of 31.32 mM (1,44g/l) while co-culture 2 (C2) reached 97.4% glycerol consumption with ethanol generation of 51mM (2.35g/l). On the other hand, molar relation was 0.83 and 0.63 (moles of ethanol produced/moles of glycerol consumed) for C1 and C2 respectively. Both total ethanol production and molar relation were significantly higher when compared to monocultivated E. coli fermentative reactor hermetically sealed where H2 accumulates and fermentation was inhibited. They also prove that electroactive Geobacter presence has an overall positive effect (eliminating H2 and increasing ethanol production with respect to glycerol consumption) over the fermentative process of E. coli. In other words, highly efficient glycerol conversion to ethanol was achieved under the conditions developed, with similar or even higher values to those previously reported for fermentation process where an argon gas is constantly applied for H2 removal.

Keywords: biofuels; glycerol fermentation; bioethanol; sintrophy; bioelectrochemical system.

COMPREHENSIVE FRACTIONATION OF RICE HUSK: A STRATEGY FOR VALORIZATION OF AGROINDUSTRIAL RESIDUES IN THE NEA REGION

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Rice husk (RH), a highly abundant lignocellulosic residue in the Argentine NEA region, remains underutilized despite its potential. This study focuses on developing an integrated biorefinery process that enables the fractionation of its four main structural components: cellulose, hemicelluloses, lignin, and silica, for subsequent conversion into high-value products. This approach addresses environmental concerns while creating economic opportunities within the region. The fractionation process was applied to rice husk obtained from a rice milling industry in Chaco. The methodology was designed in sequential steps to achieve high selectivity and yield in the recovery of each component. Initially, alkaline treatment was employed, resulting in efficient removal of lignin (82%) and inorganic compounds (95%). Lignin and silica, the primary inorganic constituents of rice husk, were recovered with high yields through acidification of the treatment liquor to pH 6 and pH 3, respectively. The near-pure recovery of these components is a critical step for their specialized downstream applications. Subsequently, additional delignification was performed using two oxygen (O_2) treatment stages, followed by treatment with a mixture of acetic acid and hydrogen peroxide (Ac:H_2O_2 1:1). This advanced delignification process reduced residual lignin content to 0.45% on a dry basis, representing nearly complete removal, obtaining high-purity cellulose, suitable for advanced cellulolytic materials. Finally, three easily recoverable organic acids were evaluated for hydrolysis and selective extraction of hemicelluloses. The use of organic acids minimizes degradation products and facilitates the recovery of hemicellulosic sugars, which can be converted into bioproducts such as ethanol or xylitol. Beyond providing a technological solution for valorizing agroindustrial waste, this work lays the foundation for developing a circular economy within the rice industry of the NEA region, transforming a low-value byproduct into multiple valuable resources. This biorefinery approach offers a promising pathway to foster innovation and sustainability in the region.

Keywords: biorefinery; rice husk; valorization; agro-industrial residues.

CIRCULARITY APPLIED TO THE SEQUENTIAL PROCESS OF COMPOSTING FOLLOWED BY VERMICOMPOSTING IN THE TREATMENT OF GRASS PRUNING, CATTLE MANURE AND TOBACCO RESIDUES

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Composting is a biological process that transforms organic waste into a nutrient-rich compost. This practice is an alternative to reducing the volume of waste that is usually landfilled in South American countries. Tobacco waste presents an environmental problem because it is either incinerated or landfilled, causing negative impacts, such as the release of pollutants and contaminants into the air, soil, and water. Based on this, this study aimed to evaluate the technical viability of tobacco waste as a bulking agent in the composting process, followed by the vermicomposting process. Three pre-composting windrows with manual turnings were investigated using different waste proportions: food waste, grass pruning, and cattle manure (windrow 1), food waste, grass pruning, tobacco waste, and cattle manure (windrow 2), and food waste, tobacco waste, and cattle manure (windrow 3). The pre-composting process lasted 15 days, followed by the vermicomposting process, being the latter investigated under six treatments (with and without wash-out to decrease electrical conductivity, being vermicomposting after windrow 1 (V1/V1W), after windrow 2 (V/V2W), and after windrow 3 (V3/V3W). The monitoring of each aerobic biological process was carried out based on temperature, pH, electrical conductivity, total solids, volatile solids, moisture, and microbiological parameters. Finally, phytotoxicity bioassays with crisp lettuce seeds (Lactuca sativa L.) were performed using the three pre-compost and the six vermicomposts produced. The temperature of the three windrows ranged from 50 ºC to 70 ºC, with 17 to 24 days remaining in the thermophilic phase. Windrow 1 and vermicomposting 3 without wash-out (V3) presented the best results in terms of C/N ratio. Regarding the phytotoxicity of composting and vermicomposting, windrow 1 and vermicomposting V2 presented the highest percentage of the Germination Index (78% to 197%). This study indicates that the biological process was viable to stabilize the agro- and urban wastes and improve circular economy, despite tobacco waste presenting substantial limitations. Grass pruning proved to be superior to tobacco as a structuring agent in relation to the stability of the compost, which is reflected in the fact that windrow 1 presented better results. Therefore, although tobacco can be used in composting with food waste and cattle manure, its isolated use is not recommended due to the limitations presented during the process.

Keywords: electrical conductivity; germination index; circular economy.

TREATMENT ALTERNATIVES FOR BROILER LITTER STACKING- ALTERNATIVAS DE TRATAMIENTO DE APILADO DE LA CAMA DE POLLO

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Self-heating through stacking is a method used to treat broiler litter inside the poultry house during the sanitary downtime period. Its goal is to reach high temperatures that allow the elimination of pathogenic organisms responsible for diseases. This process is generally recommended to last between 14 and 20 days and include an intermediate turning. To evaluate simpler alternatives, two treatments were tested: tall piles (1.20 m) and short piles (0.40–0.50 m), without turning and with a duration of 7 days. During stacking, temperatures were recorded at different pile levels (surface, center, and base), and the presence of undesirable microorganisms (Enterobacteriaceae, total and fecal coliforms), as well as the detection of genomic material of the Hepatitis virus (AdV-HCI), was analyzed before and after treatment. In the tall piles, surface temperatures increased rapidly and reached 55 °C, although they did not remain at that level for the three consecutive days recommended for effective microorganism control. At the center of the pile, temperatures reached nearly 70 °C by the second day and remained high until the end of the process. At the base, 55 °C was reached around the third day and then stabilized. This treatment led to a significant reduction in Enterobacteriaceae, total and fecal coliforms, and the complete elimination of AdV-HCI genomic material. Regarding the short piles, which started at heights of 0.42 m and 0.52 m, only the taller pile reached 55 °C at all three depths evaluated, and only the center maintained that temperature for three consecutive days. In the shorter pile, 55 °C was not reached at any point. Although there was a general trend toward reduction in the bacterial counts, only the decrease in Enterobacteriaceae was statistically significant. Additionally, unlike the tall piles, some repetitions in both short piles remained positive for AdV-HCI genomic material after treatment, suggesting that this type of stacking may not be effective for complete virus elimination. In conclusion, the treatment with tall piles for 7 days proved more effective than short piles in controlling the undesirable microorganisms evaluated.

Keywords: self-heating; poultry litter; pathogenic microorganisms; virus; bacteria.

TREATMENT OF WASTE FROM A POULTRY BREEDING CENTER BY COMPOSTING

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Conventional management of poultry farming waste is associated with greenhouse gas emissions, unpleasant odors, and the presence of pathogens, birds, and rodents. Additionally, waste disposal is often perceived as costly for producers. However, composting offers a circular economy approach that allows for the valorization of these residues, providing multiple environmental benefits by turning them into organic soil amendments. Due to the specific physicochemical and biological characteristics of poultry waste, understanding its composition is essential for appropriate environmental management, especially considering the variety of waste types generated. A particular case involves waste from poultry multiplication centers, which includes eggshells, unfertilized eggs, non-viable fertilized eggs, and discarded male and/or female chicks. These residues may also contain feed remains, feathers, bedding materials, and occasional mortalities of breeding stock. This material typically has a carbon-to-nitrogen (C/N) ratio close to 10. This study aimed to characterize the compost produced from poultry multiplication center waste combined with other agricultural and livestock by-products at the Regional Environmental Technological Industrial Park (PITAR) in San Juan, Argentina. Compost piles were prepared using mixtures of manure, garlic packing waste, and wood chips as a bulking agent. Approximately 8 m^3 piles were built using front loader machinery and turned during the thermophilic phase. Afterwards, the compost was arranged in lower windrows (30 m long and 1.5 m wide) to allow for turning and moistening with a compost turner until the maturation phase was completed. Compost samples were collected and analyzed following TMECC methodology (USDA, USCC, 2002). The physicochemical parameters showed a pH of 8.07, moisture content of 22.35%, electrical conductivity of 3.81 dS/m, a C/N ratio of 10.7, and organic matter content of 30.42%. Phytotoxicity tests using radish and wheat seeds resulted in germination indices of 116.57% and 62.62%, respectively. These values comply with the limits established by current Argentine regulations, classifying the final product as a Class A compost, suitable for agricultural use. The valorization of incubation plant waste will depend on the optimization of effective stabilization processes and the availability of suitable co-materials for composting mixtures. It is worth noting that a prior experience at a small-scale hatchery (300 breeders) located at the Alto Valle Este Agricultural School in Río Negro provided the foundation for the development and upscaling of the present study.

Keywords: incubator; poultry farming; organic amendments.

INFLUENCE OF THE INCREASE IN ANAMMOX BIOMASS ON THE EFFICIENCY OF DEAMMONIFICATION IN A MABR REACTOR

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Nitrogen is an element that can be naturally found in nature as organic nitrogen (N-org), ammoniacal nitrogen (N-NH4+), nitrite (N-NO2-), nitrate (N-NO3-) and gaseous nitrogen (N2), but its concentrations in the environment can be altered and undergo a significant increase naturally or through anthropogenic activity, such as the disposal of agro-industrial waste. Therefore, the aim of this study was to evaluate the performance of the MABR (Membrane Aerated Biofilm Reactor) reactor, before and after the addition of anammox biomass, in the removal of nitrogenous forms using a synthetic effluent rich in ammoniacal nitrogen. The experiment was divided into two stages: the reactor with the biomass before the increase (stage 1, 100 grams of biomass) and after the increase in anammox biomass (stage 2, 300 grams of biomass). The reactor had the following characteristics: 35 cm high, 9.2 cm internal diameter and a useful volume of 1.5 L. The synthetic effluent used was formulated to reach a concentration of 100 mg. L^{-1} of ammoniacal nitrogen. The reactor was housed in a temperature-controlled chamber at 30 ± 2°C. The Hydraulic Detention Time (HDT) was 24 hours. Aeration was provided at dosages of 5 minutes every 6 hours (stage 1) and 7 minutes every 8 hours (stage 2). The MABR reactor showed anammox activity in both conditions (stages 1 and 2), but in stage 1 with 100 g, a removal of 66.5% of N-NH4+ was observed and in stage 2, a removal of 92.4%. Regarding the N-NO3- and N-NO2- formed in the ammoniacal nitrogen conversion process, values of 36.86 and 0.83 mg. L^{-1} (stage 1), respectively, and 1.31 and 1.24 mg. L^{-1} (stage 2), respectively, were observed. In stage 1, there was a high concentration of N-NO3-, which indicates a greater presence of nitrite-oxidizing organisms, which justifies the lower removal of ammonia. In stage 2, this characteristic was the opposite, highlighting greater anammox activity. The pH values were in the range of 7.25 and 7.79 in stages 1 and 2, respectively, being within the range considered adequate for deammonification. The alkalinity consumption was 28.84% in stage 1, indicating anammox activity in conjunction with other nitrite-oxidizing microorganisms. In stage 2, the consumption increased to 41.10%, with a minimum value of 100 mgCaCO3.L^{-1}, suggesting a greater predominance of anammox activity. Finally, the reactor provided suitable conditions for the establishment of the anammox process, however the increase in biomass together with the other factors driving the reactor showed that stage 2 (300 g of biomass in the reactor) stood out with greater efficiency in nitrogen removal, indicating that biomass is an important factor in the performance of the process.

Keywords: ammoniacal nitrogen; deammonification; anammox; mabr; effluent treatment.

WASTE VALORIZATION

PRODUCTION OF FLOWER SEEDLINGS FERTILIZED WITH COMPOST PELLETS VS. CONTROLLED-RELEASE FERTILIZER

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In the production of flower seedlings chemical fertilizers are used that have certain advantages due to their high nutrient content, but with possible adverse effects on the environment. Currently, there are various biofertilizers with a lower environmental impact, such as compost pellets, whose pelletization facilitates handling, reduces transportation costs, and allows for more precise dosing. The objective of this work was to evaluate the effect of three doses of controlled release fertilizer (CRF) vs. compost pellet (CP) on the development of petunia (*Petunia x hybrid* cv Sophistica Lime Green) and carnation (*Dianthus chinensis* cv Super Parfait) seedlings. The doses evaluated had the same N concentration for both types of fertilizers (Dose 1:0.14 g N, Dose 2:0.28 g N and Dose 3:0.42 g N). One trial was set up per species and the treatments were: T1) Dose 1:1 g of CRF/l substrate; T2) Dose 2:2 g of CRF/l substrate; T3) Dose 3:3 g of CRF/l substrate; T4) Dose 1:5 g of CP/l substrate; T5) Dose 2:10 g of CP/l substrate and T6) Dose 3:15 g of CP/l substrate. A commercial substrate (Coco Mix, Carluccio) was used. The CRF was Plantacote Pluss 4M (N:14-P:8-K:15), and the CP (N:2.8-P:1.3-K:9) was produced with pig digestate compost. The trial was conducted in a greenhouse with manual irrigation. The experimental unit was a pot N° 12.5 (830 cc) (25 repetitions per treatment). Before and after both experiments, the pH and electrical conductivity (EC) of the substrate were measured. The number of flowers and buds (F&B), and aerial dry mass (ADM) and root dry mass (RDM) were measured for each plant. The initial pH and EC values of the substrate were 5.70 and 0.98 $dS.m^{-1}$. On average, the substrate of the CRF treatments ended with a pH: 6.23 (±0.23) (petunia) and 6.42 (±0.04) (carnation), and with an EC: 0.11 $dS\ m^{-1}$ (±0.04) (petunia) and 0.07 $dS.m^{-1}$ (±0.01) (carnation). Regarding the CP treatments, they ended with a pH: 6.73 (±0.04) (petunia) and 6.57 (±0.13) (carnation), and with an EC: 0.09 dS.m-1 (±0.02) (petunia) and 0.08 dS.m-1 (±0.01) (carnation). Regarding F&B, the petunia seedlings from T2 and T3 ($p < 0.0001$), and the carnation seedlings from T1, T2, T3 and T6 ($p < 0.0001$) had the highest values, differing from the remaining treatments. In both trials, the ADM of the seedlings of T3 had the highest values, followed by T1, T2, T5 and T6 with no differences between them ($p < 0.0001$). For RDM, there were no significant differences among petunia treatments (p: 0.0881). carnation seedlings in T4 had the lowest values and differed from the other treatments (p: 0.0213). In conclusion, the initial and final pH and EC values of the substrate in both trials were within the appropriate range (5.3-6.8 and < 1 $dS.m^{-1}$). Petunia and carnation seedlings fertilized with the highest dose (3) of CRF obtained the best development. Fertilization with the highest doses (2 and 3) of CP achieved seedlings with a development like that of seedlings fertilized with the lowest doses (1 and 2) of CRF.

Keywords: pellets; compost; chemical fertilizer; flower seedlings.

CHARCOAL AND COMPOST PELLETS: THEIR USE IN THE PRODUCTION OF YERBA MATE SEEDLINGS (*Ilex paraguariensis A. St.-Hil.*).

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In the production of Yerba Mate (YM) seedlings, some of the most important inputs are the substrate and chemical fertilizers. The objective of this work was to evaluate the residue from charcoal production (RC) as a substrate component and the compost pellet (CP) as an organic fertilizer. The treatments were: T1: Pine bark compost (CCP) + 4 g/l of controlled release fertilizer (CRL), T2: CCP + 22.85 g/l of CP, T3: CCP + 2 g/l of CRL + 11.43 g/l CP, T4: CCP + 10% RC + 4 g/l of CRL, T5: CCP + 10% RC + 22.85 g/l of CP. The pH of the CCP of T1, T2 and T3 was corrected by incorporating 3 g/l of dolomite. The RC was provided by a local charcoal burner (Leandro N. Alem Department, Misiones), this material was sieved to obtain particles between 0.5 to 1 cm. The CRL used was Basacote Plus 9M (16-8-12) and the CP were produced with pig digestate compost at IMYZA - INTA. The test was carried out under a greenhouse with sprinkler irrigation, the irrigation water used had a pH: 6.64 and electrical conductivity (EC): 0.11 $dS.m^{-1}$. Three trays of 25 cells (100 cc x cell) were used per treatment, where YM seedlings were transplanted. During the test, the pH and EC of the substrate solution were measured every 15 days using the pour-through method. At the end of the trial (7 months), 15 seedlings were randomly removed from each tray: 45 seedlings (replicates) per treatment. Stem length and diameter, aerial dry mass (ADM) and root dry mass (RDM) were measured for each seedling. The robustness index (RI) and Dickson quality index (DQI) were also calculated. T4 did not have a linear association between pH and days since transplantation (p: 0.2645). However, for the remaining treatments, Pearson's correlation was high (> 0.75) and the substrate pH trend during seedling development was positive, with associated coefficients of determination >0.56. Likewise, both the initial and final pH values were within the appropriate range (5.3-6.8). In general, the initial EC of the substrate solution was between 0.50 to 0.83 dS.m-1 and final between 0.02 to 0.04 dS.m-1. Seedlings from T1, T3 and T4 had the highest ADM and RDM values ($p < 0.0001$). The stem length of the T2 seedlings was outside the appropriate range (15-30 cm) and those of T2 and T5 were outside the appropriate range for stem diameter (3-5 mm). Seedlings from treatment 5 exceeded the appropriate RI value (≤ 8) and those from treatments 2 and 5 were below the appropriate DQI value (> 0.2). In conclusion, the use of CP or RC did not affect the adequate pH and EC values of the substrate during seedling development. However, only seedlings fertilized with half a dose of FLC and PC (T3), those fertilized with FLL (T1) and those developed in a substrate with 10% RCV fertilized with FFC (T4) were of good quality.

Keywords: seedlings; substrate; compost pellets; charcoal; yerba mate.

USES OF POTATO PRODUCTION WASTE FROM SOUTHEAST BUENOS AIRES FOR THE EXTRACTION AND CHARACTERIZATION OF POTATO STARCH

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The problem of food loss and waste is a significant global challenge. The southeast of Buenos Aires, Argentina, produce more than 50% of the country's total potatoes, and it is estimated that the percentage of loss or waste can reach 5%. The objective of this study was to utilize the potato discard by obtaining and characterizing starch for the food industry. So, different starch extraction methodologies were evaluated, and the physicochemical and functional characteristics of these starches extracted from the waste of four potato varieties were measured: Spunta, Innovator, Newen INTA, and Pampeana INTA, from the production of the Southeast Buenos Aires. The starch extraction methods used were natural decantation, forced decantation and centrifugation, which no significant differences observed; therefore, the work continued with the natural decantation methodology. The physicochemical properties of the starch samples were measured through: percentage of dry matter by the gravimetric method, ash content by the dry calcination method and starch content by the Ewers polarimetric method; the functional properties were measured by: gelatinization temperature, swelling and water retention capacity; water and oil absorption capacity, freezing stability, dispersion clarity, and emulsifying capacity. The percentage of dry matter was more than 92% in all cases, while the starch content of the samples varied between 72.99 and 74.62%, with no significant differences observed between the samples studied. The gelatinization temperature varied between 68 and 69°C, with no significant differences between the starches of the four potato varieties. The water and oil absorption capacities were 2.39 and 1.11 g of water and 1.11 g of oil/g of sample, respectively, with no significant differences observed between the samples. The water and oil absorption capacities were 2.39 and 1.11 g of water and oil/g of sample, respectively, with no significant differences observed between the samples. Furthermore, the swelling and water retention capacity at different temperatures increased at temperatures of 80 and 90 °C compared to temperatures of 60 and 70 °C, which is explained by the breakdown of the starch structure that occurs during gelatinization. The values obtained for emulsifying capacity range from 1.5 to 3.5%. Finally, transmittance values below 30% for the dispersion clarity test indicate that potato starches will generate cloudy and opaque dispersions. Starch extraction by decantation is the most viable method for large-scale application in industry, being easy to implement and low-cost. The characterization of potato starch allows the starch to be used in different forms for the food industry, reducing losses and waste in potato production and adding value to the raw material.

Keywords: waste; potato; starch; functional and physicochemical properties.

REUSE OF WINERY WASTE BIOREFINERY EFFLUENTS FOR IRRIGATION AND BIOMASS PRODUCTION IN ARID AGROECOSYSTEMS

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The Argentine wine industry generates large volumes of grape marc, sediments, and grape stalks, which can be valorized through biorefineries to produce alcohol, tartaric acid, grape seed oil, and compost. These processes yield effluents with high organic loads and elevated salinity, increasing the demand of water resources for dilution and subsequent crop irrigation. A biorefinery processing residual wine biomass produces two main effluents: one from grape marc processing, with electrical conductivity (EC) of 13.57 $dS.m^{-1}$ and pH 4.32; and another from wine lees treatment, with EC of 17.88 $dS.m^{-1}$ and pH 5.99. The use of these high-EC effluents was evaluated for irrigation of productive agroecosystems aimed at generating plant biomass for energy, animal feed, or compost substrate. Two treatments were compared: a mixed-species perennial pasture (Melilotus officinalis and Thinopyrum ponticum) and a seasonal cropping sequence consisting of summer forage (Sorghum × drummondii) followed by winter forage (Beta vulgaris var. Cicla; Beta vulgaris; and Hordeum vulgare). Each 1000 m^2 experimental unit, located in Palmira (Mendoza, Argentina), on a sandy Torrifluvent Entisol soil (initial EC at 0–60 cm depth: 3.37 $dS.m^{-1}$), was adapted for surface irrigation by furrows in a completely randomized design with three replicates. Irrigation was performed using a 1:1 (v/v) mixture of both effluents, diluted with irrigation water to achieve a final solution with EC of 2.82 $dS.m^{-1}$ and pH 6.35. Water demand was estimated based on climatic data, soil characteristics, and crop-specific requirements using average crop coefficients. The irrigation schedule was designed using WinSRFR 4.1 software, and a total of 1283 mm was applied over 11 months of experimentation. Irrigation with saline effluents increased soil organic matter content and slightly reduced pH. The high sorghum dry biomass yield (32.6 $t.ha^{-1}$), combined with the average of the proposed winter crops (11.1 $t.ha^{-1}$), resulted in a total biomass yield of 43.7 $t.ha^{-1}$ for this treatment. Meanwhile, the perennial pasture yielded 15.9 $t.ha^{-1}$ in the first year. Although the mixed pasture (*Melilotus officinalis* and *Thinopyrum ponticum*) had lower biomass productivity, it was more efficient in nutrient uptake, as soil EC (0–60 cm) was 5.17 $dS.m^{-1}$, and higher concentrations of NPK, ash, and soluble salts were detected in leaves compared to the annual crop treatment, which reached a soil EC of 8.58 $dS.m^{-1}$. For short-term biomass production, annual species would be preferable; however, if the goal is year-round nutrient recovery from irrigation effluents, mixed-species perennial pastures may be more suitable and cost-effective. These results suggest that the studied species adapted well to irrigation with saline effluents, and species selection should be guided primarily by the intended purpose. Monitoring soil salinity evolution is critical in these systems.

Keywords: distillery; irrigation; dry matter; nutrients; circular bioeconomy.

PENALTY ANALYSIS BASED ON CATA QUESTIONS TO IDENTIFY ATTRIBUTES THAT DRIVE PECAN OIL ACCEPTABILITY

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Pecan oil is an edible oil rich in bioactive compounds, with particular interest in its fatty acid profile. This oil can be obtained from crushed or cracked pecans, which are discarded by the pecan shelling industry. However, as this is a new product, it is essential to understand its sensory characteristics and evaluate consumer perception to predict its acceptance in the market. Check-all-that-apply (CATA) questions have recently experienced an increase in use. They are used to investigate consumer perceptions of various attributes. The CATA method involves multiple-choice questions presented to respondents as a list of words or phrases, from which they must select all the options they believe best describe the product under evaluation. The correct selection of attributes to use in sensory testing is important. Attributes can be related to hedonic evaluations and are essential in product characterization. Pecan oil is a product that has been rarely subjected to sensory evaluation, so there are no attributes recommended for use in sensory analysis of any kind in literature. The objective of this work was to identify the relative importance of the attributes in the overall acceptability scores of pecan oil. For this purpose, a hedonic evaluation was performed using a 9-point scale along with a CATA analysis of 10 cultivars of pecan oils. The CATA terms used were adopted from a previously conducted Projective Mapping study. The selected attributes were: sweet flavor, nutty flavor, pleasant, toasted, mild flavor, unpleasant, rancid, foreign flavor, bitter, tasteless, strong flavor, spicy, dark color, light color, opaque, bright, astringent, fluid, thick, oily, sweet odor, odorless, aromatic, and woody odor. A penalty analysis was performed with the collected data, consisting of a subtraction: A1 - A0; where A1 is the average acceptability of all consumers and samples in which the term was selected and A0 is the average acceptability of all consumers and samples in which the term was not selected. The attributes that caused the greatest decrease in sample acceptance were unpleasant, rancid, strange flavor, bitter, astringent, tasteless, and spicy; while the most relevant positive attributes were pleasant, nutty flavor, sweet, and aromatic. On the other hand, the attributes odorless, opaque, thick, oily, dark color, woody smell, strong flavor, light color, bright, fluid, toasted, mild flavor, and sweet smell Did not significantly affect the acceptability of the samples, so they could be dismissed in future evaluations using the CATA technique. This study provides information on the attributes of pecan oil that should be considered in future sensory studies of this oil.

Keywords: sensory analysis; hedonic evaluation; consumers.

NUTRITIONAL PROFILE AND PRODUCTION OPTIMIZATION OF BIOMASS PRODUCED BY *Yarrowia Lipolytica* QU69 USING DIFFERENT AGRO-INDUSTRIAL RESIDUES AS CARBON SOURCES

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The use of fermentation to transform waste has advantages such as low process cost, ease of application of microorganisms, improved digestibility, and improved nutritional value. *Yarrowia Lipolytica* (YL) is a yeast widely known in the food technology field due to its extensive use in the synthesis of organic compounds of interest. This study aims to evaluate the use of YL in fermentation processes under different carbon sources, having as main choice agro-industrial residues from small agricultural properties in the central-western region of Paraná (whey, cassava peels, sweet potato peels, pumpkin peels, banana cutting residues) for subsequent nutritional evaluation and optimization of this process. The residues were dried at 50 °C for 24 hours, ground in a hammer mill and sieved to 6-8 mesh, stored in glass vials with lids at room temperature. The protein content of the residues and fermented biomass were obtained by the Kjeldahl method. The total lipid content was performed by the Bligh-Dyer method and the lipid profile by GC-MS. To prepare the inoculum containing yeast cells, GYP agar containing 2% glucose, 1% peptone, 0.5% yeast extract and 2% agar was prepared; the yeast was isolated by exhaustion and incubated at 28 °C for 48 hours. $2x10^6$ CFU/mL of YL cells were used and a mineral supplementation medium composed of 1% nitrogen source (sodium nitrate, ammonium sulfate and urea), 0.1% monobasic potassium phosphate and 0.05% magnesium sulfate was used. Fermentations were carried out in a Dubnoff-type agitation bath at different speeds (0, 50, 100 rpm) for nine days and at different temperatures (20-40 °C). Erlenmeyer flasks with a capacity of 125 mL were used, containing 5% residue as a carbon source and 50 mL of the supplementation medium. The flasks containing the residue and the mineral medium were autoclaved, added with 1 mL of the cell suspension containing $2x10^6$ CFU/mL and incubated in a bath. Subsequently, the production of proteins and lipids using different carbon sources was evaluated, as well as the optimization of the process (agitation, temperature and nitrogen source). The results showed that, in general, good increases in proteins were obtained when compared to the raw residue (22-342% increase) and good increases in total lipids (39-660% increase) after 9 days of fermentation. The fatty acids found in greater quantities in the biomass obtained were palmitic, stearic and linoleic acids. Through the experiments performed, it was concluded that the yeast *Y. lipolytica* QU69 can be used in bioconversion processes. The processes used for bioconversion during the experiment did not present high investment costs and use of materials without risks of contamination and aggression to the environment. Among the conditions tested in the study, it was concluded that when cassava peels were used as a carbon source, in a fermentation bath with Dubnoff-type agitation at 100 rpm, urea as a nitrogen source and a temperature of 40 °C, the best results were achieved in terms of protein and lipid production.

Keywords: yeast; fermentation; agro-industrial residues; proteins; lipids.

BOCASHI AS A SUBSTITUTE FOR CHICKEN MANURE IN A CROP OF ANCO SQUASH (*Cucurbita L. moschata*) FOR SEED WITH INTEGRATION OF LOCAL AGRICULTURAL AND AGRO-INDUSTRIAL WASTES IN SAN JUAN, ARGENTINA

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This study evaluates the effectiveness of bocashi organic amendment on Anco squash (*Cucurbita L. moschata*) crop intended for seed production, as an alternative to non-composted chicken manure that is widely used in horticultural production in the Cuyo region, although its use is restricted under Good Agricultural Practices (GAP) in Argentina (Ley 18284 CAA, art. 154 Tris: Resolución Conjunta n.º 5/2018). Bocashi is a solid organic amendment that transforms local agricultural and agro-industrial waste into high-value amendments. It is obtained through a biooxidative process that accelerates the degradation of organic matter, raising the temperature between 65 and 70 °C, which allows the elimination of pathogens. Moreover, it increases the number of microorganisms and improves the diversity of the soil food web, enhancing the formation of soil aggregates. The trial was carried out in a crop intended for seed production in the locality of Angaco, San Juan (Argentina). Together with the producer, four treatments were determined and distributed in a completely randomized design. The treatments were: “T”, control, with 8 $t.ha^{-1}$ of non-composted chicken manure; “B1”, with 8 $t.ha^{-1}$ of bocashi; ‘B05’, with 4 $t.ha^{-1}$ of bocashi; and “BGG”, a mixture of 4 $t.ha^{-1}$ of chicken manure and 4 $t.ha^{-1}$ of bocashi. Their effect on seed yield was evaluated by analysis of variance with Fisher's LSD test ($\alpha = 0.05$). Statistical analysis showed that seed yield responded directly to the amendments. Seed yield ($kg.ha^{-1}$) was significantly higher in the B1 and BGG treatments (693 and 728 $kg.ha^{-1}$) than in T and B05 (428 and 382 $kg.ha^{-1}$). Additionally, it was observed that the BGG treatment produced the highest number of seeds and B1 achieved the highest production efficiency (seed yield index, in seed (g)/pulp (kg)). Results from this study indicate that bocashi is an agronomically viable alternative, providing superior effects to uncomposted chicken manure for squash seed production. Its application, either in full dose or in combination with chicken manure, significantly increases seed yield. This study not only validates bocashi as an effective bioinput, but also as a strategic tool for transforming agricultural residues into a high-value product that improves the sustainability and profitability of the production system.

Keywords: bocashi; organic amendment; seed production; bio-input; waste valorization.

APPARENT SOIL PHOSPHORUS BALANCE FOLLOWING THE APPLICATION OF COMPOSTED FEEDLOT MANURE

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Feedlot residues have been recognized as an important source of nutrients (nitrogen, phosphorus, and potassium) and currently represent a valuable agronomic resource as a soil amendment and/or fertilizer for grain and silage crop production systems. The agronomic use of manure in mixed crop-livestock systems has been increasingly adopted by many farms in northwestern Buenos Aires Province, Argentina. Previous studies have reported increases in soil extractable phosphorus (P) levels following a single manure application. The objective of this study was to calculate an apparent phosphorus (P) balance in a long-term experiment (LTE) established at a commercial feedlot. The LTE began in 2017. Two rates of composted manure, 10 and 20 t ha^{-1}, were applied every two years (2017, 2019, 2021, and 2023), along with an untreated control (0 t ha^{-1}), prior to maize planting within a maize-soybean rotation (late-planted maize followed by soybean). Phosphorus inputs (total P supplied through mineral fertilizer and manure) and outputs (P removal through maize and soybean grain harvest) were quantified, and the total P balance (inputs minus outputs) was calculated for the three treatments (0, 10, and 20 t ha^{-1}). Maize was fertilized with 50 kg ha^{-1} of monoammonium phosphate (MAP) in all growing seasons, whereas soybean received no mineral fertilizer. Therefore, the control treatment (0 t ha^{-1}) received 11.4 kg P ha^{-1} from mineral fertilizer, while the 10 and 20 t ha^{-1} treatments additionally received P supplied by manure Phosphorus inputs from manure were 32 kg (2017), 33 kg (2019), 53 kg (2021), and 22 kg ha^{-1} (2023) for the 10 t ha^{-1} rate, and 63 kg (2017), 65 kg (2019), 107 kg (2021), and 46 kg ha^{-1} (2023) for the 20 t ha^{-1} rate. Total P inputs for the 0, 10, and 20 t ha^{-1} treatments were 45, 185, and 326 kg P ha^{-1}, respectively. Phosphorus outputs were estimated from grain yields using removal coefficients of 3 kg P t^{-1} for maize and 5 kg P t^{-1} for soybean. Total P outputs for the 0, 10, and 20 t ha^{-1} treatments were 136, 145, and 163 kg P ha^{-1}, respectively. The apparent phosphorus balance for the 2017–2023 period was −91 kg P ha^{-1} for the control, +40 kg P ha^{-1} for the 10 t ha^{-1} treatment, and +163 kg P ha^{-1} for the 20 t ha^{-1} treatment. These results indicate that biennial applications of composted manure generate a positive phosphorus balance, resulting in residual soil P accumulation that may contribute to sustaining crop productivity and reducing mineral fertilizer requirements over the medium and long term.

Keywords: extractable phosphorus, manure, soil, application rate.

EVALUATION OF COMPOSTABLE FILMS FOR BEEF PRESERVATION UNDER AEROBIC RETAIL DISPLAY

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Meat packaging is predominantly manufactured from petroleum-based plastics. However, the widespread use of these materials raises significant environmental concerns. In response to these issues, blending polylactic acid (PLA) with other biopolymers and incorporating natural plasticizers offers a promising strategy to improve PLA's functional properties without compromising its compostability (Koh et al., 2018). The objective of this work was to assess the performance of a PLA-based film for conventional plastic packaging in preserving beef under aerobic retail display conditions. To achieve this, PLA films were produced via extrusion and compression molding. Commercial polyvinyl chloride (PVC) film for food was used as conventional packaging. Beef was obtained from 24 finished pasture-fed heifers (281 ± 23 kg LW) slaughtered in a commercial packing plant. A rib section (Longissimus dorsi muscle) encompassing the 10th to 13th ribs from each left side of the carcass was removed and divided into five steaks. Four steaks (10th to 12th) were individually placed on food-grade polystyrene trays and assigned randomly to one of two type film (PLA or PVC) and then to one of two storage time (3 or 7 d). Storage was carried out in a refrigerated chamber at 2 ± 2 °C under continuous LED lighting to simulate aerobic retail display conditions. The 13th rib steak served as the 0-d storage time reference. Measurements of pH (Testo) and color (Konica Minolta D600 colorimeter) were recorded for each steak. To quantify total mesophilic aerobic bacteria (TMAB), all steaks from 8 rib sections (subsampling) were swabbed at the corresponding assigned storage time. Data was analyzed using a split plot design with steak as the experimental unit. Storage time influenced pH and color parameters, in agreement with Holman et al. (2022). The pH decreased on day 3 (5.52 ± 0.04), returning to baseline levels (5.64 ± 0.04) by day 7 ($P<0.05$). The L* value and hue angle increased ($P<0.05$) by day 7 (35.64 vs 36.99, 0.400 SEM; and 41.63 vs 45.25, 0.400 SEM; respectively), while a* and chroma values decreased ($P<0.05$; 15.29 vs 13.01, 0.522 SEM; and 20.47 vs 18.52, 0.522x SEM; respectively). The b* value decreased ($P<0.05$) on day 7 from day 3 (14.11 vs 13.14, 0.244x SEM). Count of TMAB remained low (<0.15 CFU/cm²) and showed no significant differences between treatments ($P<0.05$). No effects of film type were observed in any of the measured parameters. These results suggest that the compostable PLA film preserves main quality attributes of meat, which are crucial for consumer purchase decisions. While further studies on meat spoilage are needed, PLA-based films show promise as a sustainable alternative to conventional single-use plastic packaging.

Keywords: compostable packaging; renewable resources; beef.

AGROINDUSTRIAL BY-PRODUCTS AND INSECT MEAL AS SUSTAINABLE FEED STRATEGIES FOR LAMB PRODUCTION

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The livestock sector in Patagonia faces unique challenges related to the scarcity and high cost of conventional feed sources, which are often imported over long distances. In this context, the use of agroindustrial by-products and novel protein sources emerges as a sustainable and locally grounded alternative. This work summarizes a series of trials evaluating the nutritional composition and effects on animal performance of sheep fed with three alternative feed resources: wet brewers' spent grain, dried brewers' spent grain, and black soldier fly larvae meal. In all trials, body weight, body condition score, average daily gain, feed intake and feed conversion ratio were recorded. Wet brewers' spent grain and dried brewers' spent grain are by-products from the brewing industry, which generates hundreds of tons annually in the region. Their high fiber and protein content make them suitable as ruminant feed. In two feeding trials with Merino sheep, wet brewers' spent grain was successfully used in winter supplementation for female yearlings, leading to higher weight gain and improved body condition. Dried brewers' spent grain was tested as a 35% inclusion in feedlot diets for finishing lambs, replacing soybean meal. The results showed no significant differences in average daily gain, dry matter intake, or feed conversion ratio suggesting its potential as a viable alternative to conventional protein sources in feedlot diets. Black soldier fly larvae meal was evaluated as a protein source in isonitrogenous and isoenergetic diets for finishing Merino lambs, replacing soybean expeller at a 10% inclusion rate. The larvae were produced and processed national from potato waste as feed. The study found no significant differences in growth performance, feed intake, or body condition relative to a conventional feedlot diet, supporting the potential of insect meal as a climate-smart alternative in ruminant diets. These studies demonstrate that the use of agroindustrial and insect-derived by-products can be integrated into lamb production systems without compromising animal performance. Beyond their nutritional value, these feed resources contribute to the circular economy, reduce environmental pressure from waste accumulation, and lower the carbon footprint of lamb production by decreasing reliance on imported feed. In Patagonia, where livestock systems must adapt to both environmental and economic constraints, the valorization of locally available residues offers a promising path toward more resilient and sustainable animal production systems. Looking ahead, the combined use of brewers' spent grain as a substrate for local insect rearing could represent a next step in resource optimization, enabling the production of high-quality protein while closing local nutrient cycles.

Keywords: agroindustrial by-products; alternative feeds; circular economy; insect meal; sheep.

FROM WASTE BIOMASS TO VALUABLE PRODUCT: PROPERTIES AND APPLICATIONS OF BIOCHAR DERIVED FROM DIFFERENT FEEDSTOCKS

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Biochar is a carbon-rich material obtained through pyrolysis (heating in an atmosphere deprived of oxygen) of biomass. Its physico-chemical properties can be tuned by selecting the feedstock and the pyrolysis conditions. This versatility allows for its application across various fields and the revalorization of pruning and agricultural residues. In this work, a comprehensive physicochemical characterisation of biochar obtained from papyrus, cannabis and strawberry waste at three different temperatures (400, 600, and 800 ºC) was carried out and a comparison of their performance in its application as soil amendment for improving crop yield, as an adsorbent of contaminant compounds and as electrode material is presented. Biochar produced at low temperatures (below 600 ºC) retains surface functional groups formed through thermochemical transformation of biomass components like cellulose and lignin. These oxygen-containing groups, such as carboxyl and hydroxyl, play a crucial role in biochar's interaction with water, chemical compounds and microorganisms. Given the well-documented benefits of biochar for improving soil quality and plant development, the performance of biochar produced in our laboratory as a soil amendment in lettuce growth (Lactuca sativa var. Elisa) was tested. Biochar produced at 400ºC and 600ºC significantly enhanced the growth of early-developed plants, with the biochar at 400ºC showing the most pronounced effect on root and shoot dry weight. Among the different feedstocks, strawberry and cannabis-derived biochar exhibited the best performance in enhancing plant growth. Biochar is also widely applied as an adsorbent for contaminants in water, wastewater, and soil due to its large surface area, high porosity, relatively low cost and minimal environmental impact. We assessed the ammonia-adsorption capacity of the obtained biochar, since ammonia is a major contributor to water contamination and eutrophication, and it is also the main component of nitrogen fertilizers. Results showed biochar produced at low temperature (400ºC) had the highest adsorption capacity, likely due to electrostatic interaction between ammonia and negatively charged oxygen-containing surface functional groups. The high adsorption capacity of biochars makes them suitable for both water and wastewater treatment, as well as enhancing nitrogen retention in soil, thereby improving the fertilizer efficiency. At higher pyrolysis temperatures (over 600ºC), the carbon structure of biochar becomes more ordered, resulting in the formation of graphene-like sheets that confer electrical conductivity to the material. Exploiting this property, we evaluated cannabis and papyrus biochar produced at 800ºC as electrode material in a three-electrode electrochemical cell for the cultivation of Geobacter sulfurreducens. This electroactive model bacterium can use an electrode as an electron sink, producing an electric current coupled with its metabolic activity. With both materials, the electrochemical performance was comparable to that of electrodes made of graphite, a traditional material used in several electrochemical and bioelectrochemical systems, which has a higher production cost and carbon footprint than biochar. This research underscores the versatility and notable potential of agroindustrial waste-derived biochar. By modifying the conditions of its production, the material has been shown to effectively promote plant growth, serve as a suitable ammonia adsorbent and act as an alternative to graphite electrodes.

Keywords: biochar; plant growth; adsorption; electrode material.

ALKALINE CEMENTS FROM RESIDUES AND BY-PRODUCTS: EVALUATION OF HYDRATION KINETICS BASED ON JANDER'S MODEL

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The civil construction sector represents one of the largest sources of anthropogenic greenhouse gas emissions, specifically due to the production of ordinary Portland cement (OPC). Faced with this environmental challenge, alkaline cements (AC) emerge as a sustainable alternative to OPC, with less environmental impact. In addition to significantly reducing emissions associated with cement production, ACs favor the recovery of industrial waste and by-products, promoting the integration of circular economy practices in the sector. When activated by alkalis, these materials develop cementitious matrices with physicochemical and mechanical properties comparable to those of traditional cement. The performance of these cementitious matrices is closely linked to the hydration kinetics of the pozzolanic compounds present in the system, which, in this context, are represented by industrial residues and by-products. Thus, an in-depth understanding of the kinetic hydration mechanisms of these materials is critical for the development of more durable, efficient, and environmentally sustainable binders. This study investigates the kinetic hydration behavior of an AC formed by photovoltaic module glass (PMG) and oyster shell hydrated lime (OSHL) in systems with different levels of initial mechanical strength — classified as high (+), medium (+/-) and low (-). The experimental analyses were performed at five ages of cure: 7, 14, 28, 63 and 91 days. The objective was to characterize the evolution of the degree of hydration of the developed AC, in order to verify whether the matrix obtained from residues presents efficient kinetic mechanisms of hydration. To this end, the quantification of hydration was performed based on Jander's diffusional model, through which the value of the kinetic exponent (N) is obtained, derived from mathematical adjustments to the experimental curves, this parameter allows the identification of the predominant stage of the reaction, according to the three-phase model described in the literature (phase I: $N<1$; phase II: $1<N<2$; phase III: $N>2$). The analysis showed a continuous advance in hydration over time in all groups, but with marked differences regarding the kinetic control regime. The "+" system showed a gradual transition between the kinetic phases, indicating a progressive hydration mechanism. The "-" system reached Phase III early, suggesting the anticipated predominance of diffusion as a limiting step of the reaction, which compromises the continuity of the reaction and reduces its effective rate, due to the excess of ions. The "+/-" system showed a strongly diffusional behavior from 28 days of curing, with $N>9$ exponents in the most advanced ages. The adjustments showed high coefficients of determination ($R^2 > 0.82$), indicating good adherence of the Jander model to the experimental data. The analysis reinforces the importance of diffusion as a limiting factor for hydration in late phases, especially in compositions with greater pozzolanic reactivity. These results contribute to the understanding of kinetic mechanisms using residues and by-products, providing subsidies for the optimization of formulations with a view to increasing mechanical performance and durability. In addition, the use of these materials promotes the mitigation of improper disposal of solid waste, reinforcing the principles of sustainability and circular economy.

Keywords: waste and by-products; hydration kinetics; jander model; diffusional reaction; kinetic analysis.

VALIDATION OF NEW BIOFERTILIZERS BASED ON INSECT FRASS ON GROWTH OF LETTUCE (*LACTUCA SATIVA L.)*

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The European Union is committed to promoting the use of biofertilizers. It advises farmers to optimise the application of chemical fertilisers or replace them partially or completely with environmentally friendly and economically viable biofertilizers. As a by-product of insect production, insect excrement (frass) has great potential to be used as a partial or complete substitute for NPK fertilizers. The aim was to verify the potentials of frass as organic fertilizer. This study used vermicompost (VC), frass from Hermetia illucens (HI) and Tenebrio molitor (TM) as the main ingredients for developing new pelletized biofertilizers. The organic-mineral (NPK; 7-7-7-7) treatments evaluated were: i) BOMIF1 (VC), ii) BOMIF2 (VC+HI), iii) BOMIF3 (VC+TM), iv) BOMIF4 (VC+HI+TM). The organic treatments (5-5-5) were: (v) BOMIF5 (VC), (vi) BOMIF6 (VC+HI), (vii) BOMIF7 (VC+TM), (viii) BOMIF8 (VC+HI+TM) and (ix) IN200 (conventional inorganic fertilization, 15-15-15). The control treatment was no fertilization. These treatments were applied to a lettuce crop (Lactuca sativa L. var. baby leaf) in a greenhouse under controlled conditions, in plastic pots (Ø 11 cm, containing 1.5 kg of soil), at a dose of 200 kg N ha^{-1} at transplanting. During the crop cycle, non-destructive measurements of chlorophyll (SPAD) and plant cover (%) were carried out. Harvesting took place after 60 days. The production of fresh and dry biomass (g plant-1) was quantified. Yield was significantly ($p<0.0001$) affected by fertilization treatments. Lettuce showed a direct response to higher NPK values at BOMIF 1 to 4 (7-7-7), performing better than with organic-focused biofertilizers (BOMIF 5 to 8). Organic biofertilizers and vermicompost (VC) only outperformed the non-fertilized treatment (C) statistically. However, the organic-mineral biofertilizers increased the yield obtained with the IN200 reference. The results suggest that frass could be used as an alternative to mineral fertilizers. However, other types of crops and the possible biostimulant effects of frass on plants must be considered to fully understand the mechanisms and potential of this new organic fertilizer.

Keywords: circular economy; insect frass; vermicompost; fertilization; lettuce.

EVALUATION OF SOILLESS SYSTEMS AND BIO-INPUTS DERIVED FROM AGRO-INDUSTRIAL WASTE FOR SUSTAINABLE COCKTAIL TOMATO PRODUCTION

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Intensive tomato cultivation under conventional production systems has important environmental challenges in the province of Mendoza, including soil degradation, salinization, and dependence on synthetic chemical inputs. In response, this study evaluated the effects of soilless cultivation systems and nutrient solutions formulated with bioinputs on the vegetative and productive performance of Solanum lycopersicum var. Cocktail "OP" plants. The trial was carried out in a greenhouse at INTA Mendoza Experimental Station (33°0'10.88"S - 68°52'1.02"W). Three cultivation systems were compared: grow bags (B), continuous modular container (CMC), and soil (S); along with five nutrient solutions: water (control), biol, aerated compost tea, non-aerated compost tea, and a commercial fertilizer. Systems B and CMC were based on composted residual biomass: B system contains tree pruning compost (commercial), CMC used compost from wine industry wastes. The biol, applied at 10%, was produced via anaerobic digestion of goat manure, fresh plant waste, and mineral inputs. Compost teas were made from compost of wine industry wastes with added goat manure and leaf litter, prepared with or without active aeration, and applied undiluted. The commercial fertilizer was applied at a dose of 2 g/m². A split-plot randomized complete block design was used with four replicates per treatment. Nutrient solutions were applied weekly at 300 ml per plot (0.4 m², 3 plants). Variables evaluated included total yield per plant, average fruit weight, number of fruits per plant, relative chlorophyll index (RCI), stem diameter, and °Brix. Irrigation volume and frequency were kept constant across all treatments. Results showed that the cultivation system was the main determinant of yield. Plants grown in B system showed significantly higher yield (1192 g/plant), followed by S (950 g) and CMC (896 g), which did not show statistical differences. The nutritional treatments generated differences only for the quantity of tomatoes per plant, where B, produced the highest quantity (106.14), showing no differences between the CMC (70.08) and S (76.46) cropping systems. The rest of the variables did not generate differential response to the nutrient treatments. No significant interaction was found between cultivation systems and nutrient solutions, indicating that the effects of the latter are independent of the substrate system used. The root environment emerged as a key factor in crop productivity. In this study, soilless cultivation systems using compost-based substrates, along with liquid bio-inputs such as biol and compost tea, demonstrated potential as sustainable alternatives to soil-based production. These systems contribute to circular economy models by valorizing organic waste biomass.

Keywords: solanum lycopersicum; biofertilizers; compost; agroindustry; sustainability; substrates; soilless cultivation.

NUTRIENT RECYCLING THROUGH LIQUID DIGESTATE USE IN ORNAMENTAL CROP FERTILIZATION

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Anaerobic digestion of pig manure (PM) is a technology in continuous development in Argentina. However, its sustainability depends on the proper valorization of both the biogas and digestate. The digestate is a semi-liquid material rich in macro- and micronutrients and can be used as a biofertilizer in intensive systems, replacing inorganic fertilization (IF). In this context, the objective of this study was to evaluate the effect of liquid pig digestate (LPD) on two ornamental species and their substrate. The LPD was collected at the outlet of a solid/liquid separation system connected to a large-scale anaerobic reactor for PM treatment. The species Tagetes patula and Salvia splendens were grown in 370 mL pots with commercial substrate. Based on the inorganic nitrogen (N) content, four treatments were applied: T0 (control with distilled water), T1 (LPD, high dose: 200 mg/L N), T2 (LPD, low dose: 100 mg/L N), and T3 (NPK 18-18-18 IF: 200 mg/L N), with 15 replicates per species. The LPD was diluted with distilled water to adjust the inorganic N concentrations. Physicochemical variables were analysed in both the LPD and the substrate, as well as agronomic variables of the crops. The LPD had a slightly basic pH (7.9 ± 0.1), high electrical conductivity (EC) (15.9 ± 0.1dS/m), high organic matter content, and it was observed that 70% of total nitrogen (TN) was in ammoniacal form. In T. patula, total dry weight (TDW) and aerial fresh weight (AFW) were higher in T1 and T3 ($p< 0.05$), while aerial dry weight (ADW) was significantly higher in T1. The SPAD index was similar between T1, T2, and T3, and differed from the control. Regarding the number of flowers (NF), T1 showed a positive trend, while for the number of buds (NB) and stem height (SH), T1 recorded the highest values, with significant differences compared to T0, T2, and T3 ($p< 0.05$). In S. splendens, greater values of AFW, SH, and stem dry weight (SDW) were observed in T1 ($p< 0.05$), while TDW showed no differences between T1 and T3. In ADW, the best performance was observed in T3. For stem diameter (SD), T1 showed a trend toward higher values, although without significant differences. The number of nodes did not differ among treatments. The SPAD index was higher in T1 and T3, which is associated with the higher nitrogen concentration applied. In both crops and across all treatments evaluated, the EC of the substrate at the end of the trial remained within adequate ranges (0.168–0.279 dS/m). Likewise, the pH remained slightly acidic (5.6–6.4), promoting nutrient availability. Additionally, the highest NO_3^- content was recorded in T1, associated with the ammonification of organic N present in the LPD, followed by a nitrification process under favourable pH, EC, and oxygen conditions. It is concluded that total or partial replacement of IF in intensive ornamental crops using LPD is feasible. Additionally, the use of LDP contributes to improving the environmental quality of livestock systems and promotes nutrient recycling within production systems.

Keywords: manure valorization; anaerobic digestates; intensive crops; anaerobic digestion; pig manure.

EFFECTIVENESS OF STRUVITE AS A PHOSPHORUS SOURCE IN WHEAT CULTIVATION ON A RHODIC ULTISOL

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Phosphorus (P) is essential for the growth of agricultural crops; however, its availability in tropical soils is limited due to high adsorption and slow diffusion, which necessitates the application of phosphate fertilizers. The low phosphorus use efficiency and its subsequent accumulation in the soil—mainly resulting from the high rates of mineral phosphate fertilizers commonly applied in cropping systems—increase environmental risks and reinforce the dependence on non-renewable sources such as phosphate rock. A promising alternative is struvite, a magnesium ammonium phosphate obtained through the chemical precipitation of nutrients present in effluents. This source is characterized by its slow P release and can be used either in its pure (chemical) form or combined with organic residues, resulting in organomineral fertilizers. This study aimed to evaluate the potential of struvite as a phosphorus source for wheat cultivation under greenhouse conditions in Rhodic Ultisol. The experiment was conducted at the Department of Soil Science of the Federal University of Santa Maria (UFSM), RS, Brazil, using the wheat cultivar BRS TR271. A completely randomized design was used, with five replicates and seven treatments: control (no P added); 100% triple superphosphate (TSP); 25% organomineral struvite-based fertilizer (ESTorg) + 75% TSP; 50% ESTorg + 50% TSP; 75% ESTorg + 25% TSP; 100% ESTorg; and 100% pure struvite (chemical) (ESTpura), totaling 35 experimental units. The fertilizer doses were adjusted based on crop requirements, following the CQFS-RS/SC (2016) guidelines. Fertilizers were applied in furrows, covered with soil, and followed by sowing (10 plants per pot). The shoot dry matter (SDM) and soil available P content (Mehlich-1) were evaluated. Treatments with 50% and 75% ESTorg yielded the highest SDM values (6.70 g and 6.71 g), significantly surpassing the control (4.12 g). The highest soil available P concentration was found with 100% ESTpura (45.90 mg P kg^{-1}), followed by 100% ESTorg (41.41 mg P kg^{-1}) and 75% ESTorg + 25% TSP (27.47 mg P kg^{-1}). Lower values were observed with 25% ESTorg + 75% TSP (18.23 mg P kg^{-1}), 100% TSP (15.59 mg P kg^{-1}), and the control (7.33 mg P kg^{-1}). Struvite, particularly in organomineral form combined with TSP, enhanced phosphorus supply and wheat development in Rhodic Ultisol. These findings highlight the potential of struvite as a viable alternative for more sustainable phosphate fertilization, a potential that will be further supported by complementary analyses, including P content in plant tissues, grain yield, and field validation studies.

Keywords: phosphorus fertilization; swine manure; alternative phosphorus source; triticum aestivum; sustainability.

VALORIZATION OF FRUIT AND VEGETABLE WASTE AS A DIETARY RESOURCE IN GRYLLUS ASSIMILIS FEED

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This study presents an innovative and sustainable strategy for the development of balanced feed based on the rearing of Gryllus assimilis fed with fruit and vegetable waste. The aim was to valorize agro-industrial residues by incorporating them into insect diets, in order to generate protein-rich biomass with high nutritional value and reduce the environmental impact associated with food waste. The trials were conducted at the Bioassay Laboratory of the Food Technology Institute (LB-ITA), where a semi-controlled rearing system was designed (24–28 °C, 40 % RH, 12L:12D photoperiod, and water supply), using ventilated plastic containers. Early nymphal stages of crickets were used (n=100/treatment) and were fed ad libitum with a seasonal mixture of fruit and vegetable waste (lettuce, carrot, orange, and potato), while the control treatment received a commercial feed-based diet. Upon reaching adulthood, the individuals were harvested, frozen, and dried in an oven at 100°C, then ground to a fine powder (250–350 µm). Total protein, fat, moisture content, and fatty acid profile were analyzed. Results showed no differences in the time required to reach the adult stage between treatments (60 days), with a final average weight of 400–500 mg per individual, indicating that the tested formulations did not affect the cricket's life cycle. The cricket powder from the waste-fed treatment presented a protein content of 49.93% (dry basis), fat content of 34.84%, and moisture content of 17.07%, while the control showed 52.34% (dry basis) protein, 26.12% fat, and 3.46% moisture. These results show that it is possible to successfully rear crickets on fruit and vegetable waste and to obtain a low-cost, protein-rich source. This approach demonstrates the technical potential of agro-industrial waste revalorization through insect rearing, offering a scalable, sustainable, and low environmental impact method for obtaining functional proteins for the animal feed industry. In this way, the bioconversion and revalorization of fruit and vegetable waste contribute to the circular economy.

Keywords: cricket farming; food waste; circular economy; protein ingredients; cricket powder.

ACTIVATED SLUDGE REVALORIZATION ON HYDROCARBON-POLLUTED SOIL VERMIREMEDIATION

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Residue revalorization has become a major concern worldwide, especially in developing countries, as an affordable source of organic amendments and nutrients, mainly destined to agricultural purposes. Nonetheless, there is still public reticence about certain materials from human-origin like the sewage sludge obtained as a byproduct from municipal wastewater treatment. The aim of this work was to evaluate the efficiency and biological quality criteria for the vermiremediation of polluted soil (spiked with 3500 mg/kg of diesel) employing activated sludge as material rich in organic matter and microorganisms. Three mixtures with different soil (S) proportions (80.25, 70.25 and 60.25%) were combined with activated sludge (AS) (18.25, 28.25, 38.25%, respectively) and wheat straw (1.5%). They were pre-stabilized for two weeks, divided in 9 treatments and earthworms from different species were added (Eisenia fetida and Amynthas morrisi, separately or combined) along with negative controls (no earthworms). Vermiremediation process lasted 28 days. Physicochemical characterization tests were performed at initial and final days of the experiment, including Total Petroleum Hydrocarbons (TPH), thermogravimetry (TGA) and scanning electronic microscopy (SEM). Additionally, citometric screenings of earthworm coelomic extracts were used to register acute or chronic cytotoxicity, and germination-assays were performed employing the vermiremediated products to assess phytotoxicity and maturity. Most of vermiremediation treatments degraded TPH below the quantification limit (i. e. 500 ppm). The treatments with E. fetida alone and in combination with A. morrisi were the most efficient ones in terms of pollutant degradation. SEM images revealed that AS increases the matrix porosity. Also, the presence of organic compounds is remarkable. Final products showed further surface exposition and a fragmented texture due to the ingestion of mixture particles by earthworms, converting them into biomass amorphous aggregates. In addition, TGA studies showed an increase in the mass loss rate related to larger proportions of AS and the presence of earthworms. Citometry screenings of extracted coelomic fluids from earthworms revealed a shift between the controls of both species -at the beginning of the experiment- compared to the ones obtained at the end. For E. fetida, eleocytes proportion noticeably decreased while amoebocytes remain constant or slightly increased in one treatment (80.25% S), while for A. morrisi, both eleocytes and amoebocytes drastically increased in all treatments, with only a single exception (80.25% S combined with E. fetida). This observation could probably indicate that A. morrisi individuals presented a more sensitive immune response to diesel exposure, compared to E. fetida. Finally, most of vermiremediation treatments exhibited germination indexes above 60% (no phytotoxicity) or 80% (maturity) for corn (Zea mays) and soy (Glycine max), revealing a moderate to high tolerance of the cited species, while the values obtained for tomato (Solanum lycopersicum) where significantly lower for all products, in exception to one treatment. Therefore, tomato was the most sensitive vegetable species to diesel polluted soil aqueous extracts. This work emphasizes the application of earthworms for soil bioremediation as an economical technology which, along with physicochemical and ecotoxicological tests, ensures the quality of the final products in accordance with national and international legislations.

Keywords: bioremediation; earthworms; ecotoxicity; organic residues; diesel.

CULTIVATION OF AGARICUS SUBRUFESCENS ON RESIDUAL PLEUROTUS PULMONARIUS SUBSTRATE AND EVALUATION OF PHYTOTOXICITY FOR USE AS SOIL AMENDMENT

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Within the framework of the circular bioeconomy, the reuse of residual substrates from winter cultivation of oyster mushrooms (Pleurotus pulmonarius) was evaluated as an alternative to composted substrates for the summer cultivation of the medicinal mushroom Agaricus subrufescens. Three lignocellulosic materials — poplar sawdust, barley straw, and sunflower seed hulls — were compared in their original form and after a previous cultivation cycle with Pleurotus. The sterilized substrates were inoculated with spawn grain (5% w/w), incubated for 40 days, and fructified for 100 days (25–30 °C, 80–90% RH), using peat as casing layer. To evaluate environmental impact, the phytotoxicity of the post-Agaricus substrates was assessed through a bioassay with Lactuca sativa, using aqueous extracts (25–100%, pH 6.5) and measuring growth inhibition relative to a distilled water control. Residual substrates from Pleurotus cultivation initiated basidiome production earlier (51–79 days after casing) than the original substrates, with no significant differences in yield. In the latter, the previous breakdown of the lignocellulosic matrix may have enabled faster nutrient access by Agaricus, making them more suitable for production systems in subtropical regions with a limited summer season. The successive cultivation of two mushroom species reduces phytotoxicity levels from 100% (in sawdust, sunflower seed hull, and barley straw) to 70% in residual sawdust substrate, 72% in residual straw substrate, and 86% in residual sunflower seed hull substrate, suggesting their potential use as soil amendments at low concentrations. These results demonstrate the potential of residual substrates for sustainable fungal species rotation and their final disposal in small-scale agroproductive systems, facilitating soil ecosystem integration and reducing the energy demand associated with composting.

Keywords: agaricus subrufescens; mushroom residual substrate; pleurotus pulmonarius; phytotoxicity; soil amendment.

DEVELOPMENT OF LACTUCA SATIVA AND ZEA MAYS WITH OLIVE MILL WASTEWATER COMPOST AS FERTILIZER AND SUBSTRATE

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Spain has traditionally used the three-phase extraction system to obtain olive oil. This method also produces an olive mill wastewater sludge (OMW) as a by-product with high phenolic content, phytotoxic effect, strong odor, and with high environmental pollution potential. As management alternative, the OMW can be co-composted with different materials, which allow to condition their characteristics The aim of this work was to assess the agronomic use of composts obtained from OMW as main ingredient; 1) as fertilizers in a two-season pot experiment on lettuce (Lactuca sativa) and; 2) assess the composts as ingredient of a substrate for soilless crops. The composts were called T1, T2, T3 and T4 depending on the mixture of materials used: cattle manure (CM) or goat manure (GM) as N source, and almond tree pruning (Alm) or vineyard pruning (Vn) as C Source. Every compost contained 50% f.w. of OMW and every mixture was replicated with 1% f.w. of biochar as compost additive. In addition, Vermicompost were used as stabilized organic treatment, Cow manure as Fresh organic treatment and conventional Fertilizer (NPK 15-15-15) as Inorganic treatment. For the pot experiment, all treatment was applied adjusted to 200 kg N/ha, only at the beginning of the first growth season (23°C, 60% of relative humidity and 12h/12h light/dark photoperiod. Green cover factor (Canopeo) and chlorophyll content (SPAD) were measured for each plant after 10, 25 and 45 days. The harvesting was done after 45 days and yield of crop and physicochemical properties of soil were measured. The remaining soil was used for the second growth season. The substrate test was performed using maize (Zea mays) Each compost (T1 and T4) was applied mixed with coconut fiber in a concentration of 12.5%, 25%, 50%, and 100%, maintaining 100% of coconut fiber as control treatment. Each treatment was tested in 10 seedling cells (260 cm3). 15 days after the germination of half the cells of the Control, all plants were cut and their aerial and radicular part were weighed in fresh and dried. All composts treatments showed changes on the oxidizable C of the soil, increasing it above organic and inorganic treatments, and this change persists to the end of second growth season. In addition, available K was significantly incremented by OMW composts in both cycles due to the OMW high K content. Yield, Canopeo and SPAD of compost treatment showed no significant effect if compared with the Control without fertilization. In both growth season, the greatest SPAD and Yield correspond with Inorganic fertilizer. Regarding the use of compost as a substrate, T1 and T4 demonstrated their potential as an ingredient in substrate in concentrations up to 29.2% and 42.6%, respectively, with phytostimulant effect on germination. Furthermore, no phytotoxic effect on growth were observed at concentrations of 100%, as surviving plants always experienced more aerial and radicular growth than Control. The phytotoxicity in germination for 50% of the seeds (LC50) was 65.5% and 75.7%.

Keywords: olive mill wastewater; composting; organic fertilizer; phytotoxicity.

EVALUATION OF PRACTICES IMPLEMENTED BY A LARGE-SCALE OLIVE OIL MILL TO MANAGE ALPERUJO: SENSITIVE VARIABLES ASSOCIATED WITH ITS USE AND IDENTIFICATION OF OPPORTUNITIES FOR IMPROVEMENT

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The Sarmiento Department, in the province of San Juan, stands out as Argentina's main center for olive oil production. Managing byproducts, particularly alperujo (AL), presents an environmental and logistical challenge. One of the region's leading mills is implementing different strategies to manage more than 16,000 t of AL each year, including AL distribution on farm internal roads, controlled application of the byproduct in olive groves, and co-composting it with grape stalks. The main objective of this study was to evaluate these practices, identify sensitive variables, and generate applicable recommendations. The effect of AL distribution on farm internal roads was analyzed by monitoring physical and chemical changes in the deep soil profile (up to 2.00 m) in treated and control areas. Controlled application of AL between the rows of the olive grove was analyzed by determining quality indicators in the upper 0.20 m of the soil. Finally, the composting process was analyzed through quality and maturity analyses of the final product obtained. Regarding AL distribution on roads, results show that deep soil profiles, which were sandy and gravelly in nature, showed no significant changes in pH, organic matter (OM), or total phenols (TP), suggesting that deeper layers were not affected. Despite these results, it was recommended not to implement this practice due to the risk of adverse effects resulting from improper dosage control or runoff from heavy rainfall. Controlled application of AL between the rows improved soil quality by reducing electrical conductivity and increasing organic matter and macronutrients. Based on these findings, a maximum dosage of 20 t/ha was recommended, along with alternating application areas to optimize benefits and minimize risks. Regarding the compost quality assessment, it showed values in accordance with regulations, with conductivity levels slightly higher than recommended and signs of immaturity. Based on these results and considering soil characteristics and the tolerance of the olive crop, it was suggested to apply the compost at a dose of 10 t/ha as mulching on the irrigation line, mitigating potential phytotoxicity while further improving the fertility and structure of the soil. To summarize, after the assessment, the company prioritized co-composting for alperujo management, keeping controlled application to soil as a secondary option.

Keywords: olive pomace; compost; olive; by-products.

BARLEY GRAIN PRODUCTION AND QUALITY WITH DIGESTATE AND IRRIGATION IN NORTHERN ARGENTINA

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Barley grains for malting require specific quality levels of protein content and size, which depend on optimal crop growth. Digestate, a byproduct of biogas production, is nutrient-rich and widely available in Santa Fe province. The aim of this study was to evaluate whether the available barley varieties, fertilized with digestate and supplemented with irrigation, could serve as a new productive alternative during subtropical winters. The experimental soil was nutrient-deficient, and the application of 18,000 liters per hectare of digestate supplied 92 kg of nitrogen, 38 kg of phosphorus, and 123 kg of potassium per hectare. Six barley cultivars were sown on June 29, 2023, in a randomized complete blocks design. The plant health status of the cultivars and biomass production were optimal during the initial vegetative stage, which was supported by 100 millimeters of irrigation due to below-average rainfall. Flowering occurred between September 18 and 22. Mapping of ears and grains to identify pathogens and crop damage revealed that abundant rainfall in September favored the presence of Fusarium Head Blight (caused by Fusarium graminearum) particularly affecting the Ainará INTA and Verónica INTA cultivars. Additionally, necrotic spots with fungal structures (conidia compatible with Drechslera/Pyrenophora) were observed on leaves, indicating foliar infection that caused chlorosis and early senescence. The diagnosis showed that Spot Form Net Blotch of barley, caused by Pyrenophora teres f. maculata, was affecting the cultivars Ainará INTA, INTA 7302, Verónica INTA, and Militza INTA, in decreasing order of severity, under these environmental conditions. The average yield across all cultivars was 2592 kg/ha. Militza INTA achieved the highest yield at 3269 kg/ha, surpassing Verónica INTA with 2662 kg/ha, INTA 7302 with 2635 kg/ha, and Ainará INTA with 1800 kg/ha. Regarding commercial quality parameters, all cultivars exceeded 14% grain protein content. However, Ainará INTA was the only cultivar that did not meet the minimum of 80% grains retained on a 2.5 mm sieve. These novel results in northern Santa Fe indicate that three out of four cultivars met the required standards. These findings suggest that digestate is suitable for supplementing barley nutrition. Additionally, foliar area loss due to diseases, and floral unit reduction caused by environmental conditions, negatively influenced both yield and quality. It is recommended to consider earlier sowing dates and fungicide applications in future practices to prevent yield and quality losses.

Keywords: biogas; nutrients; crop health; cereal.

ADSORPTION-OXIDATION: USE OF SOLID WASTE IN A SEQUENTIAL "SELF-CLEANING'' PROCESS FOR TREATING CONTAMINATED WATER

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This work proposes the use of sargassum biochar, as well as its hybrid version with iron oxide (Fe_3O_4), in a sequential process of adsorption and advanced oxidation for the removal of dyes from contaminated waters. The proposal aims to use waste-derived materials as "self-cleaning" catalytic systems, offering a sustainable approach to wastewater treatment. The materials were produced by a facile synthesis via a one-pot hydrothermal technique. The spectroscopic analyses by FTIR revealed that the three materials (sargassum in natura, biochar and magnetic biochar) have bands associated with the functional groups typical of organic materials, such as O-H/N-H and C=O stretches. The presence of an additional band at 780 cm^{-1} in the magnetic material indicated the formation of the Fe-O bond, confirming the incorporation of the magnetic phase to the composite. The elemental composition of the materials was determined by EDX. It was observed that the magnetic biochar had 96.28% iron on its surface, in contrast to the much lower proportions in the precursor materials. This high concentration suggests an effective coating of the carbonaceous surface with Fe_3O_4 particles, giving the material promising catalytic properties. The photocatalysis tests were performed using 0.1 g of material, with methylene blue solution (50 ppm) at pH between 5 and 6, for 1 hour. The magnetic composite obtained a removal of 95.21% of the dye only with exposure to light, and this value increased to 99.53% with the addition of hydrogen peroxide (H_2O_2), indicating the efficient generation of hydroxyl radicals. The highlight of the work is the fact that the material can act as an "intelligent" system, promoting both the adsorption and degradation of contaminants without the need for additional catalysts. This study highlights the potential of magnetically functionalized sargassum-based materials as sustainable and recoverable solutions for water decontamination via combined adsorption and advanced oxidation.

Keywords: advanced oxidation processes; dye removal; magnetic composite; sargassum-derived biochar; water treatment.

EVALUATION OF DIGESTATE AS FERTILIZER IN SOILS CULTIVATED WITH CORN AND SORGHUM

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Digestates (D) from biogas are increasingly applied as fertilizers in Argentina. They contain nitrogen, phosphorus, and potassium, but their optimal application rates and impacts on soil properties remain unclear. This study aimed to evaluate whether short-term digestate application improves soil organic carbon (SOC), total nitrogen (TN), available nitrogen forms (NO_3^- and NH_4^+), extractable phosphorus (Pex), and exchangeable cations in agricultural soils from Pergamino, Buenos Aires, Argentina. D doses of 0 (D0), 10 (D10), and 30 (D30) m³/ha were tested in a randomized block design with three replicates, at two sampling times: 40 and 300 days after application, during the 2022–2023 growing season. The digestate had a pH of 8.9 and electrical conductivity (EC) of 18.2 dS/m. At the D30 rate, it supplied 158 kg C/ha, 159 kg N/ha, 31 kg P/ha, 134 kg K/ha, 63 kg Ca/ha, 141 kg S/ha, and 269 kg Na/ha. Across the three sampled depths (0–10 cm, 10–20 cm, and 20–40 cm), SOC (1.83%, 1.55%, and 0.94%) and TN (0.16%, 0.13%, and 0.08%) remained unchanged regardless of digestate dose or sampling time (at planting and post-harvest). However, NO_3^- levels at 0–10 cm doubled from D0 (61 mg/kg) to D10 (119 mg/kg) and tripled at D30 (226 mg/kg) after 40 days, while NH_4^+ also increased (7.6, 13.6, and 20.9 mg/kg across treatments). From 10–20 cm depth, only NO_3^- increased (68.6, 91.0, and 149.4 mg/kg), while no changes occurred at 20–40 cm (48.6 mg/kg). Pex concentrations were similar across digestate doses but varied with depth (41.0, 34.3, and 14.6 mg/kg). After 300 days, NO_3^- and NH_4^+ returned to similar levels across all treatments and depths (33–28 mg/kg). In contrast, Pex significantly increased in D30 at 0–10 cm (27.2, 32.4, and 63.1 mg/kg) and at 10–20 cm (14.9, 24.9, and 30.1 mg/kg), with no change at 20–40 cm (14.3 mg/kg). Soil pH was unaffected, but EC slightly rose at 0–10 cm (0.26, 0.33, and 0.44 dS/m) and 10–20 cm (0.19, 0.22, and 0.29 dS/m) after 40 days, then declined to baseline (0.07 dS/m) after 300 days with no significant differences between treatments or depths. Potassium (K^+) increased in D30 soils at 0–10 cm (2.8 cmol/kg) compared to D10 and D0 (2.3 cmol/kg), maintaining this level over time. Calcium (Ca^{2+}; 9.6 cmol/kg) and magnesium (Mg^{2+}) showed no changes, and sodium (Na^+) remained low overall, with minor fluctuations over time at the surface level (0.35 vs. 0.29 cmol/kg). In summary, digestate application enhanced nitrogen and phosphorus availability for corn and sorghum without altering SOC. Pex and K^+ remained stable with the D30 rate, while reapplication of D10 may help sustain nutrient supply for future crops.

Keywords: biogas; nutrients; nitrogen; phosphorous; cereal.

USES OF STEVIA AGRICULTURAL PRODUCTION RESIDUES AS A PROBIOTIC ADDITIVE IN POULTRY PRODUCTION TO REPLACE ANTIBIOTICS

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For over ten years, the Development Lab has been working on both Stevia vegetable production(1) and the development and formulation of various non caloric sweetener for direct use or for the food industry. A non-published analysis done by our research group shows, among other results, that in the southern region of Córdoba, production is approximately 3 tons/ha of dried Stevia leaves per year. The term "dried leaves" actually includes stems, which represent 45% by weight. The most valuable product for sweetener production is actually the leaf, although a certain percentage of stems can be used in some products. This implies that stems are a low-value byproduct that easily becomes agricultural waste. Within the scope of our laboratory and the Initia Limited Cooperative, several avenues for adding value to stems have been tested. On the other hand, poultry production in Argentina has experienced significant development for the past 20 years; Poultry meat consumption grew from 8 to 49.5 kg/inhabitant/year in 2024. Likewise, international and national legislation requires the elimination of the use of growth promoters antibiotics (GPA), which leads to the investigation of new zootechnical tools that sustainably increase productivity (2,3). This has guided research towards the search for natural additives that fulfill digestive functions, that favor the early maturation of the immune system and modulate the microbiota (3). Stevia is a phytobiotic that presents antioxidant, bacteriostatic and anti-inflammatory properties. In previous research, we found that its incorporation into the avian diet (various preparations from leaves), improved intestinal health (2, 3) and productive variables. In this research, the formulation of an additive based on Stevia stems (as an agricultural residue) is proposed, to optimize intestinal health, carcass quality and productive variables in broiler chickens. This objective arises from the need in the productive sectors for innovative products that allow them to meet their production goals with high standards of quality and safety, guaranteeing safe food for consumers, and using sustainable, biocircular, and environmentally friendly production methods. This work addresses how to use these agricultural residues in the development of an additive that replaces the use of GPAs in poultry production, particularly in the production of broiler chickens. This additive, for commercial use, would benefit both the livestock sector and the agroecological sector of small-scale stevia producers in Córdoba.

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Keywords: agroecology; circular bioeconomy; stevia; poultry production; intestinal health.

FROM OLIVE PRODUCTION TO BIOCHAR: CHALLENGES AND OPPORTUNITIES IN SUSTAINABLE OLIVICULTURE

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Argentine olive growing is consolidating its position as a strategic sector for the PBI economy, with an annual production of 30,000-35,000 tonnes of olive oil, making it one of the top ten producers in the world. Seasonal pruning is an issue that should not be ignored, as incineration is still the most common method of disposing of this organic waste. The production of biochar from these idle wastes would avoid this problem. This solution offers a double advantage: waste management and the production of materials that, depending on their properties, could be used in various applications: soil improvement, pollutant absorption, steel production, carbon sequestration, among others. In addition, the issuance of carbon credits could be seen as a return of cash flow to the agricultural system. In this study, biochars were produced from olive tree prunings, both in an industrial scale slow pyrolysis reactor (EKKO, GreenPower®) at 600 ºC. The physico-chemical properties of the biochars: specific surface area, ash, fixed carbon, polyunsaturated aromatic hydrocarbons (PAHs) were measured in order to determine which application would be more suitable (PLAPIQUI UNS CONICET). We obtained biochar with high organic C content, 60% fixed carbon and free of PAHs. (< 10 ppb). Biomasses, after pre-treatment, result in biochar with a specific surface area in the range of 12-14 m2 g-1 and a high concentration of functional groups. Considering all these properties and the fact that they are alkaline in character (pH 8.0), the application of biochar from pruning tree waste would be a soil amendment. The emission of carbon credits should not be disregarded in this case, since the main tests suggested by the European Biochar Certificate (version 10.4) standards were fulfilled. Furthermore, based on these results, the application of these materials for component of biofertilizers is envisaged between other uses. The use of non-valuable biomass from pruning waste for the production of biochars with specific applications is an important contribution to the development of local bio-economies.

Keywords: olive; pruning; pyrolysis; bioeconomy carbon soil stock.

SENSORY CHARACTERIZATION OF PECAN OILS GROWN IN ARGENTINA USING THE CATA TECHNIQUE

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In Argentina, commercial cultivation of pecan [Carya illinoinensis (Wangenh.) K. Koch] has shown sustained and accelerated growth in recent years, accompanied by significant increases in production. This has also increased the number of discarded pecans, either because they are too small, which decreases their value, or because they break during the shelling process. Due to their high lipid content, these residues can be used by the food industry to produce products such as pecan oil. These oils offer significant potential, as contain compounds with beneficial health effects, and consumers are increasingly interested in these types of products. However, as this is a novel product, it is essential to identify its sensory characteristics and understand consumer perceptions in order to anticipate its market acceptance. Sensory analysis is a key tool for evaluating the organoleptic properties of foods through the senses. The Check-All-That-Apply (CATA) technique has gained popularity in recent years. This method allows for exploring consumer perceptions of a wide variety of product attributes. The objective of this study was to perform sensory characterization of oils obtained from different pecan cultivars grown in Argentina to anticipate consumer acceptance. For this, the oils of ten pecan cultivars were obtained by pressing at 35°C using a hydraulic press. The nuts had a moisture content of 5.5% at the time of processing. Sensory evaluations were carried out using the CATA methodology. 30mL of each sample were served in 100mL vessels coded with three-digit numbers. A Latin Square design was used to alternate the position of samples and the order of attributes for each consumer. 94 consumers participated. Correspondence Analysis (CA) was used to get a bi-dimensional representation of the samples and the relationship between samples and terms from the CATA question. The percentage of variance explained by the first two dimensions of the CA was 80.96%. A group of pecan oils from the Cape Fear, Oconee, and Samner cultivars were located at positive values of the first dimension and negative values of the second dimension, being mainly described as toasted, aromatic, nutty flavor, sweet, pleasant, and woody odor. Located at positive values of the first and second dimension were the Nacono cultivar, described as unpleasant, rancid, astringent, dark in color, with a strange, bitter, and strong flavor, and the Pawnee cultivar. Meanwhile, located at negative values of the first dimension and positive values of the second dimension, were the Kiowa cultivar, characterized by being tasteless and odorless; and the Shoshoni, Choctaw, and Maramec cultivars. Finally, the Harry Super cultivar located at negative values in the first and second dimensions, being mainly described as, with a mild flavor, and light in color. In conclusion, the cultivars most liked by consumers were Cape Fear, Samner, Oconee and, to a lesser extent, Harry Super. These cultivars were located at negative coordinates in the second dimension. On the other hand, the least liked cultivars were Nacono, due to its unpleasant characteristics, and Kiowa, due to its lack of flavor and aroma.

Keywords: consumer perception; waste; food industry.

EVALUATION OF THE USE OF COMPOSTED MANURE IN AN AGRICULTURAL ROTATION

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The intensification and concentration of production in Argentine dairy systems leads to the generation and accumulation of slurry and solid waste. Applying this waste to the soil as an organic amendment offers a solution to the problem, allowing for the recovery of soil fertility and increased crop production (García, Charlón 2011). The objectives of this study were to evaluate the application of previously composted dairy solid waste to a crop rotation (corn/cover crop/soybean), mitigate basic soil nutrient deficiencies, and generate local/regional data. The trial was conducted at La Julia farm (Tres Lomas), a dairy farm. Solid manure, obtained from sieving, was composted for 100 days and then applied to a plot designated for crop rotation, with a sandy loam texture. Four treatments were tested in 20.8 m^2 plots, with four replicates. The treatments were: 1- Control (T) without fertilizers, 2- raw manure (E) applied as is, 3- composted manure (EC), and 4- the dose of chemical fertilizer used by the producer (Fq). The compost dose was 40 tons/hectare prior to corn planting. Corn was planted on December 21, 2023. This crop was harvested on June 10, 2024, followed by cover cropping (rye) and soybean planting on November 27, 2024, which was harvested on May 12, 2025. Determinations: initial soil conditions: 1.7% organic matter, 8.5 ppm phosphorus, pH 7, EC 0.42 dS/m, and at the end of the corn crop. Grain yield of corn and soybean crops: Results: The results obtained at corn harvest showed no significant differences in grain yield, except at the P1000 ($P=0.04$) for treatments E and EC. Soybean grain production showed positive results in favor of treatments EC and E ($P = 0.04$). Soil analyses at the end of the corn cycle did not yield statistically significant results in soil composition for the evaluated variables.

Conclusions: The incorporation of composted material into the soil is slower and has a residual effect. The crop requirements were met, with differences between treatments T and Fq in the second crop. The data generated allow for further investigation into the behavior of crops in rotation with respect to these applications.

Keywords: nutrients; crops; yield.

BIODEGRADABLE ADHESIVE TAPES OBTAINED FROM SOYBEAN DERIVATES

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The development of sustainable and eco-friendly adhesive tapes has gained significant attention due to increasing environmental concerns and the need to reduce reliance on petroleum-based materials. This study explores the utilization of soy protein and modified soybean oil as renewable raw materials to produce a biodegradable pressure sensitive adhesive tape with competitive adhesive properties. Soy protein (SPC), known for its film-forming ability, serves as the carrier of the adhesive, while epoxidized soybean oil (ESO) was the main component of the pressure sensitive adhesive (PSA).

The adhesive carrier was formulated as follows: SPC (55.5%), glycerol (16.7%), buffer pH 10 (27.7%) and salicylic acid (3%) and obtained through thermal-compression molding. The carrier film was characterized by thermogravimetric analysis (TGA), moisture content (MC), total soluble matter (TSM) and mechanically in a microtensile test as described in ASTM D1708-02a standard.

The PSA was obtained from the mixture of ESO and a polymeric diacid as described by Teper et al.(Teper Marinelli, Ruseckaite, y Ciannamea 2025), coated over the SPC film and covered with a non-stick release film to obtain the PSA tape. The system SPC film-PSA-release film was then subjected to the following thermal treatment: 1) stabilization at 50°C for 15 min; 2) heat ramp of 5°C/min unto 160°C (22 min); and 3) isothermal step at 160°C for 43 min. Then, the adhesive tapes were stored in an environmental chamber at 23°C and relative humidity (HR) of 65%.

The adhesive performance was evaluated through peel strength (ASTM D3330, method A), tack (ASTM D6195, method A), and shear resistance tests (ASTM D3654), demonstrating that the soy-based adhesive tape exhibits comparable or superior performance to conventional synthetic adhesives in certain applications. Additionally, the biodegradability of the tape was confirmed in soil, highlighting its environmental benefits.

The adhesive tapes developed showed potential as labels, due to high tack (2.4 N/cm2) and the high resistance shown during peeling tests. These biodegradables labels have potential application in many industries and could be available at relatively low cost.

This study demonstrates the feasibility of using soy protein and modified soy oil as sustainable alternatives in adhesive tape production, offering a promising solution for reducing the environmental impact of pressure-sensitive adhesives. Further optimization of crosslinking agents and processing conditions could enhance the adhesive's performance for industrial applications.

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Keywords: pressure sensitive adhesive; sustainable materials; epoxidized soybean oil; soybean protein concentrate.

FROM WASTE TO RESOURCE - ASSESSING THE FEASIBILITY OF PARTICLEBOARD PRODUCTION USING BREWER'S SPENT GRAIN

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Brewer's spent grain (BSG) accounts for approximately 85% of the solid waste generated during beer production. In line with circular economy principles, there is a growing interest in repurposing industrial by-products like BSG. Given its compositional similarity to wood, BSG has been explored for producing lignocellulosic materials, such as particleboards. Manufacturing particleboards from BSG offers a valuable way to utilize a large quantity of this waste. This study explores the production of BSG-based particleboards using two sustainable approaches: 1) binderless boards made through thermo-compression with water, where the BSG particles self-bind, and 2) boards that use soy protein concentrate (SPC) as a natural adhesive. The research focused on optimizing the processing parameters to produce boards with a target density of 1000 kg/m^3 and a thickness of 5 mm. To assess their performance, the boards were compared to a control panel made from BSG and a phenolic resin. The boards properties, including the modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB), thickness swelling, and water absorption, were evaluated in accordance with ASTM D 1037-93. The results showed that the properties of the binderless BSG boards were comparable to those of boards made from other biomass residues. In addition, sustainable boards can be produced from BSG, using SPC as a bio-based adhesive, without the addition of synthetic additives or substrates. The study suggests their potential for use in interior non-structural applications.

Keywords: bsg; lignocellulosic residues; circular economy; mechanical properties; revalorization.

FROM WASTES TO ADSORBENTS - PEANUT SHELLS FOR ORGANIC POLLUTANTS REMOVAL

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According to the United States Department of Agriculture (USDA) in 2024, 50 million tons of peanut were generated. Argentina is one of the leading producers of peanut, located in the sixth worldwide place. From its industrial production, around 25% corresponds to shells, which are actually not completely utilized. This situation underscores the urgent need for this biowaste valorization. Peanut shells are a recurrent waste, abundant in lignin, cellulose, and hemicellulose content (Fermanelli et al., 2022). A viable valorization alternative consists in their pyrolyzation. From this thermal process under an inert atmosphere, among biooil and gases, a solid product called biochar is obtained. To improve biochar´s physicochemical characteristics, it could be subjected to thermochemical processes that released its internal channels, thus enlarging its surface area and pore size (Ding et al., 2023). Thus, the transformation of the residual shell into a valuable activated carbon (AC) with noticeable adsorption characteristics could be achieved. Besides, water suffers from numerous anthropogenic contaminants, among them, industrial dyes are of great relevance. Coloured effluents from textile dye manufacturing, leather, paint, cosmetic and paper industries represent a serious environmental problem. One of the most commonly used dyes is Methyl Orange (MO), an anionic dye that belongs to the azo group. This compound presents a p-amino azobenzene that makes it toxic and carcinogenic, producing a serious threat to the lives of animals and human health (Tahari et al., 2022). Also, dyes absorb sunlight hindering photosynthesis. Thus, specific treatments should be done to remove these water pollutants. Adsorption is one of the most studied methodologies and ACs from renewable and residual sources are ideal candidates for this purpose. For this study, AC from peanut shell was put in contact with MO aqueous solution (8x10 -6 M). In each test, 200 mL of the solution were contacted with AC at room temperature and natural pH. Samples were periodically taken, filtered- to separate the adsorbent- and analyzed in a Persee T7DS UV-Vis Spectrophotometer, scanning between 200 and 900 nm. It was found that AC could remove almost 98% of the dye after 90 minutes. Contact time, MO:AC ratio and reuses were also evaluated. It was found that AC is capable of removing this type of organic contaminants even after three reuses, although its efficiency is reduced in the last cycle. Based on these results, it is possible to propose that activated carbon obtained from the residue of the peanut production process is a recommended adsorbent for the treatment of water containing organic pollutants.

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Keywords: peanut shells; biowaste valorization; pyrolysis; activated carbon; dyes adsorption.

EFFECT OF ORGANIC FERTILIZATION WITH PELLETED COMPOSTED PIG DIGESTATE ON THE GROWTH OF SALVIA GREGGII GROWN IN SOILESS GROWING MEDIA

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The composting of the solid fraction of digestates improves its quality, achieving stability and maturity parameters suitable for use as a biofertilizer. Pelletizing the compost facilitates its handling, transport, and application. The objective of this study was to evaluate the effect of three types of pellets made from composted pig digestate (PCDP) as organic fertilizers on the growth of Salvia greggii plants, compared to a controlled-release inorganic fertilizer. The organic fertilizers used were: PCDP (NPK 2.9-1.3-9) (C), PCDP with 5% zeolite (NPK 2.8-0.9-6) (CZ), and PCDP with 5% activated charcoal (NPK 1.7-1.3-4.2) (CA); and as inorganic fertilizer: Basacote plus 3M (NPK 16-4-10) (F). Based on nitrogen content, two doses of each fertilizer were evaluated: dose 1: 320 mg and dose 2: 640 mg of N per liter substrate. There were eight treatments (four fertilizers × two doses). A commercial substrate (Z-Floricultura, Terrafertil) was used, with a pH of 4.80 and an electrical conductivity (EC) of 0.52 $dS \cdot m^{-1}$. The experimental unit was one plant in a 1.1-liter pot. A completely randomized design with ten replicates was used. The trial lasted 70 days. At the end of the experiment, the pH and EC of the substrate, SPAD index, and shoot (SDM) and root dry mass (RDM) of each plant were measured. The highest final pH values of the substrate were observed in the treatments fertilized with both doses of C and CZ (average: 7.23), while the lowest value (6.2) was recorded in the substrate with dose 2 of CA. The highest EC was found in the substrate with dose 2 of CA (1.06 $dS \cdot m^{-1}$), and the lowest values in substrates with dose 1 of F and C, and both doses of CZ (average: 0.39 $dS \cdot m^{-1}$). The highest SDM values were obtained with both doses of F ($p<0.05$). The lowest SDM values occurred in the treatments with dose 1 of CZ and CA, while the remaining treatments had intermediate values with no significant differences between them ($p<0.05$). The highest RDM values were obtained with dose 1 of C and dose 2 of CZ ($p<0.05$). Plants treated with both doses of F showed higher SPAD index values compared to the rest of the treatments, with no differences between them ($p<0.05$). In conclusion, the best growth was achieved in plants fertilized with the higher dose of inorganic fertilizer. The growth achieved with the three organic fertilizers, at both doses, was lower than that obtained with the lowest dose of the inorganic fertilizer. The lowest dose of organic fertilizers CZ and CA resulted in lower plant growth compared to the other treatments.

Keywords: pellets; solid fraction of digestate; composting; intensive cropping; biofertilizer.

POTATO FLOUR: A SUSTAINABLE ALTERNATIVE TO WASTE POTATO FLOUR TO PRODUCE BAKED GOODS

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The districts of Southeast Buenos Aires (SEB) produce more than 50% of the country's total potatoes, both for processing and fresh consumption, and it is estimated that there is a high percentage of loss or waste (5%). These losses can be reduced by applying simple technological alternatives that generate value. The objective of this work was to take advantage of the waste from potato production to obtain, characterize, and utilize a by-product. To do this, waste from two varieties (Spunta and Innovator) was used and flour was obtained by dehydration at 50/55ºC for 5 h. The physicochemical quality of fresh potato and flour was determined by dry matter and starch. Functional properties such as water retention capacity (WRC), water solubility index (WSI), swelling capacity (SBC), water absorption capacity (WAC), oil absorption capacity (OAC), foaming capacity (FC), and muffins made with 100% wheat flour and 100% potato flour were evaluated in flour. In turn, they were asked to choose between the samples according to their preference. Fresh potatoes showed a percentage of dry matter of 16.16% and 19.96%, and a starch content of 8.43% and 12.8% for Spunta and Innovator, respectively; flour showed 90.17% and 86.59% dry matter, and 56.43% and 55.07% starch for Spunta and Innovator, respectively. The CRA was 4.68 g of water/g of sample and 3.97 g of water/g of sample, the ISA obtained was 12% and 9%, the CH was 35.65 g of water/g of sample and 34.88 g of water/g of sample, the CAA was 323% and 266%, for Spunta and Innovator flour respectively; the CAAc was 98.33% in both flours and, finally, the CE was 65.33ml and 78 ml and the EE was 93.89% and 98.29% for Spunta and Innovator flour respectively. The overall acceptability of muffins made with wheat flour was 86.4% and those made with potato flour was 75.6%. The 100% wheat muffins had greater acceptability for their flavor and texture (85.8 and 85.6%) compared to the 100% potato flour muffins (79.2 and 72.6%). 68.1% of consumers preferred wheat flour muffins and 31.9% preferred potato flour muffins. The physicochemical, functional and sensory determinations of the flours yielded results that provide relevant information for the development of baked products. Dehydration is a sustainable and simple technology that allows for a longer shelf life compared to fresh raw materials and minimizes production waste by transforming it into value-added products.

Keywords: potato; waste; flour; baked goods.

EVALUATION OF THE INCORPORATION OF BREWER'S SPENT GRAIN EXTRACT INTO RESIDUAL YEAST FILMS FOR ACTIVE PACKAGING APPLICATIONS

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The extensive use of synthetic non-biodegradable polymers in packaging rises environmental pollution. Bio-based polymers offer a sustainable alternative. The brewing industry produces large amounts of by-products, mainly brewer's spent grain (BSG) and residual brewer's yeast (RBY). Proper management of these residues reduces disposal problems and adds economic value[1,2]. BSG, rich in antioxidant phenolic compounds, shows promise for active packaging[1]. This study aims to incorporate BSG antioxidant extracts into RBY-based films to develop active packaging systems. BSG extracts were obtained under reflux with 60% (v/v) ethanol for 60 min. For film preparation, a dispersion of 5% (w/v) RBY cells was sonicated (30 s pulses, 100% amplitude, 15 min), then centrifuged to collect the sediment (cell wall-rich in β-glucan and proteins). A 5% (w/w) dispersion was prepared, treated at 90 °C for 20 min, and glycerol (20% w/w) and BSG extract were added in 5, 10 and 15 % (w/w). Casting method at 50 °C was used to prepare the films. Mechanical properties and Water vapor permeability of the films were determined according to ASTM D882-97 and ASTM E-96 standards, respectively. Film thickness was 0.11 ± 0.01 mm. Migration tests were carried out in ethanol 95% during 10 days at 40 °C, following Standard EN 13130-1:2004. Antioxidant capacity of the released compounds during migration tests was evaluated using the ABTS method in terms on Radical Scavenging Activity (RSA, %)[2]. No significant effect of BSG extract was observed on TS, EM, or WVP of the films. The increase in elongation at break with higher extract concentration may be due to interactions between the extract and the yeast polymer matrix. Weight loss in water increases with the content of BSG extract indicating that film solubility is significantly affected. Regarding migration tests, higher antioxidant activity was found in extracts from samples containing BSG. However, control samples also showed antioxidant capacity, attributable to the known antioxidant properties of the yeast cell wall[3].These results demonstrate that incorporating BSG extract into residual yeast films is a promising approach for developing active antioxidant materials.

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Keywords: bagasse; brewing industry; casting films; bio-based; revalorization.

LEACHING ENHANCES CHEMICAL PROPERTIES OF A SOLARIZED SPENT GROWING MEDIUM AND IMPROVES TAGETES ERECTA GROWTH

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Leaching is an alternative for reconditioning substrates with high salt content. The objective of this study was to evaluate the effect of leaching with water of different qualities and at different volumes on some chemical properties of a previously used and solarized substrate, as well as on the growth of Tagetes erecta plants. Seven treatments were evaluated: Groundwater with leaching fractions of 25% (G-0.25), 50% (G-0.5), and 100% (G-1) of the pot volume; desalinated water with leaching fractions of 25% (D-0.25), 50% (D-0.5), and 100% (D-1); and a non-leached control (C). Groundwater had an electrical conductivity (EC) of 0.83 $dS \cdot m^{-1}$, an alkalinity of 380 ppm $CaCO_3$, and a Na content of 135.6 ppm; desalinated water had an EC of 0.08 $dS \cdot m^{-1}$, no alkalinity, and a Na content of 4.57 ppm. A completely randomized design with ten replicates was used, with one 700 ml pot per replicate. The spent and solarized substrate originated from ornamental plants grown at the INTA Institute of Floriculture and consisted of peat, pine bark compost, pruning waste compost, and perlite. Leaching treatments were applied by manual irrigation to the potted substrate. The following day, seedlings were transplanted. Plants were watered manually and fertilized with a soluble fertilizer. After leaching, substrate pH, EC, and Na content were determined. At the end of the growing cycle, shoot dry mass (SDM), root dry mass (RDM), and the number of flower buds plus open flowers (FN) were evaluated. The lowest pH values were recorded in C (5.92) and D-0.25 (5.84), and the highest in G-1 (6.5) and D-1 (6.45). The highest EC (1.36 $dS \cdot m^{-1}$) and Na concentration (387.87 ppm) occurred in C, while the lowest values were found in G-1 (0.33 $dS \cdot m^{-1}$, 154.33 ppm) and D-1 (0.21 $dS \cdot m^{-1}$, 144.33 ppm). The highest SDM was observed in treatments D-0.5, G-0.5, and G-1, while the lowest was in C, which differed significantly from the others ($p<0.0001$). The highest RDM was recorded in D-0.5, followed by G-0.5 and G-1, while the RDM of the remaining treatments was similar ($p<0.0001$). The lowest SPAD index was observed in C, followed by G-0.25, with no differences among the other treatments ($p<0.001$). Regarding FN, D-0.5 showed the highest value, although it did not differ from G-0.5, D-1, and G-1; the lowest value was found in C ($p<0.0001$). In conclusion, leaching the spent substrate with water volumes equivalent to 50% of the pot volume, with both water qualities, reduced EC and Na content in the substrate and enhanced Tagetes erecta seedling development.

Keywords: spent growing media; leaching; reuse; ornamental crops; salinity reduction.

USE OF MANURE IN THE YIELD AND QUALITY OF COVER CROPS USED AS DEFERRED FORAGE IN A GOAT PRODUCTION SYSTEM UNDER THE MBGI APPROACH

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Proper forage management in Argentina's semi-arid region is a key strategy to improve the efficiency of livestock systems, particularly goat production. In this context, the sowing of winter forage crops, in addition to fulfilling ground cover functions and improving soil quality, can also be used as forage and deferred as a strategic reserve for critical times of the year. The objective of this study was to evaluate the yield and quality of deferred forage from a winter pasture mixture following the incorporation of different types of manure.The trial was carried out at the experimental field of INTA EEA Santiago del Estero, Silípica Department. Four treatments were arranged in 12 plots of 144 m² each, in a completely randomized design (CRD) with three replications: a control treatment (T0), without manure, and three treatments with different types of manure: poultry litter (GG), fresh goat manure (GCN), collected from corrals six months prior, and aged goat manure (GCV), stored for over a year. The manure was applied five months before sowing (02/10/2023), at a rate of 5 t.ha^{-1}, and incorporated superficially. Before superficial irrigation, on 18/03/2024, a pasture mixture was sown in 30 cm inter-row spacing, consisting of inoculated vetch (Vicia villosa), triticale (× Triticosecale Wittmack), and forage barley (Hordeum vulgare). When 80% of the grasses had headed and 50% of the legume was in bloom, the crop was mowed and left to dry in the field for four days. Baling was performed on 18/08/2024 using a manual baler (METALÚRGICA AJM), which produces bales with average dimensions of 90 × 40 × 40 cm. The weight of the bales from each treatment was recorded to determine the total dry matter (DM) produced, extrapolated per hectare (DM/ha). Forage quality was evaluated by measuring crude protein (% CP), dry matter content (% DM), and ash content (% Ash). Data were analyzed through ANOVA, and treatment means were compared using Tukey's test. Initial results showed that the manually produced bales had an average weight of 10.87 kg (±0.93). Dry matter yield did not show significant differences among treatments, ranging from 5241.2 kg.ha^{-1} (GCV) to 6345.37 kg.ha^{-1} (T0), with the control treatment showing the best performance. Similarly, no significant differences were observed in forage quality variables. Dry matter values (%) were: GCV (83.5), T0 (84.6), GG (85.4), and GCN (86.5). Crude protein was highest in GCN (15.27%), followed by GG (15.1%), while T0 and GCV showed lower values of 13.8% and 12.1%, respectively. Ash content remained within acceptable ranges, from 10.4% (GCV) to 11.1% (GCN). In conclusion, the first crop established after manure application did not show significant improvements in forage yield or quality compared to the unamended soil. However, its use could have positive effects on subsequent crops and represents a valid strategy for the management of agricultural waste, contributing to more sustainable practices in livestock systems in semi-arid regions.

Keywords: manure; forage; goats.

CONTRIBUTION OF SILA LACCASE TO THE VALORIZATION OF LIGNIN FROM SUGARCANE RESIDUES IN THE CONTEXT OF BIOREFINERIES

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Lignin, a complex aromatic polymer in lignocellulosic biomass, remains underutilized due to its recalcitrant structure. However, it holds great potential as a renewable source of high-value chemicals. Among emerging biotechnological strategies, laccases and peroxidases are of particular interest to enable the selective depolymerization and transformation of lignin. These enzymes can facilitate the conversion of lignin to lignin-derived aromatic compounds (LDACs), which can then be transformed into valuable compounds such as vanillin and bioplastic precursors, supporting sustainable and circular bioeconomy models. In a previous study, we demonstrated that SilA, a bacterial laccase from Streptomyces ipomoea, can transform lignin from sugarcane residue biomass pretreated by steam-explosion (SCRSE) into phenolic compounds. In this study, we evaluated the contribution of SilA to the valorization of the lignin fraction of SCRSE either before or after saccharification of structural polysaccharides, in the context of potential application in biorefineries. We investigated whether (a) pretreatment with SilA could aid saccharification of plant structural polysaccharides from SCRSE and (b) if treatment with SilA after saccharification of polysaccharides from SCRSE could improve the release of LDACs, aiming to valorize the residual solid biomass. First, SCRSE was treated with SilA, and then the resulting solid fraction was hydrolyzed with Cellic®CTec2 (CCTec2), a complete, efficient industrial cellulase/xylanase enzyme blend, and the concentration of reducing sugars released (as glucose equivalents) was measured by the dinitrosalicylic acid (DNS) method. The treatment with SilA did not result in any difference in saccharification, with 5.8 mg/mL of reducing sugars measured in both the SilA-treated and the no-laccase control samples. This suggests that treatment with the laccase did not contribute to the accessibility of cellulose and hemicellulose to polysaccharide-hydrolytic enzymes. We next investigated if treatment with SilA of the residual solid fraction of SCRSE (after saccharification with CCTec2) could result in an improvement of the release of monoaromatic compounds. For this experiment, SCRSE was first treated with CCTec2, and the resulting solid residual biomass was incubated with SilA, in the presence or absence of the redox mediator β-(10-phenothiazyl)-propionic acid (PhCOOH). In parallel, a control reaction with no CCTec2 was treated under the same conditions with SilA. Quantification of monoaromatics by HPLC revealed an overall 30% increase in LDACs released by SilA (in the presence of PhCOOH) from CCTec2-treated SCRSE compared to SilA treatment of SCRSE. In particular, there was a statistically significant increase in the amount of p-coumarate released, which improved from 23.6 ± 0.6 (SCRSE) to 44.0 ± 5.0 µM (CCTec2-treated SCRSE). These results support the notion that SilA can be used to extract valuable components from the residual biomass solid fraction after saccharification of polysaccharides, contributing to further valorization of the lignocellulosic biomass.

Keywords: lignocellulose; lignin; laccase; biorefineries; sugarcane.

XYLANOLYTIC ENZYMES OF PAENIBACILLUS XYLANIVORANS PRODUCE FUNCTIONAL XYLOOLIGOSACCHARIDES AND FERMENTABLE SUGARS FROM LIGNOCELLULOSIC BIOMASS

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Agroindustrial residues and subproducts rich in hemicelluloses, such as blue agave bagasse (BAB) and wheat bran (WB), represent valuable feedstocks for the sustainable production of enzymes and bioactive compounds. Xylan is the main hemicellulose component and varies in structure depending on the plant source, presenting as arabinoxylans (AX, arabinose decorations) or glucuronoxylans (GX, methyl-glucuronic acid substitution -MeGlcA), which are potential substrates for high-value bioproducts. Paenibacillus xylanivorans is a xylanolytic, mesophile, halotolerant bacterial strain from soil previously isolated by our group. We evaluated its extracellular xylanolytic activity and secretome profile when grown on WB and BAB, substrates rich in AX and GX, respectively. Extracellular enzyme extracts from WB (E-PxWB) and BAB (E-PxBAB) cultures reached the highest xylanolytic activity after 48 h (6.15 ± 0.55 IUxyn/mL) and 144 h (3.93 ± 0.41 IUxyn/mL) of incubation, respectively. Proteomic analysis revealed the presence of xylanases belonging to the GH10, GH11 and GH30 families, with varying relative abundance depending on the substrate. We had previously expressed as recombinants and characterized PxXyn10A and PxXyn11B, that can act on all types of substituted and unsubstituted xylans. In this work, we expressed, purified and characterized the extracellular GH30, and studied its contribution to the deconstruction of xylans. PxXyn30_8 acted exclusively on glucuronoxylans (E.C. 3.2.1.136), as predicted by sequence identity. The hydrolysis of beechwood xylan (BX) produced a range of long acidic xylo-oligosaccharides (UXOS), confirming its relevance for specific glucuronoxylan hydrolysis. To assess its potential in biomass valorization, we tested the recombinant enzymes on BAB, the main residual solid waste stream of Tequila industry that generates 400 Kg of bagasse per ton of agave processed. After a mild alkali extrusion pre-treatment to open the fibers, BABe was formed by 47.5% cellulose, 21.2% xylan and 19.5% lignin. The combination of the xylanses to hydrolyze either BX or BABe had a synergic effect, with a marked increase in the release of the monosaccharide xilose (X1) and a change in the products profile when combining PxXyn30_8 with PxXyn10A or PxXyn11B. Finally, we analyzed the antioxidant capacity of the UXOS/XOS enzymatically produced from BABe by the ABTS+ radical discoloration assay. The UXOS produced by PxXyn30_8 (100 µg/mL) were more effective in reducing the ABTS+ radical, achieving 40% antioxidant activity, compared to the XOS/UXOS produced by PxXyn11B and PxXyn10A, individually or in combination with PxXyn30_8, which reached only up to 10%. These results suggest that MeGlcA decorations are key contributors to the bioactivity of UXOS. Overall, our results demonstrate the capacity of P. xylanivorans xylanases to valorize underutilized agroindustrial residues like BAB, yielding not only fermentable sugars but also bioactive XOS with antioxidant properties of interest in the food, feed and cosmetic industries.

Keywords: xylanases; xylo-oligosaccharides; paenibacillus xylanivorans; blue agave bagasse; antioxidant activity.

CHARCOAL FINES FROM ARGENTINE CHACO AS POTENTIAL BIOCHAR: CHEMICAL CHARACTERIZATION AND LEACHING RESPONSE

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The Argentine Chaco Region is known for its significant charcoal production, which generates a residue charcoal fines (a charcoal fraction with a diameter of ≤ 2 cm) that can be transformed into biochar. This study evaluates the chemical properties of three types of charcoal fines from the region: (M1) light/heavy mix, (M2) Prosopis ruscifolia, and (M3) Chaco province mix, as well as their response to washing, in order to explore their suitability as a soil amendment.

The original charcoal fines samples exhibited the following chemical characteristics: organic matter content (Calcination) between 65.5% and 86.2%, total nitrogen (Kjeldahl Method) from 0.97% to 1.47%, extractable phosphorus (Olsen Method) between 52.9 and 56.2 ppm, total potassium (Acid Digestion) from 8,238 to 9,000 ppm, and a cation exchange capacity (CEC) (sodium chloride at pH 2.5) between 19.0 and 36.3 mEq/100g. These findings indicate good fertility, but a limiting factor for agricultural use is the high salinity (EC suspension 1:5 between 2.14 and 2.93 dS/m) and, in one sample, a very high alkalinity (pH suspension 1:5 8.7), which could cause crop toxicity and affect micronutrient availability. To evaluate the leachates, a completely randomized experimental design with a total of 48 units was used, simulating precipitation events equivalent to 600, 450, 300, and 150 mm/year. The results revealed significant differences in ion mobility. The charcoal fines from sample (M2) showed the highest values for electrical conductivity, soluble potassium (Flame Photometry), soluble sodium (Flame Photometry), and salts in the leachates, indicating a greater release of these ions. This trend was decreasing with higher leaching volumes for (M2), unlike the other samples. Post-leaching char maintained salinity levels ranging from slightly to strongly saline (EC suspension 1:5 = 0.57 to 2.51 dS/m) and alkaline pH ranges (7.6 to 8.2). In conclusion, the charcoal fines from the Argentine Chaco possess a chemical composition rich in nutrients and organic matter, making them a promising material for biochar production. However, it is essential to address the challenges of their high salinity and alkalinity through specific washing or treatment strategies to mitigate their limiting effects for use as a soil amendment, especially in the alkaline or sodic-alkaline soils of the region. This study lays the groundwork for future research focused on optimizing processing, quality certification, and the potential valorization of both the biochar and its leachate by-products.

Keywords: charcoal; biochar; soil amendment; chaco region; leachate.

RESPIROMETRIC ASSAY IN SOILS COVERED WITH STRAW AND UNCOVERED AMENDED WITH BIODIGESTATE DERIVED FROM FOODSERVICE ORGANIC RESIDUES

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Anaerobic recycling of food waste by biodigestion generates biodigestate as a renewable nutrient source, yet agronomic success depends on the rate and extent to which the added organic matter decomposes in soil; consequently, this study quantified the decomposition kinetics of increasing biodigestate doses derived from food residues applied to a medium-textured soil left bare (s) or mulched with 12 t ha^{-1} of sugarcane straw (c). A respirometry assay adapted from CETESB method L6.350 (1990) was set up in respirometers containing 500 g of soil (bare or mulched) irrigated with the following treatments: T1s and T2c = control soil; T3s and T4c = 50 m^3 ha^{-1}; T5s and T6c = 60 m^3 ha^{-1}; T7s and T8c = 110 m^3 ha^{-1}; T9s and T10c = organomineral fertiliser (60 m^3 ha^{-1} + 30 kg N ha^{-1} + 54 kg K_2O ha^{-1}). Each respirometer contained a flask of NaOH solution of known concentration and was incubated at 25 ± 2 °C; the NaOH traps were replaced periodically over 63 d, and CO_2 evolved was determined by electrical conductivity. C-CO_2 data were fitted to a first-order kinetic model to estimate potentially mineralisable carbon (C_0), the fraction mineralised (C %), and half-life ($t_{1/2}$). The biodigestate contained 10.5% C, 0.33% N (C:N = 31:1), 51 mg L^{-1} oils + greases and 725 mg L^{-1} Na. In the bare control (T1s) C_0 was 2 925 mg, with 4% mineralised and $t_{1/2}$ = 11.5 d; adding straw alone (T2c) raised C_0 to 22 010 mg, doubled C % to 10.4% and shortened $t_{1/2}$ to 7.5 d, indicating rapid consumption of straw carbon. On bare soil, all biodigestate doses kept C_0 low (≈ 2 000–2 830 mg), with 2.1–2.5 % mineralised and $t_{1/2}$ ≈ 9–12 d (T3s, T5s, T7s), showing that the effluent supplies little readily metabolisable carbon; increasing the dose from 50 to 110 m^3 ha^{-1} did not raise C %, which remained < 3 %. When the same doses were applied over straw (T4c, T6c, T8c), C_0 increased to 8 460–11 827 mg and C % to 6.7–7.2 %, but $t_{1/2}$ lengthened to 22–30 d, reflecting interaction between labile straw carbon and recalcitrant biodigestate fractions. The organomineral fertiliser yielded C_0 = 1 751 mg and 1.9 % mineralised in bare soil (T9s) versus 8 128 mg and 6.3 % under straw (T10c), with intermediate $t_{1/2}$ = 19.8 d. Low degradation rates are attributed to the biodigestate's high oil/grease content, rendering it recalcitrant and difficult to decompose—an effect exacerbated by its long hydraulic retention time—despite an optimal C:N ratio; elevated Na may further inhibit microbial activity. Straw addition supplies relatively labile carbon, stimulating microbial activity and increasing both C_0 and degradation rate, yet even under mulch the observed rates remain low compared with those reported for biodigestate or vinasse from the sugar-alcohol industry, implying potential accumulation of recalcitrant material and/or depletion of native soil organic matter after successive applications, especially in bare soils.

Keywords: biofertiliser; food waste; sugarcane straw mulch; soil carbon; decomposition rate; decomposition velocity.

AMMONIA VOLATILIZATION IN BARE AND SUGARCANE-STRAW-MULCHED SOILS AMENDED WITH INCREASING RATES OF BIODIGESTATE DERIVED FROM FOOD WASTE

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Agricultural reuse of biodigestate fits within a circular-economy framework by returning nutrients and water to their biogeochemical cycles; however, surface application under climatic conditions conducive to ammonia release can trigger volatilization losses, diminishing agronomic efficiency and contributing to greenhouse-gas emissions. This study quantified NH_3-N losses from volatilization in medium-textured uncovered soil (s) or mulched (m) with 12 t ha^{-1} of sugarcane straw and amended with increasing doses of biodigestate derived from university foodservice residues, compared with urea fertilization. The experiment, carried out in a greenhouse during the hot–humid season, used 4 kg soil pots (0.014 % N) fitted with semi-open static collectors that housed two polyurethane foams (15 cm Ø × 2 cm) impregnated with 1.5 mol L^{-1} H_3PO_4 + 5 % glycerol: the inner foam captured NH_3 volatilised from treatments and the outer foam trapped atmospheric NH_3. A completely randomized design (three replicates) comprised: T1s and T2m, 120 kg N ha^{-1} as urea; T3s and T4m, 50 m³ ha^{-1} biodigestate; T5s and T6m, 60 m³ ha^{-1} biodigestate; T7s and T8m, 110 m³ ha^{-1} biodigestate; T9s and T10m, 60 m³ ha^{-1} biodigestate plus 30 kg P_2O_5 + 54 kg K_2O ha^{-1}. Foams were replaced 2, 5, 7, 9, 12, 16, 21 and 28 days after application, extracted with 400 mL deionized water and analysed colorimetrically for NH_4^+-N. Cumulative NH_3 volatilization rose rapidly after application, peaking between days 2 and 5, then slowed until stabilising on day 28. Uncovered soil amended with ure (T1) lost 1 539 mg collector^{-1} (48.9% of applied N), whereas straw cover (T2) limited losses to 996 mg (31.6%). With biodigestate at 50 m³ ha^{-1}, bare soil (T3) volatilized 1 908 mg (86.3%), but the same dose over straw (T4) dropped to 628 mg (28.4%). The 60 m³ ha^{-1} dose showed a similar pattern: 2 645 mg (100.2%) in T5 versus 1 476 mg (55.9%) in T6. The highest dose, 110 m³ ha^{-1}, generated the greatest losses—5 162 mg (104.3 %) in T7 and 4 079 mg (82.4 %) in T8. The organomineral treatment recorded 2 670 mg (101.1 %) in T9 and 2 907 mg (110.1 %) in T10. Percentages exceeding 100 % indicate that part of the volatilized N originated from mineralization of native soil ammonium (5.54 g N pot^{-1}). In every dose, straw mulch reduced NH_3 losses by 35–67 %, demonstrating that surface cover maintains moisture, dilutes available N and restricts NH_3 diffusion, thereby preserving biodigestate agronomic efficiency while mitigating atmospheric emissions.

Keywords: biofertilizer; nitrogen losses; straw-mulched systems.

MORPHOLOGICAL AND PRODUCTIVE RESPONSES OF MARANDU GRASS TO FERTILIZATION WITH GELATIN INDUSTRY SLUDGE AND ORGANOMINERAL FERTILIZER

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The quality of pastures has a direct influence on agricultural productivity, especially in cattle farming, where forage grasses represent the main source of animal feed. However, achieving good forage productivity remains a challenge for livestock farmers, particularly during drought periods. Proper management and efficient soil fertilization are key strategies to ensure high yields even under adverse conditions. In this context, the use of organic waste as fertilizer has proven to be a promising alternative. Among these residues, the sludge generated by the gelatin industry stands out as a potential source of nitrogen, which is essential for forage development. This study aimed to evaluate the morphological characteristics and productivity of Marandu grass (Brachiaria brizantha cv. Marandu) subjected to fertilization with different doses of gelatin sludge and organomineral fertilizer. The experiment was conducted in a greenhouse, in a completely randomized design, with five treatments and six replications. The treatments consisted of the application of gelatin sludge at doses of 100, 200, and 300 $m^3\ ha^{-1}$, one treatment with organomineral fertilization (sludge + urea), and a control (no application). Seeds were sown in pots with soil previously incubated with the respective treatments. Three harvests were performed at 30-day intervals, with reapplication of the treatments at the end of each cycle. Productivity was evaluated based on dry mass (PMST), while morphological characteristics were assessed through plant height (ALTPL) and the number of tillers (NPERF), both measured before each harvest. Data were subjected to analysis of variance ($p<0.05$), followed by regression analysis. The highest PMST and NPERF yields were observed in the organomineral treatment, while the control had the lowest values. Although PMST tended to increase with higher doses, the highest value was recorded at the 100 $m^3\ ha^{-1}$ dose. For plant height, the highest average was obtained at the 300 $m^3\ ha^{-1}$ dose and the lowest in the control. It is concluded that sludge from the gelatin industry has positive effects on the productivity and morphological characteristics of Marandu grass, representing a viable alternative for forage fertilization.

Keywords: organic waste; forage; agro-industrial waste.

LABILE CARBON CONTENT IN SOIL FERTILIZED WITH LIQUID SWINE WASTE IN THE BRAZILIAN CERRADO

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The expansion of pig farming has increased the generation of organic waste, especially liquid pig waste (LPW), which is rich in essential nutrients for agriculture, such as nitrogen (N), phosphorus (P), and zinc (Zn). Its controlled use can contribute to soil fertility and increase carbon stocks, thereby improving soil quality and mitigating climate change. However, inadequate management of this waste can cause significant environmental impacts due to its high pollution potential. Therefore, it is crucial that its application is carefully monitored and properly executed. In light of this, the present study aimed to evaluate the labile carbon (LC) content at different depths and in different areas in the municipality of Sorriso (MT), Brazil. Two areas were analyzed: one with a 10-year history of DLS (liquid swine slurry) application and another without application, covered with native Cerrado vegetation. Soil samples were collected at three depths: 0–0.05 m, 0.05–0.10 m, and 0.10–0.20 m, with four replicates at each layer. LC was determined by oxidation with $KMnO_4$. In the comparison between depths, the 0.05–0.10 m layer showed higher LC in the area with native vegetation. In the other analyzed depths (0–0.05 m and 0.10–0.20 m), no statistically significant differences were found. Furthermore, no significant differences were observed between the two evaluated areas. Therefore, the application of DLS did not result in a significant increase in LC in the soil.

Keywords: organic waste; pig effluents; soil conservation.

DIGESTATES DERIVED FROM CATTLE MANURE DIGESTION APPLIED TO AGRICULTURAL SOIL IN CÓRDOBA, ARGENTINA

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The high animal stocking density in Argentinian feedlots leads to the generation of large volumes of organic waste, requiring adequate management strategies. Anaerobic digestion (AD) enables the recovery of biogas while generating digestate as a byproduct. Although the regulatory framework in Córdoba Province allows the agricultural use of digestate, there is limited regional evidence regarding its impact on soil properties and crop performance. This study aimed to evaluate the effect of surface-applied bovine manure digestate at two nitrogen-based rates on soil chemical properties and wheat (Triticum aestivum) yield under rainfed conditions. The trial was conducted during the 2024 winter growing season in Sinsacate, Córdoba, on a Typic Haplustoll soil. Two digestate application rates were evaluated: D1 = 129.5 kg N ha^{-1} and D2 = 259 kg N ha^{-1} (59,000 and 118,000 L ha^{-1} of digestate, respectively), along with an untreated control (T). Plots measured 3 × 6 m and were arranged in a randomized complete block design with three replicates. Soil samples were collected from the 0–10 cm depth and analyzed for pH, electrical conductivity (EC), organic matter (OM), nitrate nitrogen (N-NO_3), extractable phosphorus (EP), and cations (Ca, Mg, K, Na). The chemical composition of the digestate was as follows: pH= 7.8, EC = 20 dS m^{-1}, total solids = 41.2 g kg^{-1}, total nitrogen = 2.2 g kg^{-1}, N-NO_3^-= 375 mg kg^{-1}, total phosphorus (TP)= 2.6 g kg^{-1}, Ca= 2,848 mg kg^{-1}, Mg= 931 mg kg^{-1}, K= 3,636 mg kg^{-1}, Na= 1,641 mg kg^{-1}. Significant differences were found between the control (T) and both D1 and D2 for all parameters. The pH was 7.0 in T, increasing to 7.3 in D1 and 7.4 in D2 (SD 0.3). EC in T was 0.13 dS m^{-1}; in D1 it doubled to 0.24 dS m^{-1}, and in D2 it was 230% higher than T (SD 0.08). This behavior is predictable given the high salt content of the digestate. OM also showed significant differences, being 29.6 g kg^{-1} in T and increasing by 6.5% in D1 and 13.5% in D2 (SD 0.2). N-NO_3 varied significantly among treatments, with 25.3 mg kg^{-1} in T and increasing to 45.4 and 53.6 mg kg^{-1} in D1 and D2, respectively (SD 16.8). EP in T was 79.3 mg kg^{-1}, increasing to 87.2 mg kg^{-1} in D1 and 91.8 mg kg^{-1} in D2 (SD 8.2). Ca, Mg, and K did not show significant differences among treatments, while Na increased from 2.4 ppm in T to 4 ppm in D1 and 4.4 ppm in D2 (SD 1.11). Wheat yield was 6,751 kg ha^{-1} in the control, with a statistically significant decrease in D1 and D2 (5,535 and 5,573 kg ha^{-1}, respectively; SD 653). The use of digestate improved soil fertility but requires monitoring of EC and Na to prevent salinity and sodicity problems in soils and phytotoxicity in crops. Future applications should consider EP levels and continue analyzing the cumulative effects of the measured parameters on soils in upcoming agricultural seasons and in different extensive crops.

Keywords: livestock waste; soil chemical properties; agricultural soil; extensive crop; bio-digestate.

AGRONOMIC USE OF DAIRY SLURRY IN SOUTHEASTERN LA PAMPA

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The intensification and concentration of production in dairy systems leads to an increase in the generation and accumulation of slurry. Slurry, a mixture of excrement (fecal matter and urine) and feed scraps mixed with water from milking facilities, has been considered waste and a problem for producers. This waste can be a valuable input for agricultural production, preventing pollution, increasing forage production, and improving soil properties. Sixty-seven percent of the dairy farms, which contain 63% of the dairy herd and produce 114 million liters of milk annually, are located in southeastern La Pampa. This basin presents specific conditions in terms of its edaphic and climatic limitations: a shallow soil profile due to the presence of a layer of gravel, low nutrient content, high susceptibility to erosion, scarce rainfall, and periods of strong winds. In these dairy systems, there has been growing interest among producers in adopting the agronomic use of dairy slurry. The objective of this study was to evaluate forage production of corn crops under the application of dairy slurry as a source of nutrients (equivalent to nitrogen) and nitrate contamination in the soil in the southeast of La Pampa province. The trial was conducted on a pastoral dairy farm. The slurry generated at the milking facilities is stored in an artificial lagoon for later agronomic use. The slurry was chemically characterized, and application rates were calculated based on the nitrogen (N) content. Prior to applying the slurry, soil samples were taken to determine texture, current pH, extractable phosphorus, electrical conductivity, and nitrates. Slurry was applied to corn after planting in 2.5 x 30 m plots. Two slurry application rates were used: 30 kg N/ha and 60 kg N/ha, and a control, each one considered a treatment. Treatments were assigned using a completely randomized block design with three replicates. Three replicates were used per treatment. Dry matter was estimated in each plot by cutting the aboveground parts of the corn plants in triplicate, prior to silage. In addition, soil samples were taken at different depths to determine pH, EC, and nitrates. Results were analyzed using ANOVA and differences in means using the Tukey test with the statistical software InfoStat. Forage production in the treatments with slurry application was higher than in the control, and they presented statistical differences with the control, but not between them. Soil nitrate content was higher before planting; it varied very little between treatments, with the highest values between 0 and 10 cm depth. The agronomic use of dairy slurry contributes to the circular economy of dairy systems, since such as waste product like slurry, is converted into organic fertilizer (input).

Keywords: dairy systems; slurry; forage production; circular economy.

VALORIZATION FOREST BIOMASS ASHES: EXPLORATORY STUDIES

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There is a growing global need to manage forest biomass ash. Forest biomass is the organic matter from forest resources: forest plantations, native forests and forest industry byproducts (chips, sawdust, pellets, etc.). It is burned in boilers used in various industries: forestry, food, textiles and electric power, generating the solid waste known as ash. In Corrientes, Argentina, considerable forest biomass ash volumes are generated in various industries, with forest biomass power plants generating the largest volumes. This waste has potential for valorization into new byproducts. The aim was to conduct exploratory studies for forest biomass ash valorization. An exploratory literature review was conducted on forest biomass ash characteristics, its most common uses worldwide and regulations governing its use. Physicochemical characterization three industries ash in Corrientes was carried out: food, textiles and electric power. According to bibliography, ash is composed mineral salts and unburned carbon particles and other organic products resulting from the incomplete combustion of biomass. It is characterized by high pH, high electrical conductivity (EC), and good calcium oxide content. These characteristics were reported to vary greatly depending on the source biomass, the type of boiler and the combustion process, which conditions its use. This is consistent with our results, finding variations in pH (8.7–11.5), EC (0.12–5.03 dS m-1), Total Organic Carbon (0.19–22%) and calcium content (1.16–17%). Ash was proposed as alternative for construction, brick production and road consolidation. Due to its nutrient content, its reuse as mineral fertilizer (direct use) or organic fertilizer (composting) was proposed. It was also proposed as an amendment to correct low pH. In Europe, ash is included in waste regulations, establishing technical parameters for its recovery. In Argentina, its final disposal is currently in a landfill and there are no regulations to assist with its recovery. It is necessary to advance the study of their potential uses, validating them for our conditions and providing reference technical information. At INTA Bella Vista Agricultural Experimental Station (EEA), experimental modules were initiated exploring several proposals for valorizing ash with simple and accessible solutions for various users. These experimental modules are currently underway. 1) Initial eucalyptus fertilization experimental module, using ash directly as mineral fertilizer. Moderate doses (300 g plant-1) were used, with the addition of mineral N (absent in the ash due to volatilization). 2) Composting experimental module with sawdust and farmyard manure, using up to 20% ash. 3) Tomato experimental module in containers, testing 100% ash as substrate (mainly unburned). 4) Exploratory test for obtaining activated carbon. it follows there is not only one alternative to valorize the entire ash volume generated in industries, especially due to its characteristics and variability. Any ash recovery project will require knowledge of the process that produces it, the type of ash obtained, and its stability in time. The management and disposal of the ash will be determined by the possible potentially toxic elements presence, determined by reference to current regulations on hazardous waste. Further study and validation of recovery alternatives is necessary.

Keywords: bioinputs; wood ash; waste; forest industry.

SYNTHESIS OF A NIFE-LDH/CARBON QUANTUM DOT COMPOSITE FROM CASHEW LEAVES FOR THE REMOVAL OF ERYTHROSINE DYE

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The generation of waste is growing alarmingly due to human actions, such as industrial, agricultural, hospital, extractive activities, among others. In this context, the incorrect disposal of these products can generate some serious environmental problems, such as soil and water contamination, so it is necessary to have sustainability. In this context, in several regions of Brazil there is a traditional practice that is related to family farming and extractive activity, which is the cashew culture, in the Northeast of the country, where the semi-arid climate favors the development of cashew trees, this is a practice of great prominence. This activity has economic, social and environmental importance, involving both the harvesting of native cashew (plant extractivism) and cultivation in commercial plantations. On the other hand, the production of cashew generates a large amount of waste, which can cause environmental impacts when not correctly used. The main waste is the shell of the cashew nut, the pomace of the pseudofruit and discarded leaves, branches and fruits. To promote the circular economy, the present work proposes to use the residues of cashew pruning, specifically the leaves, to obtain quantum carbon dots, which will be supported by NiFe layered double hydroxides, enabling the synthesis of a composite nanomaterial to verify the viability as an adsorbent for aqueous remediation. The characteristics of the composite were obtained through the pH at the zero point of charge (pHpzc), FTIR, XRD, SEM, and TG analyses. The material produced was used as an adsorbent for the treatment of water contaminated with the red pollutant erythrosine, which is an artificial dye used in the food, pharmaceutical and cosmetic industries. Despite the diversification of applications, red erythrosine has a polluting character and is considered a potentially toxic substance, for this reason it is restricted for use in most countries of the European Union, for example. The adsorption kinetics were performed at 25o C, and with three different concentrations 10, 20 and 40 mg/L, reaching adsorption capacities of 51, 103 and 163 mg/g, respectively, reaching the equilibrium at 6 hours.

Keywords: environmental nanotechnology; circular economy; agro-industrial biowaste; functional hybrid materials; emerging contaminants.

EVALUATION OF BIOINPUTS ON THE YIELD OF EARLY MELON (*CUCUMIS MELO L.*) UNDER NEMATODE INFESTATION IN SEMI-FORCED SYSTEMS IN SANTIAGO DEL ESTERO

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Horticultural production in Santiago del Estero, particularly in the irrigated area of the Dulce River, plays a key role in the regional economy. Within this context, early melon cultivation stands out with a commercial volume of 730 tons sold at the Buenos Aires Central Market in 2024. However, its development is seriously threatened by plant-parasitic nematodes, mainly Meloidogyne spp. and Pratylenchus spp., which damage the root system and reduce both yield and fruit quality. As an alternative to synthetic agrochemicals, bioinputs biological products such as microorganisms, plant extracts, or biochemical compounds are emerging as sustainable tools for pest and disease management, while also improving crop quality and reducing environmental impact. Nevertheless, their effectiveness in semi-forced melon cropping systems has not yet been evaluated in this region. The objective of this study was to assess the effect of different bioinputs on the yield of early melon under high nematode infestation. The experiment included the following treatments: Raissan® (a chitosan-based formulation) and Supermagro (composed of agricultural residues, plant extracts, and by-products from the sugar, dairy, and meat industries), compared to an untreated control. Applications were carried out via drench at a rate of 2 L ha^{-1}. Transplanting took place on July 7, with the first application at 60 days and a second application 15 days later. Yields ranged between 42000 and 52000 kg ha^{-1}, with no statistically significant differences between treatments. However, the Supermagro treatment showed a positive trend with a 3.27% increase compared to the control, equivalent to approximately 1000 additional boxes per hectare. These results support the potential of bioinputs as viable tools in semi-forced horticultural systems, promoting more sustainable production. Further research under different agroecological conditions is recommended to validate their performance on a larger scale.

Keywords: early melon; bioinputs; plant parasitic nematodes; semi-forced systems; horticultural yield.

INTEGRATED SOIL AMENDMENT THROUGH THE APPLICATION OF BIOCHARS DERIVED FROM SOLID DIGESTATES

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The valorisation of digestates through solid–liquid separation followed by moderate pyrolysis of the solid fraction provides a circular strategy for reducing waste, sequestering carbon, and returning nutrients to the soil. This study characterised three biochars produced at 350 °C from digestates obtained by codigesting pig slurry with (1) energy-crop silage, (2) cover-crop silage, and (3) agroindustrial residues, and assessed whether co-application of the solid digestate (D) and its derived biochar (B) improves fertility, stabilises carbon, and modulates nitrogen dynamics in a typical Haplustoll. Solid fractions were dried, pyrolysed for 120 min at 350 °C, and analysed for pH, electrical conductivity (EC), total carbon (TC), total nitrogen (TN), nutrients, NMR spectra, and SEM. All biochars contained > 20 % TC, had pH 10.8-11.2, and exhibited markedly lower EC than their parent digestates. Pyrolysis reduced volatile matter by 51-56 % and phenolic compounds by up to 41 %. The factorial experiment included D at 1 % and 5 % w/w, B at 1 % and 5 %, D + B blends (1 % + 1 % and 5 % + 1 %), and an untreated control. Pots (500 cm^3) were incubated for 100 days at 25 °C and 60 % water-holding capacity. Post-incubation measurements comprised pH, EC, total organic carbon (TOC), humification degree (HD), total ammoniacal nitrogen (TAN), nitrates, and microbial respiration; data were evaluated by ANOVA and principal component analysis (PCA). Biochars contained 22.8-25.4 % TC and 1.05-1.87 % TN; the material derived from agroindustrial residues showed the greatest N retention and P-Ca enrichment. SEM revealed more numerous and larger pores in B350-1, while NMR indicated a predominance of aliphatic groups in all samples and higher aromaticity in B350-3. After 100 days, digestate only treatments increased EC and accelerated mineralisation, with TOC losses of 22-28 % and TAN-to-nitrate conversion exceeding 40 %. Biochar alone stabilised carbon (6-9 % TOC loss), kept HD < 3, and limited nitrification (10-20 % TAN decrease). Blends SDB1 and SDB2 produced intermediate TOC losses (11-14 %) and reduced TAN (25-30 %) and nitrate (20-28 %) concentrations without raising pH or EC. PCA explained 85 % of the variance, grouping the mixed treatments in an intermediate cluster characterised by chemical balance and nutrient retention. Coapplication of digestate and biochar therefore functions as an effective soil amendment: it does not markedly increase salinity, gradually retains nitrogen, stabilises carbon, and enhances microbial activity, thereby reducing environmental risks. Blends SDB1-SDB2 achieved the best overall balance, while substrate origin influenced the soil response. Fieldscale validation and a technoeconomic assessment are recommended before regional adoption.

Keywords: biochar; digestate; soil amendment; agricultural decarbonization; nutrient retention.

COMPOSTING AND UTILIZATION OF BIOSOLIDS FROM PRIMARY SEWAGE TREATMENT IN MAR DEL PLATA

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Mar del Plata, the main coastal city in Argentina, has a stable population of 667,082 inhabitants (INDEC 2022) and provides 97% coverage of water and sewer services within the urban area. All of the city's wastewater ($3m^3/s$) is conveyed to the Wastewater Treatment Plant (EDAR), where preliminary treatment includes coarse screening (4 cm), fine screening (1 cm), grit and grease removal, and rotary drum screens with 3 mm mesh. The treated effluent is discharged into the sea through a 4.1 km long submarine outfall. The solids retained in the 3 mm screens (approximately 130 m^3 per month) are treated at the composting facility located on the same site, producing a Class A organic amendment (MAyDS Resolution 410/2018). The sewer system of Mar del Plata collects pre-treated domestic and industrial effluents, mainly from the fishing and food industries. The resulting raw sludge is non-compacted, heterogeneous, with a high organic matter content and very low concentration of heavy metals. As a by-product of primary treatment, it can be composted without the need for structural bulking agents. Initially, the raw sludge is laid in trapezoidal windrows on concrete platforms equipped with leachate collection. During the mesophilic and thermophilic phases, temperature and humidity are monitored daily. Operational tasks, carried out as required by the process, include maintaining the critical mass, oxygenation through mechanical turning (using a windrow turner or front loader to aerate the base), and watering. This ensures stable and prolonged thermophilic conditions regardless of weather, allowing 100% of the windrows to meet the regulatory duration for this phase year-round. Once the thermophilic phase is complete, the windrows are moved to natural ground where the curing stage is carried out. After a period of 180 to 200 days, the material reaches the stabilization and sanitation parameters required by MAyDS Resolution 410/2018, resulting in a Class A biosolid with physical characteristics similar to humus in terms of smell, color, and texture. The project aims to valorize this by-product by transforming it into a suitable input for use as an organic amendment in silviculture. It is currently used by municipal nurseries and as final cover for closed landfill cells at the General Pueyrredón solid waste disposal site. Although it meets Class A product standards, further studies are planned to evaluate the presence and degradation of pharmaceutical residues, antibiotic-resistant bacteria, and microplastics. The impact of the compost on plant species development is also under investigation. Simultaneously, the Municipal Tree Department is conducting trials to assess germination capacity and seedling growth using this amendment. This project represents a sustainable and replicable alternative for biosolid management in medium-sized cities, integrating principles of circular economy and environmental stewardship.

Acknowledgments: To the technical staff of the Obras Sanitarias MDP laboratories for carrying out the analyses, and to President Carlos Kats for his support.

Keywords: effluents; biosolids; composting; organic amendment; waste valorization.

FROM WASTE TO ACTIVATED CARBON: ENERGY AND ENVIRONMENTAL APPLICATIONS

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As the world's population grows, so does food consumption and demand. Consequently, several food and beverage companies have experienced significant growth across all regions to meet the increasing demand. In recent years, the reuse of agricultural waste and agro-industrial by-products has sparked the interest of researchers. Fruit peels, corncobs, husks and stems, pruning sheaves, and bagasse, among others, are examples of lignocellulosic residues produced by agricultural and agro-industrial processes. Cellulose (35%–50%), lignin (25%–30%), and hemicellulose (25%–30%) are the main components of these wastes. Most of them are not utilized or treated, causing harm to people, animals, and the environment. However, due to their composition they can be used to manufacture several products with high added value, while reducing production costs. Activated carbons (ACs) are materials with high porosity and surface area that are often used as pollutant adsorbents, supercapacitor electrode materials, and catalyst supports, among others. A widely investigated alternative for sustainable ACs production is the use of wastes, including agricultural, agroindustrial, and household waste. This work presents our advances in the synthesis of activated carbons from various wastes: brewer's waste, yerba mate, cannabis stems and leaves, flour mill residue, wheat and corn stover, olive pruning, and olive oil production waste. Different synthesis and activation methodologies were evaluated, analyzing the variables involved in the processes, such as carbonization temperature, type of activating agent, impregnation ratio, activation temperature, and time. The developed activated carbons were evaluated for environmental and energy applications. The adsorption of heavy metals, CO2, and 2,4-D was studied, obtaining excellent removal capacities, even greater than those of commercial activated carbon. The highest removal capacities for CO2 were found with yerba mate ACs (173.48 gCO2/gAC) and alperujo (166.1 gCO2/gAC), for Hg with yerba mate ACs (432.33 gHg/gAC) and brewer's bagasse (380.09 gHg/gAC), for As with yerba mate ACs (0.73 gAs/gAC) and wheat stubble (0.32 gAs/gAC), and for 2,4-D with wheat stubble ACs (346.47 g2,4-D/gAC) and brewer's bagasse (243.27 g2,4-D/gAC). Electrochemical techniques were used to analyze the energy storage properties of the activated carbons for their insertion as electrode materials in supercapacitors. For this purpose, tests were performed in three- and two-electrode cells in aqueous electrolytes. In three-electrode cells, maximum capacitances of 351.5 F/g, 337.1 F/g, and 272.3 F/g were obtained for activated carbons derived from brewer's bagasse, olive pruning, and yerba mate residue, respectively. Finally, the best pouch-type supercapacitors with electrolytic membrane were the ACs from olive pruning (53.3 F/g) and cannabis residues (37.0 F/g), and the coin-cell type ACs were the yerba mate (30.32 F/g) and cannabis residues (17.4 F/g), comparable to and even superior to those available on the market. This work highlights a sustainable and efficient pathway to valorize agro-industrial residues, producing low-cost activated carbons with competitive performance for environmental remediation and energy storage applications.

Keywords: lignocellulosic wastes; activated carbons; adsorption; energy storage.

ROSEHIP (ROSA RUBIGINOSA): BIOGAS POTENTIAL OF PULPING RESIDUES IN TWO DIFFERENT PRESENTATIONS

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In NW Chubut, wild rosehip (Rosa rubiginosa) is harvested for the candy industry. A process involving heat and mechanical action separates the pulp for candy production, leaving a residue of seeds, traces of pulp, skin, and leaves. Based on sampling, it was estimated that 50.63% of the fruit is seeds. The residual material is used in pig feed, without utilizing other alternatives. This study analyzes the biogas production potential of the pulping residue (without intermediate uses), as obtained from the process – RE- (mainly whole seeds) and finely ground material in a Willey mill with a 2-millimeter (mm) mesh -RM-. Six treatments were carried out in triplicate: control (cellulose); blank (inoculum); and the two substrate presentations in two SV substrate/SV inoculum ratios of 1:2 and 1:3 (RM1:2, RM1:3, RE1:2, and RE1:3). Caramel-colored glass flasks with a capacity of 250 mL were used, containing between 3.8 and 5.6 g of rosehip and 80 g of inoculum. The inoculum was extracted from a 4,500 m^3 mesophilic CSTR biodigester, fed primarily with corn husks, corn cobs, and hen manure. The loaded flasks were sealed tightly with a septum plug and a metal cap. They were then purged with inert gas (N2) to remove all O2. To do this, a syringe was inserted into the septum to inject N2 and another to release O2 from the flasks. This procedure was carried out for 1 minute. Finally, they were placed in an incubator at 35°C. Biogas production was assessed for 42 days according to the methodology of Justesen, C. G. et al. (2019), by displacing an acidified solution containing methyl red indicator in a 1000 mL glass scrubber. The displaced liquid and the bottle were weighed (in this case to estimate mass losses between measurements and correct for biogas losses). Biogas production for each treatment was corrected by subtracting the relative amount of biogas produced by the inoculum and standardized to 0 °C and 1 atmosphere of pressure. The data were analyzed using the Tuckey test ($p < 0.01$). Among the results and conclusions, the following can be stated:

- Crushed seeds obtained a significant higher average potential biogas production volume: 249.77 mL/g SV (RM1:2), 272.05 mL/g SV (RM1:3), 112.58 mL/g SV (RE1:2), and 115.51 mL/g SV (RE1:3). Crushed seeds produced between 2.22 and 2.35 times more biogas than whole seeds, making it recommended to pre-grind seeds before incorporating them into a biodigester.
- There was no significant difference between the SV substrate/SV inoculum ratios in RE (yes in RM), so other ratios could be explored in RE that allow adjusting the minimum inoculum required to provide greater space for the digester to be used.
- This confirms the findings of Osojnik Črnivec et al. (2014), that by mechanically exposing the cellular content, the degradation rate can be increased, surely by breaking the lignocellulosic barrier of the seed surface and exposing the polysaccharides to the hydrolysis process to simple compounds.

Keywords: rosehip; biodigestion; biodigester; biogas.

EVALUATION OF COMPOST PELLETS PRODUCED FROM SUGARCANE INDUSTRY WASTE ON OAT PRODUCTION UNDER GREENHOUSE CONDITIONS

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In Uruguay, large amounts of compost are produced annually from residues generated during sugarcane industrial processing. This compost is typically applied using specialized machinery, which adds complexity to its management. Conditioning compost into pellet form would facilitate its application, allowing the use of standard fertilization equipment. This study aims to agronomically evaluate compost pellets compared to traditional compost at different application rates. Additionally, to improve their efficiency, the incorporation of plant growth-promoting microorganisms (commercial formulations of Azospirillum brasilense and Bacillus amyloliquefaciens) was evaluated in both compost types. The materials were characterized, and a pot experiment was conducted in a greenhouse. Two application rates (doses equivalent to 20 and 40 Mg ha^{-1}) of each material were applied, along with commercial fertilizers to standardize nutrient availability for plants. A control treatment without any amendment was also included. Oats were sown, and after three months of growth, the aboveground biomass was harvested. Plant tissue was analyzed for total contents of N, P, Ca, Mg, K, Na, Cu, Fe, Mn, and Zn. Soil analyses included pH and electrical conductivity (EC), as well as mineral N content (NO_3^--N and NH_4^+-N), available phosphorus (Bray 1), and exchangeable cations (Ca, Mg, K, Na, and Al).The application of traditional compost did not have a positive effect on aboveground biomass production, likely due to limited N availability for the crop. In contrast, compost pellets resulted in greater biomass and N uptake than the control. In the short term, the main nutrient contribution of compost is an increase in P availability. Compost pellet treatment led to lower P uptake by oats, as well as lower residual soil P levels compared to traditional compost, suggesting that pelletized compost released P more slowly. The application of microorganisms had a greater effect on traditional compost than on compost pellets, likely due to increased nitrogen availability from organic sources. No differences were observed between the two microbial formulations. Although it can be concluded that pelletized compost did not hinder nutrient release or plant growth, the fact that the experiment was conducted under greenhouse conditions and over a limited period restricts the scope of these conclusions. Therefore, it would be important to validate these results under field conditions.

Keywords: compost; sugarcane; uruguay; compost pellet; nutrients.

POTENTIAL USE OF AGARICUS SUBRUFESCENS SPENT SUBSTRATE FOR DYE REMOVAL FROM AQUEOUS SOLUTIONS

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Agaricus subrufescens is an edible mushroom cultivated primarily for its medicinal properties and with potential for diverse biotechnological applications. Its cultivation on agro-industrial residues, such as sunflower seed hulls, contributes to the principles of the circular economy by adding value to agricultural by-products. After mushroom cultivation, these substrates also become residual materials with potential for further reuse. Two types of sunflower seed hull-based substrates were compared: one used directly for A. subrufescens cultivation, and another previously used for Pleurotus pulmonarius cultivation before supporting A. subrufescens. Both substrates were sterilized, inoculated with 5% (w/w) grain spawn, incubated for 40 days, and fructified for 100 days at 25–30 °C and 80–90% relative humidity. After harvest, the spent substrates were homogenized and used in batch dye removal assays. Three synthetic dyes—Malachite Green, Phenol Red, and Aniline Blue—were tested at an initial concentration of 0.25 mM. For each assay, 1 g of spent substrate was incubated in 10 mL of dye solution. Dye concentration was monitored by UV-Vis spectrophotometry at specific wavelengths over 24 to 96 hours. Dye removal (%) was calculated as: $[(A_0 - A_t - A\_blank)/A_0] \times 100$, where A_0 is the initial absorbance, A_t is the absorbance at time t, and A_blank is the absorbance of the corresponding control. All experiments were performed in triplicate, and results were analyzed using one-way ANOVA. Both Aniline Blue and Malachite Green showed significant removal after 24 hours, exceeding 70%, with Malachite Green reaching maximum removal of 94.7%. Most dye was removed within the first hour, after which removal leveled off. Malachite Green removal was significantly higher using the substrate previously supporting P. pulmonarius cultivation compared to original sunflower seed hulls (89.9%). Phenol Red exhibited a distinct removal profile with slower, gradual removal over 96 hours, reaching 53.2% for the residual P. pulmonarius substrate and 29.6% for original sunflower seed hulls. The results suggest that dye removal efficiency and mechanisms are influenced by both dye chemical nature and substrate origin. Malachite Green and Aniline Blue were rapidly removed, consistent with physical or chemical adsorption interactions. Phenol Red showed progressive removal over 96 hours, indicative of different mechanisms, possibly involving extracellular enzymes such as laccases or peroxidases secreted during mushroom growth. The superior performance of substrates previously used for P. ostreatus cultivation, particularly for Malachite Green and Phenol Red removal, may result from structural or chemical modifications induced by the initial fungal cycle—potentially increasing porosity or introducing functional groups that enhance adsorption—as well as from enzymes secreted by P. pulmonarius during its growth. This study demonstrates the potential of spent A. subrufescens substrates for dye removal, illustrating how sequential fungal cultivation allows agro-industrial residues to be reused at multiple stages, including for dye removal, within a circular economy context.

Keywords: aniline blue; circular economy; malachite green; phenol red; sunflower seed hulls.

CHARACTERIZATION AND PRODUCTION OF XYLANASE XYL10E AND POTENTIAL APPLICATIONS OF XYLO-OLIGOSACCHARIDES FROM HYDROLYZED PRETREATED SORGHUM BICOLOR BAGASSE

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Termites have evolved highly efficient strategies for the degradation of lignocellulosic substrates through the combined action of endogenous enzymes, symbiont-derived enzymes, and mechanical processing. Xylanases are enzymes of significant industrial relevance due to their ability to degrade hemicellulosic biomass and generate value-added products such as xylo-oligosaccharides (XOs). In this study, we heterologously expressed and biochemically characterized two novel glycoside hydrolase family 10 (GH10) enzymes, Xyl10C and Xyl10E, identified from a metagenomic analysis of the termite gut microbiome. Furthermore, the yield of Xyl10E at larger scale was also performed to enable further functional studies. Additionally, XOs derived from the enzymatic hydrolysis of pretreated Sorghum bicolor bagasse (SBB KOH) were evaluated, focusing on their antioxidant capacity and prebiotic potential. Both enzymes exhibited activity on beechwood xylan, while Xyl10E also acted on barley β-glucan. Xyl10C showed optimal activity at pH 7.0–8.0 and 50–60 °C, whereas Xyl10E was active over a broader pH range (5.0–10.0) at 50 °C. After 8 h at 40 °C, Xyl10C and Xyl10E retained 85% and 70% of their activity, respectively. Xyl10C activity was enhanced by 5 M NaCl and inhibited by SDS and β-mercaptoethanol, while Xyl10E activity was inhibited by $MnSO_4$, NaCl, and SDS. Both enzymes hydrolyzed SBB KOH, releasing primarily xylose and xylobiose. Furthermore, Xyl10E production was optimized by scaling up the culture volume and testing different media (Luria Broth and Terrific Broth) in 2-liter Erlenmeyer flasks, both with and without deflectors. The highest yield (135.66 mg/mL) was obtained using Terrific Broth in baffled Erlenmeyer flasks. Xyl10E exhibited a specific activity of 43 U/mg on pretreated SBB KOH. For XOs production, 60 U of enzyme were incubated with 10% (w/v) SBB KOH at 40 °C for 6 h, and the hydrolysate was concentrated by centrifugal filtration (5 kDa cutoff). XOs were quantified using 3,5-dinitrosalicylic acid (DNS) with xylose as the standard. Additionally, product profiles were analyzed by thin-layer chromatography (TLC) using standard XOs, identifying mainly xylobiose, and xylotriose, xylotetraose, xylopentaose. The total yield, expressed as xylose equivalents, was 40 mg/mL. The antioxidant capacity of XOs was evaluated using DPPH and ABTS radical scavenging assays, with Trolox as a positive control. Both methods demonstrated a concentration-dependent increase in antioxidant capacity. Additionally, the prebiotic effects of XOs were assessed using the prebiotic strains Ligilactobacillus murinus CRL1695 and Ligilactobacillus salivarius CRL1702, obtained from CERELA. A preliminary assessment showed increased bacterial growth in the presence of XOs according to concentration, suggesting their potential as prebiotics. Overall, the results indicate successful enhancement of Xyl10E production at larger scale and demonstrate promising functional applications of XOs obtained from the hydrolysis of Sorghum bicolor bagasse.

Keywords: xylanase – xylo-oligosaccharides – biotechnological applications.

SHORT-TERM RESPONSE OF FORAGE CROPS TO ORGANIC MANURE APPLICATION IN AN IRRIGATED SILVOPASTORAL GOAT SYSTEM IN A SEMI-ARID ENVIRONMENT

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In agricultural systems located in semi-arid regions under irrigation, the search for sustainable strategies to improve forage productivity has gained increasing relevance. Among the most widely adopted practices is the use of manures as organic fertilizers, due to their potential to enhance crop productivity. However, their effectiveness varies according to the type of manure, storage duration, and edaphoclimatic conditions, raising questions about their actual productive impact in integrated forage systems. Despite their widespread use, experimental evidence on the effects of different types of manure on forage production under these conditions remains limited, representing a constraint for the development of sustainable management strategies adapted to such systems. This study aimed to evaluate the effect of goat manure (with different storage durations) and poultry litter on the total aboveground dry matter yield of three forage crops (triticale, vetch, and barley) sown in a goat silvopastoral system with an intensive forage production area under irrigation. The trial was conducted at the Francisco Cantos experimental station of INTA EEA Santiago del Estero (28°01′11.07″ S; 64°14′20.36″ W), Silípica Department, Santiago del Estero, Argentina. Four treatments were evaluated: T0 (control, no manure), T1 (poultry litter, PL), T2 (aged goat manure, AGM, stored >1 year), and T3 (fresh goat manure, FGM, stored for 6 months). Both manures and soil were physico-chemically characterized before application. A single manure dose of 5 $t \cdot ha^{-1}$ was broadcasted on October 10, 2023, and incorporated using a light harrow. A completely randomized design (CRD) with three replicates per treatment was used, totaling 12 plots of 144 m^2 each. Crops were sown on March 18, 2024, in alternating rows of triticale (× Triticosecale Wittmack, INTA Molle), vetch (Vicia villosa), and barley (Hordeum vulgare, Guadalupe INTA), after irrigation. Total aboveground dry matter yield under goat manure treatments (T2 and T3) was significantly lower than both the control (13.123 $kg \cdot ha^{-1}$) and poultry litter (12.099,9 $kg \cdot ha^{-1}$). Triticale and barley showed no significant differences between treatments, with average yields of 5.864,9 and 3.761 $kg \cdot ha^{-1}$, respectively. In contrast, vetch was the most sensitive species to fertilization type: the poultry litter treatment (T1) produced 1.946,3 $kg \cdot ha^{-1}$, outperforming the goat manure treatments but remaining below the control yield (2.669,8 $kg \cdot ha^{-1}$). In the short term, the application of organic manures did not enhance aboveground dry matter yield in the evaluated forage crops under irrigated semi-arid conditions. However, species-specific responses were observed depending on the manure type. These results highlight the need for further medium- and long-term studies assessing not only productivity but also cumulative effects on soil quality and the forage system as a whole.

Keywords: manure; productivity; triticale–vetch–barley.

EFFECT OF ORGANIC AND INORGANIC NITROGEN SOURCES ON LETTUCE

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Nitrogen is essential for crop development and yield. This study aimed to evaluate the effect of the nitrogen source origin on lettuce irrigated with two water qualities in two soils from La Pampa. The experiment was conducted in pots with five randomized replications over four consecutive cycles (2020 and 2021). The soils from La Pampa that were used were one sandy and the other loamy-sandy. Fertilization treatments, expressed in kg ha^{-1} of urea:organic manure, were 100Ni (100:0) and 100No+i (40:60), adjusted to provide 100 kg N ha^{-1}, and applied before transplanting lettuce in the first and third cycles. Irrigation treatments consisted of low-salinity water with electrical conductivity (EC) of 1 dS m^{-1} and higher-salinity water with EC of 2 dS m^{-1}. The organic manure was made from biotransformed residues based on onion waste and organic cow manure, while urea was used as the synthetic nitrogen source. Dry matter of roots (RDM), shoots (SDM), and total dry matter (TDM) were quantified, along with water use efficiency (WUE, kg DM ha^{-1} mm^{-1}) and nitrogen use efficiency (NUE, kg N ha^{-1}). Data were analyzed using the statistical software Infostat. A significant interaction was found between soil types, so they were analyzed separately ($p \leq 0.05$). In sandy soil, TDM averaged 876 kg ha^{-1} with no significant differences between nitrogen sources. The highest TDM value was 1085 kg ha^{-1}, found in treatments irrigated with water of 1 dS m^{-1} EC, while the lowest value was 667 kg ha^{-1} in treatments irrigated with 2 dS m^{-1} EC water, with statistically significant differences. Additionally, in 100No+i treatments, WUE and NUE were 38% higher under 1 dS m^{-1} EC water compared to 2 dS m^{-1}. In the loamy sand soil, no significant differences were found between organic and inorganic nitrogen sources. TDM averaged 694 kg ha^{-1}, with a maximum of 917 kg ha^{-1} under 1 dS m^{-1} irrigation and a minimum of 472 kg ha^{-1} under 2 dS m^{-1} irrigation, with significant differences. In this finer-textured soil, a 48% increase in efficiency was observed when a higher proportion of organic manure was used. Although no significant differences were found between organic and inorganic nitrogen sources in either soil, organic manure showed good performance in terms of efficiency and yield compared to urea-only fertilization, especially in mitigating the negative effects of saline water (2 dS m^{-1}). Despite the need for mineralization before plant uptake, organic manure demonstrated their potential as a sustainable alternative for intensive production systems.

Keywords: keywords: organic manure; water quality; irrigation; soil texture.

WHEY PERMEATE AS CARBON SOURCE FOR BIOPLASTIC PRODUCTION, USING RECOMBINANT MICROORGANISMS

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Whey is the main byproduct of cheese production. It is estimated that 5,000,000 tons of liquid whey are produced annually in the country, of which 77% is utilized through different technological processes for the production of powdered food ingredients. Among these is whey protein concentrate, which represents 36% of the total volume. During this process, a liquid fraction called whey permeate is obtained, rich in lactose and minerals, for which its disposal is not yet fully resolved: one part is destined to the production of powdered permeate for food industry, and another, largely, used for animal feed. Given this situation, to biotechnological valorization alternative for whey permeate is proposed through the microbiological transformation of lactose for the production of polyhydroxyalkanoates (PHA), biopolymers with properties similar to polypropylene, but with the advantage of being biodegradable, compostable, biocompatible, and of biological origin. Currently, some microorganisms are known, capable of synthesizing PHA, such as Ralstonia, Bacillus, and Pseudomonas, but a large proportion of microbial diversity is not culturable in the laboratory, which limits their study using traditional approaches. In this context, metagenomics represents an alternative strategy to access novel genes present in uncultured autochthonous microorganisms that could provide the ability to synthesize novel compounds or obtain active enzymes under different conditions. In the present work, a bacterial operon containing PHA biosynthesis genes was identified in the metagenome of dairy wastewater treatment ponds, previously sequenced and assembled by the Genomics and Bioinformatics group of IDICAL. These genes were amplified from metagenomic DNA by PCR, cloned into a commercial vector, and used to transform Escherichia coli 6576, a bacterial strain capable of metabolizing lactose. Bioplastic production was initially evaluated by the ability of transformed colonies with the synthetic operon to fluoresce in rich medium with Nile red fluorophore and, then, by PHA extraction in liquid batch cultures with sodium hypochlorite. The extract was analyzed by GC-FID and compared with a 3-hydroxybutyric (3HB) standard. Finally, biopolymer production was evaluated by fed-batch fermentation in a 5L bioreactor, using a minimal medium supplemented with whey permeate as a carbon source.

The use of recombinant microorganisms, transformed with novel genes, represents an interesting alternative for the revalorization of dairy industry byproducts, such as whey permeate, and the obtaining of products of great interest, like bioplastics.

Keywords: whey permeate; added value; metagenome; bioplastic; fed-batch.

MONITORING OF THE BIODIGESTATES COMPOSITION PRODUCED IN AT THE SÃO PAULO UNIVERSITY OF SÃO PAULO BIOGAS PLANT FOR AGRICULTURAL REUSE

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The principal campus of the University of São Paulo (USP) converts approximately 40 d^{-1} of post-consumer food residues from its student restaurants into biogas and digestate in the Institute of Energy and Environment’s anaerobic digester (IEE/USP), which operates at a nominal hydraulic residence time of about 60 d. Because the resulting digestate, rich in organic matter and plant nutrients, is regularly applied to agricultural soils, its comprehensive and frequent characterization is essential for detecting compositional changes in its composition due to seasonal variations in student diets or by operational variations in the digester, in order to define insurance limits for agronomic use. Over two consecutive years, samples were collected at systematic intervals, preserved and promptly analyzed for physicochemical, chemical and microbiological attributes using standard methods. Maximum values found in the biodigestates were 20.000 mg L^{-1} and 4.000 mg L^{-1}, for the parameters biochemical oxygen demand (BOD) and chemical oxygen demand (COD), respectively; pH ranged from 7.5 to 8.0; electrical conductivity attained 45 mS cm^{-1}; sodium concentrations was in the range of 1 000–2 000 mg L^{-1}, and sodium adsorption ratio (SAR) values was between 14.4–48.9, all exceeding the guideline limits for agricultural reuse (2.9 mS cm^{-1} and SAR 12) and indicating potential salinity and sodicity hazards, in the case of continuous use of this biodigestate in the soil. Oil-and-grease contents varied from 20 to 133 mg L^{-1} in the first year and from 12 to 70 mg L^{-1} in the second year. Escherichia coli persisted at 10^4–10^5 most-probable-number (MPN) 100 mL^{-1}, and viable helminth eggs occasionally exceeded the criterion of one (1,0) viable egg L^{-1}, demonstrating that digester temperatures were insufficient for complete pathogen decay, although Salmonella sp were absent. Analyses of the raw material (food) confirmed that these contaminants originated in the food waste itself; comparison of food waste and digestate showed a 50 % reduction in BOD and 2 % in total carbon, a decline in the volatile-solids-to-total-solids ratio from 0.95 to 0.50, and removal of 80–97 % of oil-and-grease, evidencing effective mitigation of organic load, whereas sodium levels remained unchanged and E. coli reduced just one logarithmic unit. Carbon:nitrogen ratio dropped from 18:1 in the food waste to < 5:1 in the digestate, reflecting the long residence time and high biogas. it should be emphasized that soil application of residues with C:N < 10:1 can deplete soil organic matter, especially in subtropical environments. Each cubic meter of digestate can supply up to 7 kg N, 0.4 kg P_2O_5 and 7 kg K_2O, plus Ca, Mg, S, Cu, B and Zn. Field rates of 15–20 m^3 ha^{-1} are capable of meeting most crops’ nitrogen and potassium demands. It is advisable to mix fruits and vegetables with food waste to dilute contaminants and promote environmentally sustainable reuse.

Keywords: food waste; biofertilizer; plant nutrients; sodium; fecal coliforms.

BIODIGESTATE REUSE OBTAINED FROM FOOD WASTE IN SUGARCANE CULTIVATION: PRODUCTIVITY AND TECHNOLOGICAL QUALITY OF SUGARCANE JUICE

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Biodigestate, effluent obtained from anaerobic digestion of organic waste by methanogenic microorganisms, accumulates in large volume as biogas production expands, requiring environmentally safe and economically viable disposal alternatives. Considering the organic load still present in the effluent and interesting levels of plants macro and micronutrients, its agricultural use appears to be a viable option for partial or total replacement of mineral fertilizers. However, depending on the raw material used and the detention time of the biodigestion process, the residue may present contaminants such as pathogens, heavy metals, and sodium, as well as an imbalance in the C:N ratio, thus requiring constant characterization, including to calculate soil application rates, to meet the nutritional demand of plants. The objective of this study was to evaluate the agricultural reuse of biodigestate obtained from biogas plant installed at the São Paulo University and fed with food waste from campus restaurants, with a detention time of 60 days. A field trial was installed in a clayed Oxysol cultivated with sugarcane 1st cycle (ratoon cane), composed of 24 plots with 5 rows spaced 1.5 m, four repetitions, six treatments. Biodigestate rates were calculated based on the N content of 60kg/ha demanded by plant, in the following treatments: (i) biodigestate providing 50 kg N ha^{-1} (11m3 ha-1); (ii) biodigestate at 100 kg N ha^{-1} (22 m3 ha^{-1}); (iii) biodigestate at 150 kg N ha^{-1} (33m3 ha-1); (iv) organomineral: biodigestate (11m3 ha^{-1}); supplemented with 100 kg N ha^{-1} and 185 kg K_2O ha^{-1}; (v) conventional mineral fertilization (60 kg of N + 185 kg of K2O ha-1); and (vi) control without fertilization. Sugarcane was planted in April/2023, after soil preparation, liming, and planting fertilization, and conducted until December/23, when the biodigestate was applied, being harvested after 1.5 years of cultivation. Sugarcane stalks was harvested manually, ground in mill, following with technological analysis of the sugarcane juice. The results indicated that increasing the biodigestate rate from 50 to 100 kg N ha^{-1} provided an increase both stalk productivity from 114 to 120 Mg ha^{-1} and 7% in TSH (tons of sugar ha-1), not differing significantly from the mineral fertilization treatment. Biodigestate rate equivalent to 150 kg N maintained the biomass gain (123 Mg ha^{-1}) but did not add sugar, indicating a saturation point. Mineral fertilizer still guaranteed the highest TRS (Total Reducing Sugar) (154.9 kg Mg^{-1}), however, the intermediate and higher doses of biodigestate preserved the Brix% and Pol% parameters, which did not differ statistically. Organomineral treatment showed high TCH (122 Mg ha^{-1}) and slight sugar dilution. Control treatment, without fertilization, reduced TCH by 16% and TRS by 12%. Such productivity and juice quality indices can be considered optimal, due to climatic conditions, which were not favorable in the 2023-2024 agricultural year, due to high temperatures and water scarcity in spring-summer. It is concluded that the dose of 100 kg N ha^{-1} via biodigestate balances productivity and quality of sugarcane juice, allowing to replace chemical fertilization in plant cane, in a sustainable way.

Keywords: circular economy; restaurant waste; anaerobic biofertilizer; saccharum officinarum; sugar and alcohol production.

EFFECT OF MANURE APPLICATION ON SOIL WATER CONTENT IN A GOAT FORAGE SYSTEM UNDER SEMIARID CONDITIONS

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Agricultural development in semiarid regions presents significant challenges for achieving sustainable production systems, with water availability being the main limiting factor. In this context, management decisions are critical to the success or failure of production. One strategy used is the application of manures and cover crops, which improve the physical properties of the soil, enhancing its water-holding capacity. This study aimed to evaluate the effect of manure application on soil water retention capacity in winter forage crops used both as cover and deferred grazing for goat production. The trial was conducted at the experimental station of INTA, EEA Santiago del Estero, using manures sourced from on-site livestock operations. The treatments included a control (T0) with no manure application, and three organic amendments: poultry litter (T1), aged goat manure (T2) stored for over a year, and fresh goat manure (T3) collected six months prior to application. Amendments were applied and superficially incorporated into the soil on October 2, 2023, at a rate of 5 $t.ha^{-1}$. Treatments were arranged in 144 m^2 plots in a completely randomized design (CRD) with three replications, totaling 12 plots. On March 18, 2024, a winter forage mix composed of hairy vetch (Vicia villosa), triticale (× Triticosecale Wittmack), and forage barley (Hordeum vulgare) was sown in alternating rows spaced 30 cm apart. Gravimetric soil moisture was sampled at two depths (0–15 cm and 15–30 cm) on five strategically chosen dates, depending on water availability, 1) October 26, 2023, following manure application and a significant rainfall event of 48 mm, 2) December 27, 2023, during the rainy season with 80 mm accumulated over 30 days, 3) March 18, 2024, the day of sowing after presowing irrigation, 4) May 8, 2024, 52 days after sowing, with 90 mm rainfall over the preceding 30 days and 5) August 1, 2024, at the end of the forage cycle, with only 2 mm rainfall over the previous 30 days. Soil moisture content showed significant differences between sampling dates, associated with climatic conditions, ranging from 35 mm (August 1) to 85 mm (March 18) across the 30 cm soil profile. No significant effects of manure treatments were detected on water storage at either depth. Moisture content ranged between 32–34 mm in the top 15 cm and 28–29 mm in the 15–30 cm layer, with a trend toward higher moisture in the control (T0) and poultry litter treatment (T1) in both layers. In this first year of manure application, no significant effect was observed on surface soil water content. Continued research is necessary to assess the residual effects of manure on water dynamics in these semiarid production systems

Keywords: manure; water retention; silvopastoral; cover crops.

PRODUCTION OF FUNGAL CONIDIA FOR THE DEVELOPMENT OF STARTER CULTURES FOR THE

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The ripening of dry-cured sausages involves surface colonization by filamentous fungi. In this process, known as surface fungal colonization, species primarily belonging to the genus Penicillium develop on the casing. This microbiological activity plays a critical role in the biochemical transformation of the product, contributing to its distinctive organoleptic characteristics through the production of specific secondary metabolites. Despite its importance in traditional dry-fermented sausages, the absence of starter cultures specifically formulated for mold coating in Argentina, along with the limited availability of adapted fungal strains, highlights a gap in local technological development.

The objective of this study was to evaluate conidial production for the development of coating starter cultures via solid-state fermentation (SSF) using spent mushroom substrate (SMS) as the fermentation matrix. Pre-selected fungal strains were tested under controlled conditions, and conidial yields were evaluated. The proposed approach offers a sustainable alternative for the development of functional fungal inoculants, while simultaneously contributing to the valorization of agro-industrial residues. These findings support the integration of circular bioeconomy principles into food fermentation systems.

Four Penicillium species (P. nalgiovense, P. brevicompactum, P. chrysogenum, and P. rubens) isolated from regionally produced, artisanal dry-fermented sausages were used. These strains had been previously evaluated for their technological and toxicological properties.

Two types of spent mushroom substrate (SMS) were used: (A) wheat straw-based substrate from Pleurotus pulmonarius cultivation after three flushes; (B) the same substrate after four flushes; and (C) poplar sawdust substrate supplemented with soybean hulls from Pleurotus ostreatus cultivation, obtained from a local edible mushroom producer. For each substrate type, 20 g samples (adjusted to 60% moisture content) were inoculated with 1×10^6 conidia/g and incubated at 25 °C for 7 days. Conidial production was quantified using flow cytometry.

Substrate A was found to be optimal for conidial production, yielding average concentrations of 3.6×10^8 and 1.2×109 conidia/ml. In contrast, the highly depleted substrate B and the compositionally distinct substrate C were unsuitable, as no conidial development was observed. These results demonstrate that SMS proved to be a suitable matrix for conidial production under solid-state fermentation. Among the conditions tested, SMS collected after three flushes supported the highest spore yields, whereas substrates from extended cultivation cycles (four flushes) or with different compositions did not support conidial development. These findings underscore the relevance of substrate condition and nutrient availability in optimizing fungal sporulation, and reinforce the potential of SMS as a low-cost, effective matrix for the production of fungal starter cultures

Spent mushroom substrate (SMS) represents a significant environmental challenge. In Argentina, there is currently no production of starter cultures for sausage surface colonization using native fungal strains. This study offers a potential strategy for SMS valorization, while simultaneously enabling the development of locally derived fungal starter cultures for use by artisanal producers of dry-fermented sausages.

Keywords: fungal conidia; solid-state fermentation; spent mushroom substrate; starter cultures; dry-fermented sausages.

APPROACHES TO THE VALORIZATION OF SHRIMP WASTE

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The Argentine red shrimp Pleoticus muelleri represents one of Argentina's most important fishery resources, with annual catches exceeding 200,000 tons. During industrial land-based processing for tail production, considerable volumes of waste are generated, mainly consisting of cephalothoraxes (heads). These by-products present limitations for fishmeal manufacturing and are frequently discarded into the environment, resulting in environmental contamination issues. The FOA (Aquatic Organism Physiology and Applied Biotechnology) research group at the Institute of Marine and Coastal Research (IIMyC-CONICET-UNMdP) has developed strategies for waste valorization through the generation of value-added products. Considering the high concentration of digestive enzymes present in these residues, a simple and economically viable technology was implemented to obtain enzymatic extracts. The obtained extracts have been evaluated for application in various industries, including aquaculture, food, and paint industries. To optimize the utilization of formulated feeds in aquaculture, where the high protein fraction increases costs and environmental impact due to inefficient utilization, strategies to improve feed digestibility are sought. In this context, progress has been made in using shrimp extracts as enzymatic additives, demonstrating significant potential improvement in fish digestive capacity. Additionally, their delivery in microcapsules was evaluated, which favored their stability under conditions inside organisms. More recently, these extracts have been employed for treating plant meals destined for feeding pacu Piaractus mesopotamicus, obtaining promising results on digestive physiology of pacu fry and the inhibitory effect of meals on alkaline peptidases. Pre-treatment of meals has improved amino acid availability and digestibility. Furthermore, protein hydrolysates and peptide fractions were obtained from shrimp waste using endogenous enzymes (autolysis). The shrimp's own enzymes demonstrated high potential for producing protein hydrolysates, as the obtained products presented antioxidant properties comparable to those treated with commercial Alcalase enzyme, even showing greater capacity as natural food preservatives. Regarding the paint industry, particularly in developing antifouling formulations, the potential of these extracts as alternatives to conventional synthetic biocides, which present environmental toxicity, was explored. The capacity of paints based on enzymatic extracts from shrimp waste to inhibit macrofouling settlement in marine environments was demonstrated. Currently, work is being conducted on optimizing formulation processes to improve paint performance. The valorization of waste generated during Pleoticus muelleri processing seeks to add value to an easily available waste stream, promoting circular economy and fishery activity competitiveness. Results obtained thus far demonstrate the potential of this approach to favor both industry sustainability and product diversification.

Keywords: pleoticus muelleri; fishery waste; enzymatic extracts; by-product valorization; circular economy.

UTILIZATION OF BEER INDUSTRY BYPRODUCTS FOR THE PRODUCTION OF FUNCTIONAL FOODS

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Spent grains is a common product generated in the manufacture of beer. The amount of brewers' spent grain (BSG) generated could be about 85% of the total by-products, which accounts for 30 to 60% of the biochemical oxygen demand and suspended solids generated by a typical brewery. Although this byproduct is of high nutritive value for humans, it is currently underexploited. In 2023, BSG was incorporated into the Argentine Food Code (Res. 29/23) for use as an ingredient in the production of food products. The objective of this study was to evaluate the suitability of BSG and its potential application for the development of a novel functional meat food. The proximate composition of BSG (artisanal beer industry from Mar del Plata) was analyzed to estimate its fiber content and incorporate it into beef meatballs. Omega-3 fatty acids from fish oil were also added to improve the lipid profile. Beef meatballs were then prepared with the addition of 0, 5, or 10% of the Nutritional Recommended Dosage of Fiber (from brewer's grain) and 0, 125, and 250 mg of Eicosapentaenoic Acid + Docosahexaenoic Acid (omega-3 fatty acids from fish oil from the Mar del Plata´s industry). The meatballs were vacuum-packed and subjected to a moist cooking process (sous vide). The physicochemical and microbiological quality characteristics of meat products were evaluated. The BSG showed average crude fiber and protein levels of 3.77 ± 1.15 % and 5.87 ± 0.31 %, respectively. It was observed that the addition of 5 and 10% BSG increased ($P < 0.001$) the cooking yield of the meatballs by 14% and 27%, respectively. Product brightness (L*) was not affected by treatments. The interaction between fish oil and BSG addition was significant ($P= 0.02$) for the red color (a*-redness) of the meat product. The addition of BSG the red color (a* value) in all oil treatments. Regardless of the level of fish oil, the addition of 5% and 10% of BSG reduced ($P< 0.05$) the b* (yellowness) value by 16% compared to the non-BSG sample (0%). Regarding the microbiological quality of the meat samples, counts ranging from <10 to 2,600 CFU/g of AMB (Aerobic Mesophilic Bacteria) were observed, along with a total absence of pathogens and values of <10 and <100 CFU/g for Total Coliforms and S. aureus, respectively. It is concluded that BSG is well suited to elaborate meat functional products. Its use in the preparation of vacuum-cooked meatballs increases cooking efficiency but affect negatively meat product color. Further studies are needed to clarify the impact of adding BSG on the quality of this type of cooked meat products.

Keywords: brewers´ spent grain; meatballs; nutrition; fiber; omega-3.

POTENTIAL FOR REUSE OF TREATED WASTEWATER IN NORTHERN PATAGONIA

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The reuse of treated wastewater (TWW) for irrigation enables nutrient recovery while reducing discharges into natural water bodies. In Northern Patagonia—a region characterized by aridity and increasing water stress—this practice presents a valuable opportunity, particularly when directed toward irrigated agricultural production. Furthermore, the Interjurisdictional Authority of the Limay, Negro, and Neuquén River Basins promotes a zero-discharge policy into these rivers.

This study aims to quantify the potential reuse of TWW for crop irrigation. Official data were used to identify and classify all existing wastewater treatment plants in the provinces of Río Negro and Neuquén, totaling 61 facilities: 56% based on facultative lagoons and 34% on activated sludge systems. Nutrient levels in treated water are particularly high in lagoon-based systems.

Using the Ingeniero Jacobacci plant (facultative lagoons) as a case study, the potential for irrigating alfalfa and willow (Salicaceae) crops was estimated. Irrigation requirements were calculated using the FAO 56 methodology (Allen et al., 1998), based on average historical climate data and the FAO ETo Calculator. Evaporation from lagoon surfaces was also estimated.

The plant currently receives effluents from 250 households, producing an estimated 150–250 L/household/day. Two reuse scenarios were evaluated: (1) annual reuse with storage of surplus water during low-demand periods; and (2) direct use in January, the peak irrigation month. Under average conditions, 1.5 ha of alfalfa and 1.9 ha of willows could be irrigated annually with storage, or 0.6 and 0.4 ha respectively through direct application. At present, the plant has at least four hectares available that could be used for this purpose.

As the sewer system currently serves less than 10% of local households, the potential expansion is considerable. Given that Ingeniero Jacobacci is a small to mid-sized town, scaling up this practice across the 61 surveyed plants could provide a significant contribution to regional water reuse strategies in the context of increasing scarcity.

Keywords: irrigation; nutrient recovery; reuse; environmental remediation; efficient water use.

CHARACTERIZATION OF SPENT SUBSTRATES FROM PLEUROTUS PULMONARIUS PRODUCTION FOR THEIR POTENTIAL USE AS SUBSTRATE CONDITIONERS FOR SEEDLINGS

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The management of agro-industrial waste presents a crucial environmental challenge and a significant opportunity for circular economy strategies. Agricultural practices often deplete soil organic matter and carbon, necessitating sustainable alternatives. In this context, spent mushroom substrates (SMS) from edible fungi like Pleurotus pulmonarius are an underutilized post-harvest biomass. These SMS, initially rich in carbon, hold value as soil conditioners and growing substrates, potentially replacing peat in horticulture—a slowly replenishing ecological resource. This study aims to characterize the physicochemical properties of P. pulmonarius SMS to evaluate their viability as a support medium for plant seedlings, promoting residual biomass valorization and agricultural sustainability.

For this characterization, SMS from Pleurotus pulmonarius (strain 883/19) were collected from six formulations: Lenga + wheat bran, Lenga + bagasse, Peat, Barley, Barley + wheat bran, and Barley + bagasse. Samples were oven-dried at 70°C to constant weight and then ground using a High-Speed Multifunction Grinder (model HC-300).

pH was determined using a Consort C830 from a 1:1 (v/v) substrate:distilled water solution. After a 2-minute settling period, readings were taken. Electrical Conductivity (EC) was measured with a Hanna Instruments Soil Test™ HI 98331, following the same 1:1 solution preparation protocol. Soluble phosphorus was quantified using a VISOCOLOR® kit: 1g of sieved substrate was extracted with buffer, filtered, and a diluted aliquot was reacted with P1 and P2 reagents. Absorbance was measured at 690 nm using a Shimadzu 160-A spectrophotometer. Finally, Water Holding Capacity (WHC) was assessed by adding 40 mL of distilled water to 5 g of substrate in perforated tubes, allowing percolation for 24 hours. WHC was calculated based on the retained water volume relative to the substrate weight.

Preliminary results for Pleurotus pulmonarius SMS characterization reveal promising agricultural potential. Average pH values ranged from 5.15 to 5.78, which is slightly more acidic than the ideal range for seedlings (5.5-6.3) but generally favorable for many plant species. This range warrants discussion on nutrient availability.

Electrical Conductivity (EC) showed wide variation, from 0.93 to over 4 dS/m. Lower EC (e.g., 0.93 dS/m) indicates suitability for seedling germination, while values exceeding 4 dS/m (barley formulations) suggest potentially detrimental salt accumulation. Lenga-based formulations had elevated EC (1.10 to 1.25 dS/m), but still within acceptable limits if blended.

Soluble phosphorus levels varied significantly, from 0.053 to 13.035 mg/kg. Substrates with higher concentrations could reduce external fertilization needs, while lower levels indicate potential deficiencies.

Water Holding Capacity (WHC) ranged from 40% to 180%. High WHC (lenga formulations) implies excellent water retention, potentially reducing irrigation frequency. However, excessively high WHC could lead to aeration issues, emphasizing the need for further trials to balance WHC with drainage and other factors for specific plant species.

SMS, beyond being a nutrient source, offer stabilized organic matter and improved water retention, making them valuable as soil conditioners and substrates for plant propagation.

Keywords: waste valorization; pleurotus pulmonarius; seedlings; spent substrate; circular economy.

VALORIZATION OF BREWER'S SPENT GRAIN FOR THE DESIGN OF SUSTAINABLE MULTILAYER PACKAGING

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Brewer's spent grain (BSG) is the main by-product of the brewing industry, generated in large quantities during beer production. In Argentina alone, over 400,000 tons of BSG are produced annually, most of which remains underutilized or discarded with limited valorization. In this work, BSG was used as a raw material to produce cellulose-based cardboard, which served as the supporting layer in bio-based multilayer packaging, developed by coating it with renewable polymer films.

Cardboard sheets were obtained from BSG through a multi-step process involving acid hydrolysis with sulfuric acid, alkaline treatment with sodium hydroxide, filtration, manual pressing, and drying (Mussatto et al., 2006). These sheets were then used as substrates for the fabrication of bi-layer materials. The polymeric films, based on polylactic acid (PLA) and plasticized PLA, were previously produced by extrusion and subsequently shaped by compression molding. The plasticized formulation included 12.5 wt% triethyl citrate (TEC) as plasticizer (PLA–TEC). The final bi-layer structures were assembled by applying the films onto the BSG-derived cardboard using compression molding.

The composite structures were evaluated for their suitability in packaging applications. Firstly, adhesion between layers was assessed by field emission scanning electron microscopy (FESEM) and standardized adhesion tests according to ASTM D3359–22 (2010), revealing good interfacial adhesion and structural integrity of the multilayer system.

Moreover, the addition of PLA-based coatings significantly improved the functional properties of the material. Compared to the uncoated substrate, bi-layer structures exhibited enhanced mechanical performance, including higher Young's modulus, tensile strength, and elongation at break. The uncoated cardboard showed a Young's modulus of 0.14 GPa, a maximum tensile strength of 0.7 MPa, and 0.7% elongation at break. While the addition of PLA or PLA–TEC yielded materials with a modulus of 0.5 GPa, a maximum tensile strength of 7.3 MPa, and an elongation at break of 2.7%.

In addition, the coatings substantially reduced water vapor permeability (WVP), enhancing the barrier properties. The WVP of the uncoated cardboard was 1.5 × 10-9 $g/m^2 \cdot s \cdot Pa$, whereas the PLA-coated and PLA–TEC-coated bi-layers showed values of 1.5×10^{-10} $g/m^2 \cdot s \cdot Pa$ and 7 × 10-11 $g/m^2 \cdot s \cdot Pa$, respectively.

These findings demonstrate the potential of BSG as a renewable feedstock for the development of bio-based, functional multilayer packaging materials, offering a promising route for the valorization of agro-industrial waste within the agri-food sector.

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Keywords: brewer's spent grain; cellulose; polylactic acid; biobased packaging.

COMPOSTING BEHAVIOUR OF BI-LAYER SYSTEMS COMPOSED OF A WASTE-DERIVED CARDBOARD AND A PLA-BASED COATING: A STRATEGY FOR THE VALORIZATION OF AGRO-INDUSTRIAL WASTES

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Agro-industrial residues represent a resource for the development of compostable materials intended for short-term applications, such as single-use packaging. Brewer's spent grain (BSG), one abundant byproducts of the brewing industry, can be used to produce cellulose-based substrates, contributing to circular economy strategies. When combined with biodegradable polymers like polylactic acid (PLA), plasticized with triethyl citrate (TEC), these materials may offer a sustainable alternative to conventional, fossil-based packaging.

This study aims to evaluate the compostability of bilayer systems composed of BSG-derived cellulose cardboard coated with PLA-TEC films under controlled thermophilic composting conditions. The focus is on the valorization of agro-industrial waste through the development of low-cost materials with improved end-of-life management.

BSG were used to obtain the cardboard sheets through a multi-step process (Mussatto et al., 2006). On the other hand, polymeric films based on polylactic acid (PLA) and plasticized PLA with 12.5 wt% of triethyl citrate (TEC), were obtained by extrusion and compression molding. Then, the bi-layer systems were prepared by compression molding the polymeric films onto the cardboard sheets.

Samples were incubated for 90 days in a thermophilic composting environment following the IRAM 29421:2018 standard. The degradation process was tracked by visual inspection and mass loss measurements at various time points. The cardboard showed signs of degradation as early as day 2, with softening and microbial growth, progressing to fragmentation by day 7, and near-complete disintegration by day 23. In contrast, the PLA-TEC bilayer remained visually intact through day 11, after which surface whitening, polymer detachment, and gradual disintegration were observed. By day 44, the cardboard retained only ~16% of its initial mass, while the bilayer retained ~30%. After 90 days, no visible residues of either material were found in the compost.

Structural and thermal changes were analyzed to understand the underlying degradation processes. X-ray diffraction (XRD) patterns showed a gradual loss of crystallinity in the cellulose matrix and reduced PLA peak intensity over time. Thermogravimetric analysis (TGA) revealed a shift of the main decomposition peaks toward lower temperatures, indicating increased thermal instability. Differential scanning calorimetry (DSC) showed a progressive increase in glass transition temperature (Tg), attributed to triethyl citrate (TEC) migration, and a decrease in melting temperature (Tm), associated with polymer chain scission and reduced molecular weight.

Overall, the results demonstrate that the PLA-TEC coating delays but does not inhibit the composting process. Both the uncoated cardboard and the bilayer system were effectively biodegraded within 90 days, confirming their compostability. This study supports the use of BSG-derived substrates combined with biodegradable polymers to develop functional, end-of-life-manageable materials, adding value to agroindustrial waste streams through environmentally compatible solutions.

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Keywords: brewer's spent grain; cellulose; polylactic acid; biobased bilayer material; composting.

TRIALS NETWORK OF PIG SLURRY AGRONOMIC USE IN THE PAMPAS MACRO-REGION

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Using livestock waste as an amendment is one way to make the most of it. In this way, using the soil as a receptor for livestock by-products enables some of the nutrients to be restored and assimilated by plants, reducing the need for mineral fertilisers. To apply slurry correctly, it is necessary to understand its composition, the initial nutrient content of the soil, and the nutritional requirements of the intended crop. In order to: i) implement and promote practices that contribute to the sustainability of production systems with the least environmental impact, and ii) to maintain and recover the productive capacity of soils for sustainable production by using organic amendments in the Pampas macro-region. To this end, a network of trials involving the application of pig slurry was set up. Based on previous experiences of INTA researchers working with groups of pig producers affiliated with the Chambers of Pig Producers in the provinces of Córdoba, Entre Ríos, Santa Fe and Buenos Aires, guidelines and work strategies were agreed upon. The aim was to generate and disseminate information on the efficient agronomic use of pig slurry within the framework of Good Agricultural Practices. The amounts of nutrients delivered to the soil by different doses of pig slurry, and the effect of these on the soil's chemical, physical and biological properties, as well as on the production and yield of the evaluated crops, are currently being evaluated in a coordinated and systematic way. The trials will be carried out on pig farms with agricultural land for applying pig slurry. Each trial will follow the same working protocol depending on the application system used. This will facilitate analysis and comparison of data between farms and within the same farm over time. This will enable yield trends and soil parameters to be visualized over time. Participating Chambers of Pig Producers and INTA will organize training sessions, meetings and workshops to share and disseminate the information generated. This proposal aims to provide local information on the agronomic use of pig slurry at the level of each territory in the Pampas macro-region.

Keywords: pig slurry; trial network; pampas macro-region; inta.

PRODUCTION OF BIODEGRADABLE POLYMERIC FILMS FROM KERATIN EXTRACTED FROM SHEEP WOOL AND POTATO STARCH FOR AGRICULTURAL APPLICATIONS

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In Argentina, particularly in the southeastern region of Buenos Aires Province, sheep farming is a traditional activity that remains underutilized due to the low commercial value of coarse wool, limited technological advancement, and high levels of informality along the production chain. As a by-product of this sector, coarse wool is frequently discarded or insufficiently exploited, despite its high keratin content, a fibrous protein with an ordered molecular structure and high aspect ratio, suitable for material development.

This study aims to valorize this agro-industrial residue by developing biodegradable polymeric films based on keratin extracted from sheep wool and potato starch. The resulting bio-based films are intended for use as agricultural mulch in greenhouse environments, providing a renewable alternative to conventional petroleum-based plastics. This strategy aligns with circular economy principles by transforming a low-value by-product into a functional material with both environmental and agronomic benefits.

On one hand, a keratin solution was prepared from degreased wool using an aqueous treatment with 4 mol/L hydrogen peroxide at 60°C, adjusted to pH 10 with sodium hydroxide, for 3 hours. The solution was then filtered to remove insoluble solids. On the other hand, a mixture of starch and glycerol (as plasticizer) in a 2:1 weight ratio was dispersed in distilled water, stirred at room temperature for 15 minutes, and then heated to 90°C for another 15 minutes. Once gelatinization was achieved, the keratin solution was added in a starch:keratin ratio of 7:3. Beforehand, the keratin solution had been sonicated with carbon black (2% relative to the starch mass) to adjust the color of the final film. Finally, copper sulfate (10% relative to the starch mass) was added as a fungicidal and bactericidal agent. The mixture was stirred without heating for 10 minutes and then poured into a plastic Petri dish and dried in an oven for 24 hours at 50°C. The extracted keratin and the resulting films were characterized by Fourier-transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), and X-ray diffraction (XRD).

The extracted keratin showed high purity according to the obtained FTIR spectrum. The films exhibited a glass transition temperature near 60°C, as measured by DSC, and a low degree of crystallinity, similar to that of non-plasticized starch films, based on the XRD spectra. TGA analysis revealed that the blends have a wide degradation temperature range, starting at around 200°C. According to FTIR characterization, one surface of the film showed a higher starch content—evident by its spectral similarity to pure starch films—while the other surface exhibited a greater proportion of keratin. This asymmetry may influence how the film interacts with soil components and biodiversity, depending on how it is oriented when used as mulch. Applicability tests are currently underway.

The extraction method efficiently repurposes wool waste in a simple manner. Furthermore, using a low-value by-product to create biodegradable materials adds value and contributes to pollution reduction and environmental sustainability.

Keywords: renewable resources; biodegradable materials; sheep wool; keratin; potato starch.

VALORIZATION OF AGRO-INDUSTRIAL WASTES THROUGH THE INTEGRATION OF ANAEROBIC DIGESTION AND BLACK SOLDIER FLY (H. ILLUCENS) LARVAE REARING

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The sustained growth of the global population and its quality of life have led to an increase in waste generation, as well as in the demand for energy, food, and feed. The bioconversion of organic wastes using Black Soldier Fly Larvae (BSFL) has emerged as a promising solution for their treatment and the production of protein-rich feed and oils. In order to further enhance the value of organic matter, recent efforts have focused on integrating this process with anaerobic digestion (AD). This study explored the integration of both technologies as an innovative valorization strategy for various wastes from Buenos Aires Province's Agri-food System. A bioconversion trial was conducted using five experimental diets: DI) brewer's spent grain (100%); DII) potato sticks (50%) and potato peels (50%); DIII) potato sticks (30%), potato peels (50%), and wheat bran (20%); DIV) potato sticks (30%), potato peels (50%), and pre-treated wheat bran with liquid fraction of anaerobic digestate (20%); DV) pre-treated wheat bran with liquid digestate (100%). Upon reaching the prepupal stage, larvae were harvested and the following parameters were evaluated: A) survival rate (SR); B) larval weight gain (LWG); C) bioconversion rate (BCR); D) substrate reduction (%SR); and E) larvae protein and lipid content. Additionally, the chemical composition and biochemical methane potential (BMP) of the substrates were assessed before and after the bioconversion. Cumulative biogas production was plotted over digestion time and experimental data was fitted to a second-order kinetic model. Larvae fed with DIII showed the highest SR, LWG, and BCR (91±7 %; 4.76±0.79 g; 7.26±1.21 %). Those fed with DI exhibited the highest % SR and protein content (33.46±3.70%; 47.39%), while DII-fed larvae showed the highest lipid content. Moreover, the combination of digestate with potato wastes (DIV) resulted in improved SR, LWG, and %SR compared to DII. The bioconversion process enriched the post-larval residues (frass) in recalcitrant components, affecting biogas production kinetics (Bmax and b) with varying sensitivity. Diets rich in digestible compounds (DII, DIII, DIV) yielded high biogas and methane production even after the bioconversion. The inclusion of liquid digestate in DIV as a pretreatment likely contributed to the increase in both Bmax and b compared to DIII. These findings represent a first approach to the technological integration in the region and may serve as a basis for scaling up the strategy and developing recommendations, aimed at achieving waste management practices with greater added value and socio-environmental benefits.

Keywords: anaerobic digestion; black soldier fly larvae; biochemical methane potential; bioconversion; agro-industrial waste.

ANAEROBIC DIGESTION OF CATTLE MANURE AND AGRONOMIC RECOVERY OF ITS PRODUCTS IN WHEAT CULTIVATION

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This study aimed to evaluate strategies for nutrient recovery and agronomic use of the byproducts generated by the anaerobic digestion (AD) of feedlot cattle manure. Four 60-liter horizontal semi-continuous digesters were operated at 35 ± 1 °C and fed daily with different substrate formulations: T1 – liquid fraction from manure diluted in water (1:4); T2 – liquid fraction from manure diluted in 100% digestate; T3 – manure diluted in water (3% TS); T4 – manure diluted with 40% water and 60% digestate (3% TS). All treatments used dairy cattle digestate as inoculum, and biogas production was monitored daily. After the AD period, the digestate (biofertilizer) and solid fraction (from T1 and T2) were used to formulate fertilization strategies for wheat in a greenhouse experiment. A control treatment with conventional mineral fertilization (T0) was also included. The treatments combined different proportions of organomineral fertilizers and digestate based on ammonium nitrogen content, using standard recommendations for wheat. Results showed that specific methane yield was highest in T2 (482 $NLCH_4$/kg VS), where digestate was fully recycled as diluent, followed by T3 and T1. However, the highest volumetric methane production (per liter of reactor) occurred in T4 (0.27 LCH_4/Lreactor·day), suggesting that partial recycling is a promising strategy for maximizing biogas production while minimizing digestate output. Wheat productivity was significantly higher in T3 (3.33 g of grain/plant) compared to the mineral control (2.10 g), highlighting the potential of digestate as a nutrient source. In T4, high potassium levels were observed due to digestate reuse, reinforcing the importance of monitoring nutrient balance. These findings demonstrate that combining solid-liquid separation and digestate recycling enhances nutrient recovery, reduces the need for clean water, and improves the agronomic value of the byproducts. The integrated use of digestate and solid fractions in crop production represents a promising approach for circular bioeconomy and sustainable manure management.

Keywords: nutrient recycling; greenhouse experiment; ammonium nitrogen; sustainable agriculture; solid-liquid separation.

VALORIZATION OF CARROT AND GREEN APPLE BAGASSE: EFFECTS OF CONVECTIVE DRYING ON PHENOLIC COMPOUNDS, ANTIOXIDANT CAPACITY, AND POLYPHENOL OXIDASE ACTIVITY

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Fruit and vegetable bagasse represents a major by-product of juice processing industries. These residues retain a significant content of bioactive compounds, including phenolic compounds and other antioxidants, which are of great interest for the development of functional ingredients. The objective of this study was to evaluate the effect of convective dehydration at different air temperatures (50, 60, and 70 °C) on total phenolic content (TPC), antioxidant activity (DPPH), and polyphenol oxidase (PPO) activity in carrot and green apple bagasse, obtained from a cold-press detox juice industry. Samples from three different production batches were ground and dehydrated by convection at 50, 60, and 70 °C (air velocity: 0.6 m/s) until constant weight was achieved. The total phenolic content (Folin-Ciocalteu method), the total antioxidant capacity (DPPH) and polyphenol oxidase (PPO) enzyme activity were determined using colorimetric methods. Results demonstrated that total phenolic content (TPC) was significantly higher in the fresh carrot and green apple bagasse compared to dehydrated ones ($p < 0.05$). In carrot, the highest value was recorded in the fresh sample (485.47 µg gallic acid eq./g dry mass -DM-), while the lowest values were observed at 50 and 60 °C (306.27 and 303.68 µg/g DM, respectively). No significant differences were found among dehydration temperatures in carrot while a progressive reduction in phenolic content was observed with increasing air temperature in apple, with a marked 63% decrease from fresh (2703.53 µg/g DM) to 70 °C (985.18 µg/g DM), showing significant differences between treatments. Regarding total antioxidant capacity (DPPH), a significant reduction was observed after drying in both matrices. In carrot, antioxidant activity decreased from 2.36 µmol Trolox eq./g DM (fresh) to values between 1.00 and 1.23 µmol/g in dried samples. In green apple, the decline was more pronounced, from 35.40 µmol/g DM (fresh) to approximately 8 µmol/g after dehydration. In addition, the thermal treatments effectively inhibited PPO activity, which may contribute to greater oxidative stability and extended shelf life of the dehydrated product compared to the fresh counterpart. Given the role of PPO in enzymatic browning, its activity can be considered a useful indicator of product stability during processing and storage. In conclusion, the application of convective drying is essential for the stabilization of these highly perishable by-products from the juice industry. Despite the loss of certain bioactive compounds, the dehydrated bagasse retains valuable components such as fiber, micronutrients, and residual antioxidant activity. Therefore, it can be used as a functional ingredient for the development or fortification of food products, contributing to waste reduction, promoting sustainable practices, and promoting circularity in the agri-food industry.

Keywords: vegetable bagasse; dehydration; functional ingredient; waste revalorization.

VALORIZATION OF BY-PRODUCTS FROM THE CHEESE, FRUIT, AND BEEKEEPING INDUSTRIES AS A SUSTAINABLE ALTERNATIVE FOR DEVELOPING A WHEY-BASED FOOD PRODUCT

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The Argentine cheese industry generates 12 million liters of whey per day—a valuable byproduct that is largely discarded or used for animal feed due to limited equipment and technical knowledge in small-scale operations. To promote a circular economy, efforts are focused on integrating whey with other bioresources. Pectin, a high-value compound typically imported, can be extracted from orange peels—an agro-industrial waste—thus reducing residues and adding value. Honey from southeastern Buenos Aires, known for its quality but often exported in bulk without highlighting its origin, is also being explored as a natural sweetener. Aligned with this valorization approach, the objective was to characterize whey, pectin from orange peels, and regionally produced honey, for the development of a whey-based dessert using pectin as a texturizing agent and honey as a natural sweetener.

Whey was sourced from cheese production waste in the Mar y Sierras dairy region and characterized by pH, density, and acidity to assess its suitability as a base matrix. Pectin was extracted from orange peels using microwave-assisted acid extraction (MAE) and characterized by its degree of esterification (DE) and anhydrogalacturonic acid content (%AGA). Honey, provided by INTA Balcarce, was analyzed for pH, acidity, HMF, color, moisture, diastase activity, and sugar content. Subsequently, five dessert formulations were tested. Whey analysis classified it as sweet whey, with a pH of 6.52 ± 0.025, density of 1027.15 ± 1.05 g/mL, moisture content of 92.91% ± 0.35, total solids of 7.10% ± 0.36, and acidity of 9.375 ± 0.239 °Dornic. The pectin exhibited a degree of esterification (DE) of 66.48 ± 1.81, corresponding to high-methoxyl pectin, and an anhydrogalacturonic acid content (%AGA) of 62.50 ± 3.87—within the acceptable range defined by the Argentine Food Code, indicating good quality and purity. Physicochemical analysis of the honey revealed a color of 35 mm Pfund (extra light amber), 16.4% moisture, pH 3.6, acidity of 13 meq/kg, electrical conductivity of 0.21mS/cm, HMF content of 9 ppm, and a sugar composition of 38.9% fructose, 37.4% glucose, and undetectable sucrose, with a fructose/glucose (F/G) ratio of 1.04. Melissopalynological analysis identified predominant botanical species including sunflower, eucalyptus, lotus, melilot, and Trifolium sp. Sensory evaluation described a semi-solid texture with small crystals, medium sweetness, floral aroma of medium intensity, and medium persistence in ther mouth. Five dessert formulations were developed by combining whey with 20% sugar and varying pectin content (2.5%, 4%, 5%, 7.5%, and 10% of total weight). Preliminary formulation studies are ongoing to determine the optimal composition. Physicochemical, functional, and sensory analyses are still in progress; however, early sensory evaluations suggest that the 5% pectin formulation shows the highest acceptability. The analyses conducted have enabled a detailed characterization of the base ingredients. Results confirm that whey is a suitable matrix for incorporating and interacting with pectin extracted from byproducts, while regional honey emerges as a promising sweetener whose value is enhanced when its origin is highlighted. This development offers an innovative pathway for the utilization of waste from various local industries, fostering sustainability and circular economy practices in the region.

Keywords: sustainable food; whey; circular economy; functional food; food innovation; pectin.

DEVELOPMENT OF A SOIL BIOFERTILIZER VIA FERMENTATION OF HERMETIA ILLUCENS BIOMASS CULTIVATED ON INDUSTRIAL POTATO RESIDUES

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This study presents the development of a biologically active soil bio-regenerator derived from Hermetia illucens larvae, as part of the FITBA 2024 project, a joint initiative between the Universidad Tecnológica Nacional, Facultad Regional Mar del Plata (UTN FRMDP) and the company PROCENS SAS. The approach aims to transform industrial potato waste into a high value bio input within a circular bioeconomy framework. Larvae of Hermetia illucens were fed exclusively with a formula containing potato industry by-products. After completing their larval cycle, the biomass—composed of larvae and frass—was processed into a homogenized paste and subjected to a controlled biological fermentation (aerobic enzimatic composting) for eight days. The resulting material was characterized to evaluate its potential properties as a soil bio-regenerator, due to its content of biologically active compounds.

The process was monitored at three time points (day 0, 3, and 8), focusing on the degree of protein hydrolysis, the antioxidant capacity by DPPH radical inhibition, and the electrical conductivity as an indicator of soluble nutrient release. The degree of hydrolysis increased significantly over time, from 0% to more than 60%, indicating active proteolytic breakdown. Interestingly, the antioxidant activity showed a different trend: it peaked at day 3 (71.83% DPPH inhibition), then decreased to 42.7% by day 8. This suggests that the bioactive antioxidant compounds—likely peptides, phenolics, or other low molecular weight metabolites—are maximally released or formed during the early stages of the process but degrade or polymerize over time.

Electrical conductivity, which reflects the concentration of soluble ions such as ammonium, phosphate, and organic acids, also increased during the first days (from ~850–1400 µS/cm to ~1600 µS/cm), then stabilized at 2280 µS/cm by day 8. This behavior indicates a phase of intense mineralization and nutrient release, followed by stabilization. These values are within acceptable agronomic limits, suggesting safe application to soils without risk of salinity stress. The combined interpretation of these variables reveals that the product reaches its maximum biological activity around day 3, both in terms of antioxidant potential and nutrient availability. Beyond this point, the product transitions toward maturity and chemical stabilization, maintaining its function as a soil amendment while losing some of its transient bioactivity. This novel process provides a sustainable and replicable solution for the agroindustrial sector, especially for managing carbohydrate-rich waste streams. The resulting product holds dual potential: as an organic soil enhancer and as a carrier of bioactive compounds with potential biostimulant or soil-restoring effects. Its elaboration using industrial waste and insect biotechnology aligns with principles of circular economy, offering environmental, agronomic, and economic benefits.

Keywords: black soldier fly; industrial potato waste; fermentation; soil biofertilizer; circular bioeconomy.

USE OF HYDROLYSATES FROM FISHERY BY-PRODUCTS IN RAINBOW TROUT DIETS AND EVALUATION OF THEIR ANTIOXIDANT EFFECT

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Shrimp fishing (Pleoticus muelleri) is one of the most important activities in the Argentine fishing sector, accounting for 27% of total landings. In 2024, 222,163 tons were caught, of which 61,111 tons were exported as processed (headless) products, generating approximately 40,740 tons of solid waste. These residues, which are currently not efficiently utilized, represent an environmental liability due to their accumulation and improper disposal. However, through biotechnological processes such as autolytic hydrolysis, it is possible to recover valuable biomolecules (proteins, lipids, antioxidants, and pigments) that serve as an alternative, low-cost source of high-quality protein and lipid ingredients, with the potential to partially or fully replace fishmeal and fish oil in aquafeed formulations, in line with international requirements to reduce their use. In Argentina, one of the most widely farmed species is rainbow trout (Oncorhynchus mykiss), which reached a production of 4,078.25 tons in 2023, representing 73.9% of the total volume produced by the national aquaculture industry. This context presents an opportunity to apply new technologies aimed at the design and development of specialized feeds for intensive farming systems.

The aim of this study was to formulate and evaluate a balanced diet for rainbow trout (Oncorhynchus mykiss), in which 9% of the fishmeal (FM) in a standard diet was replaced with an autolytic hydrolysate obtained from shrimp heads (HACL), and to analyse its effect on growth and antioxidant capacity in both the fillets and the liver, a key organ in fish metabolism and detoxification. To obtain the HACL, shrimp heads were ground and incubated at 45 °C for 60 minutes. The experimental diet contained 55% FM and matched the protein profile of the control diet (LACUI), which contained 64% FM, both providing approximately 46% crude protein. The bioassay was conducted in triplicate using a recirculating aquaculture system and triploid females provided by the Centro de Ecología Aplicada de Neuquén (CEAN), with an initial average weight of 313 ± 30 g. Fish were fed for 30 days with a daily ration equivalent to 1.5% of the biomass. At the end of the bioassay, trout fed the HACL diet reached an average weight of 382 ± 24 g, while those fed the LACUI diet reached 396 ± 27 g, with no significant differences in weight gain (Student's t-test, $p > 0.05$). Regarding antioxidant capacity, no activity was detected in the muscle of fish from either treatment; however, a slight improvement was observed in the liver of fish fed the HACL diet (43.26 ± 1.84% DPPH radical scavenging activity) compared to those fed the control diet (40.89 ± 1.80%). These preliminary results suggest that partial replacement of FM with HACL does not negatively affect growth performance and may provide functional hepatic benefits, opening the possibility of increasing its inclusion in future formulations, in line with the principles of sustainability and circular economy.

Keywords: aquaculture; rainbow trout; fishing waste; autolytic hydrolysate; fish meal.

VALORIZATION OF CANNABIS WASTE FROM MEDICINAL OIL PRODUCTION: A CIRCULAR APPROACH TO AGRO-INDUSTRIAL RESIDUES

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The growing interest in the medicinal use of Cannabis sativa has led to a considerable increase in the production of cannabis oil, which in turn generates significant amounts of agro-industrial residues, particularly leaves, stems, and roots. These biomass components, traditionally considered waste, represent a valuable and underutilized resource. This study focuses on the detailed physical, chemical, and techno-functional characterization of these residues, evaluating their potential for various sustainable applications, including the development of biochar, functional flours, and potential inputs for soil and material improvement strategies.

Samples of dried Cannabis sativa residues (leaves, fine stems, coarse stems, and roots) were provided by the companies Mediplant and Green Health, located in Campogrande del Acequión, Department of Sarmiento, San Juan, Argentina. After appropriate drying, grinding, and sieving, the materials were stored under controlled conditions to preserve their properties prior to analysis. A comprehensive set of laboratory analyses was performed to determine critical parameters such as moisture content, ash percentage, protein, lipid, and crude fiber levels, as well as lignocellulosic fractions including lignin, cellulose, and hemicellulose. In addition, various physicochemical properties were assessed, including water activity, pH, titratable acidity, and soluble solids. All tests were performed in triplicate to ensure statistical reliability and reproducibility.

The results revealed a remarkably high content of crude fiber in all biomass fractions, especially in fine and coarse stems (>96%) and leaves (75%). The leaves also showed a relatively high lipid content (5.18%) and significant ash levels (19.74%), suggesting their suitability for both energy valorization and nutritional enhancement. The carbon content was highest in coarse stems and roots, exceeding 43%, which is a favorable indicator for thermochemical conversion processes. Techno-functional analysis of Cannabis sativa leaf flour demonstrated a water absorption capacity (CAW) of 1.89, oil absorption capacity (CAA) of 4.38, and good emulsifying properties (28% emulsification and 27% emulsion stability), highlighting its potential as a novel ingredient for food, cosmetic, or pharmaceutical applications. Culinary tests using the flour were successfully conducted to explore its integration into real-world formulations.

Roots were further valorized through a controlled pyrolysis process conducted at 450 °C for two hours, resulting in the production of high-quality biochar. The resulting material exhibited a high fixed carbon content (62.71%), very low moisture (2.54%), high alkaline pH (10.27), and moderate electrical conductivity. These properties make it suitable for soil amendment, pH correction, and carbon sequestration purposes. Furthermore, the biochar displayed excellent water retention capacity and an appreciable content of organic matter, reinforcing its environmental benefits.

This study demonstrates the substantial potential of Cannabis sativa residues as valuable raw materials for circular economy strategies. The research offers viable options for waste recovery in the agro-industrial sector and promotes resource efficiency. The integration of biorefinery approaches not only contributes to environmental sustainability but also opens up new avenues for the development of functional ingredients, soil improvement technologies, and renewable materials for broader industrial use. These findings highlight the relevance of biomass recovery practices in supporting local economies and advancing global sustainability goals.

Keywords: cannabis sativa wastes; biochar; functional flour; circular economy; biomass valorization.

TWO-STAGE VALORIZATION OF AGRO-INDUSTRIAL RESIDUES: EXTRACTION OF HIGH-VALUE COMPOUNDS AND PYROLYTIC POTENTIAL

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The agro-industrial sector in San Juan, Argentina, generates significant amounts of organic residues, which often remain underutilized or are disposed of through environmentally unfriendly practices. This study proposes a two-stage valorization strategy aimed at maximizing the recovery of valuable compounds and energy products from three local agro-industrial residues: brewery spent grain (BSG), pomegranate peel (PGP), and industrial quince residue (IQR).

In the first stage, ultrasound-assisted extraction (UAE) was employed as a green and efficient technique to extract high-value compounds. Extraction conditions were previously optimized for each matrix. For BSG, furfural extraction using phosphoric acid as solvent reached a maximum concentration of 103.26 mg/g under pH 1.7, 74.5 °C, and 45.1 min. PGP showed the highest polyphenol yield (8394.22 mg gallic acid/100 g sample) using distilled water at 70.0 °C for 60.0 min and a solid–liquid ratio of 1:20. IQR achieved a pectin yield of 11.91 % under optimal conditions of pH 2.12, 83.5 °C, and 48.6 min, using citric acid as extracting agent. These results demonstrate the effectiveness of UAE in recovering valuable bioactive compounds using environmentally friendly solvents and moderate operating conditions.

In the second stage, the exhausted residues were characterized through proximate analysis (moisture, ash, volatile matter, and fixed carbon) to assess their suitability for thermochemical valorization via pyrolysis at 500 °C under inert nitrogen atmosphere. The pyrolysis product distribution was estimated based on the compositional data. BSG (moisture: 3.51%, ash: 2.71%, volatile matter: 76.53%, fixed carbon: 17.25%) yielded 69.23% biochar, 5.84% bio-oil, and 24.92% syngas. PGP (moisture: 4.03%, ash: 2.68%, volatile matter: 78.74%, fixed carbon: 14.55%) yielded 58.32% biochar, 8.92% bio-oil, and 32.76% syngas. IQR (moisture: 3.42%, ash: 0.74%, volatile matter: 78.50%, fixed carbon: 17.34%) produced 69.59% biochar, 5.91% bio-oil, and 24.50% syngas.

The initial recovery of furfural, polyphenols, and pectins allows the extraction of compounds with high market value and application potential in food, pharmaceutical, and chemical industries. Following this, the pyrolysis of the exhausted biomass enables the generation of energy carriers, mainly in the form of biochar and syngas. Among the residues, PGP exhibited the highest proportion of gas products, linked to its slightly higher volatile matter and lower fixed carbon content. In contrast, BSG and IQR showed similar and elevated biochar yields, suggesting their potential as carbon-rich solid fuels or soil amendments.

In conclusion, the proposed sequential valorization strategy successfully integrates the recovery of high-value bioactive compounds and energy products from agro-industrial residues. This biorefinery approach contributes to circular economy principles by reducing waste, minimizing environmental impact, and generating economic value from by-products of agro-industrial processes in arid regions.

Keywords: sustainable valorization; biorefinery; brewery spent grain; pomegranate peel; industrial quince residue.

SPATIAL ANALYSIS OF POTENTIAL CONTRIBUTIONS OF LIVESTOCK MANURE TO NUTRIENT BALANCES IN ARGENTINA CROPPING SYSTEMS

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Cattle, pig and poultry production systems have undergone a process of intensification and concentration in Argentina in recent decades. This helped optimize production but also increased the generation of large quantities of animal manure in a reduced land-base. Manure contains significant amounts of nutrients, which can be used to fertilize crops. The objectives of this study were to (i) estimate the annual generation of nitrogen (N) and phosphorus (P) in animal manure from concentrated animal operations (dairy and beef cattle, pig, and poultry) at second-level administrative division (department/parties) in Argentina, and (ii) to estimate potential contributions of manure nutrients to crop fertilizer needs at the same spatial scale, possible hot-spots for nutrient accumulation and opportunities for nutrient re-distribution. Data on livestock population and crop yields at the second-level administrative division were retrieved from a variety of databases (SENASA, SAGyP). The methodology used by the Argentine National Inventory Report for greenhouse gas emissions was adapted to estimate livestock N excretion, N losses with manure treatment systems, and manure N potentially available for application to cropland. Values of P excretion for different livestock categories were retrieved from best available published data by the American Society of Agricultural and Biological Engineers and used for estimation of potential manure P available for land application. Calculations were refined considering data from local sources on livestock and manure management strategies implemented by Argentine producers. Preliminary results for dairy livestock show large absolute quantities of N and P generated in departments in central Cordoba province (San Justo, San Martin) and Santa Fe province (Castellanos, Las Colonias). Similarly, departments in southern Cordoba (Rio Cuarto, Union, Marcos Juarez) showed the largest generation of nutrients associated with pig production. In both cases, considering the cropland available for nutrient application in each district resulted in low nutrient contributions per unit of land for majority of departments/parties (<30 kg N/ha/yr, <10 kg P/ha/yr). Further analysis is currently being conducted for poultry and beef cattle production systems, as well as the integration of all livestock.

Keywords: manure; livestock; argentina; nutrient balance.

COVERAGE AND BIOINPUTS IN LETTUCE (LACTUCA SATIVA L.): PRELIMINARY EVALUATION

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In the current context of transforming production systems, the valorization of resources plays a central role in advancing towards sustainability models. In horticultural crops, the use of mycorrhizae, covers, and anti-frost blankets not only improves crop development and stability, but also represents strategies to revalue inputs and promote more sustainable management. These technologies allow for the optimization of natural resource use, reduction of dependence on high-cost external inputs, and adaptation to adverse climatic conditions, thus consolidating a more efficient and sustainable horticulture (CONICET-INTA, 2024). The objective of this work was to evaluate and integrate simple strategies, such as the use of plant covers, plastic, anti-frost blankets, and mycorrhizae, to improve productive efficiency and environmental sustainability in lettuce cultivation. The trial was conducted in Azul (Buenos Aires), in plots of 1 m² within a total area of 20 m², under a completely randomized design with three replications. Four treatments were evaluated: control (T0), plant mulch (T1), plastic mulch (T2), and frost protection blanket (T3). Furthermore, each plot was divided into subplots with and without bio-inputs (Eco Mambo mycorrhizae + nettle manure). The sowing was done in seedbeds and the transplanting took place when the seedlings reached the second pair of true leaves, planting frame of 0.2x0.2m. The evaluated variables were: Total Plant Length (cm), Fresh Aerial Weight (FAW, g), Root Weight (RW, g), Total Weight (TW, g), Number of leaves per plant, Dry Aerial Weight (DAW) and Roots (DRW). The data were analyzed using ANOVA and the LSD mean comparison test ($P \geq 0.05$). The results indicate that the anti-frost blanket significantly outperformed all evaluated variables in the other treatments, with a Total Fresh Weight per plant of 236.75 g, a Total Length of 48.67 cm, and a Productivity of 51.5 T/ha. The combination with bioinputs enhanced plant growth compared to the rest of the treatments. In the case of vegetative and plastic covers, the use of bioinputs did not significantly differ from the control. The fresh weight of bio-fertilized roots was higher in the anti-frost blanket and plastic cover treatments, respectively. In the plastic cover, a deformation was observed in the neck area of all plants, resulting from adaptation. There were no significant differences for the variables of dry aerial and root weight. In conclusion, preliminary data indicates that the anti-frost blanket promotes improved productivity and development of lettuce crops, possibly due to its temperature-regulating effect. In turn, the use of bioproducts such as mycorrhizae and natural fermented extracts like nettle puree could be considered complementary due to their positive effect, especially in sustainable management schemes, contributing to the reduction of the use of synthetic chemical products. Plant or plastic covers can be an alternative in systems with an economic-environmental focus, to optimize water resource use and limit weed growth, thereby reducing labor and input usage. To use plastic covers, the cost of the plastic and its impact on sustainable models must be quantified, a topic that could lead to new research.

Keywords: resources; lettuce; bioinputs; anti-frost blanket; coverage.

REUSE OF SOLARIZED STRAWBERRY SUBSTRATE IN ORNAMENTAL PRODUCTION OF TAGETES ERECTA: EFFECT OF LEACHING ON CHEMICAL PARAMETERS AND PLANT GROWTH

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Strawberry cultivation in soilless systems has proven to be more efficient than traditional soil-systems, offering higher yields, lower water and fertilizer use, and improved ergonomics for workers. However, one of the main challenges lies in the management of the large volumes of used substrate, which may become a significant waste problem if not properly handled. Solarization is a physical disinfection method that effectively reduces pathogen load in the substrate, making reuse feasible. Nevertheless, recycled substrates often accumulate soluble salts that can negatively affect new crops. Leaching with water is a simple technique that can reduce salt content and enhance the substrate. This study aimed to evaluate the effect of different water volumes used for leaching on the chemical properties of solarized, recycled substrate and to determine its suitability for the ornamental production of Tagetes erecta, a species of commercial interest. The trial was conducted in Coronda, Santa Fe Province, Argentina (lat. -32.004011, long. -60.926635). The substrate used in strawberry cultivation consisted of peat, composted pine bark, and perlite. After two years of use, the substrate was collected, homogenized, and solarized for 45 days (January–February) to achieve disinfection. Following solarization, the substrate was placed into polypropylene pots (750 ml volume and 13 cm top diameter), and the following treatments were applied: T1: Leaching with 750 ml of distilled water; T2: Leaching with 375 ml of distilled water and Control: No leaching. Leaching was performed manually by irrigating the substrate with distilled water. Chemical analyses included electrical conductivity (EC, dS/m), pH, and concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, and sodium (mg/L). Seedlings were transplanted one day after treatment. The crop was grown in a greenhouse, irrigated as needed with well water, and fertilized weekly with a soluble fertilizer (18-18-18). A completely randomized design was used, with 15 replicates per treatment. Plant height, canopy diameter, and the presence of buds and flowers were evaluated at 15, 30, and 45 days after transplanting. Data were subjected to analysis of variance (ANOVA) to identify statistically significant differences among treatments. Leaching treatments significantly reduced substrate salinity compared to the control. EC in the untreated control was 0.54 dS/m, while T1 and T2 recorded values of 0.28 and 0.32 dS/m, respectively, with no significant differences between them. The pH remained constant at 5.8 across all treatments. No significant differences were found among treatments in plant height, canopy diameter, or the presence of buds and flowers. The measured values were within the typical range for Tagetes erecta, indicating good adaptation to the recycled substrate, even without leaching. These results suggest that although leaching effectively reduces salinity, its absence does not adversely affect the development or commercial quality of T. erecta seedlings. The recycled and solarized strawberry substrate proved suitable for the commercial production of Tagetes erecta, even without leaching treatment. This practice represents a sustainable and cost-effective solution for substrate reuse. Further studies are recommended to assess its performance with other ornamental or horticultural species, thereby broadening its potential applications.

Keywords: recycled substrate; solarization; leaching; ornamental production; electrical conductivity.

REVALUATION OF WATERMELON RINDS AS A SOURCE OF BIOACTIVE COMPOUNDS: A STUDY ON SAMPLES FROM SANTIAGO DEL ESTERO, ARGENTINA

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Watermelon (Citrullus lanatus) cultivation in Santiago del Estero, Argentina, is of great productive interest and primarily intended for the domestic market. It is a fruit with a high water content and vitamins, minerals, and antioxidants in abundance. The rind is an important source of dietary fiber and citrulline, an antioxidant associated with benefits for cardiovascular health and the circulatory system. However, this portion is not usually consumed directly and represents between 30 and 40% of the fruit's total weight. It is generally used to make jam and juices, or is simply discarded, which can contribute to the generation of organic waste and cause environmental pollution. The objective of this work was to extract and quantify the content of phenolic compounds, determine the antioxidant activity, and particularly the citrulline content in the rind of two varieties of watermelons produced with bioinputs, in Santiago del Estero, Argentina. To evaluate the effect of the use of bioinputs on production and seeking to increase the functional quality of the watermelon rind, the bioinput Biosmart® was used versus conventional fertilizers, and two varieties of watermelon: Hollar and Delicia. The crop yield (kg ha-1) was determined, and from the rind, the extraction and quantification of total phenolic compounds (TPC) was carried out by the Folin Ciucalteu method, antioxidant capacity (AC) by the DPPH• free radical decolorization method, both expressed as mg gallic acid per 100 g of rind, and the citrulline content expressed as mg citrulline per 100 g of rind. The results obtained showed that the use of bioinputs increased yield by 23% compared to cultivation with conventional treatments. This type of production with bio- composites did not significantly influence ($p>0.05$) the TPC (84-118 mg gallic acid/100 g of rind), AC (17-23 mg gallic acid/100 g of rind) and citrulline content (158-213 mg citrulline/100 g of rind) of the different varieties, however, a tendency was observed for the Hollar variety treated with bioinput to present higher TPC and AC. The use of bioinputs in watermelon production showed promising potential, reflected in an improvement in production yield. Although no statistically significant differences ($p>0.05$) were observed in the functional parameters, the Hollar variety treated with bioinputs showed a favorable trend regarding TPC and AC. Watermelon rind is a valuable source of natural antioxidants, the use of which contributes to an innovative strategy for valorizing agricultural by products that are typically discarded or have little value, through the development of functional ingredients for the food, pharmaceutical, and cosmetic industries, achieving not only a reduction in waste but also in environmental impact.

Keywords: citrullus lanatus; bioinputs; rind; functional parameters.

PRODUCTION OF FUNCTIONAL FLOUR FROM CARROT (DAUCUS CAROTA) WASTE PRODUCED IN SANTIAGO DEL ESTERO, ARGENTINA

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Carrots are one of the most consumed vegetables worldwide. In Argentina, production was 300,282 tons in 2022, with Santiago del Estero being the second largest producing basin. However, in washing, sorting, and packaging centers, significant waste is produced (around 50%), due to a large volume of carrots that do not meet the quality, size, and shape standards imposed by the market. This, in addition to implying a significant economic loss for producers, has negative consequences for the environment, as the waste decomposes, generating pest proliferation and unpleasant odors. It is known that cutting stress in this vegetable combined with UV-C radiation can generate an increase in antioxidant compounds in plant tissue. To reduce the volume and cost of discards, the objective of this study was to develop a flour from UV-C treated carrots with a higher content of bioactive compounds, which can be used as a functional ingredient in food production. We worked with Chantenay carrots produced in Santiago del Estero, Argentina. They were washed with potable water, disinfected in a NaClO solution (200 ppm for 5 min), drained, and grated using an industrial food processor. Except for the control, the grated carrots were irradiated with UV-C doses of 10, 25, and 50 kJ m-2. They were then placed evenly on plastic mesh trays in a forced-air dehydrator at 80°C for 4 h (optimized through previous work carried out by the group), obtaining a product with a humidity of 7-8% and aw= 0.4. Once dehydrated, they were ground in a knife mill and sieved through a N°18 mesh (1 mm). The color of the flours was determined using a Minolta colorimeter (CR-350), using the parameters L* (lightness), a* (red tones), and b* (yellow tones), and the C* (intensity) and Hue (hue) indices were also calculated. Total phenol content and antioxidant capacity were also determined. Results were analyzed by ANOVA, with a DLS test for comparison of means. The treatment with 10 kJ m-2 showed significantly higher a*, b*, and C* values, while the 50 kJ m-2 treatment showed the highest Hue. These UV-C treated flours showed higher phenolic compound content and greater antioxidant capacity (approximately 15%) compared to the control, with no significant differences between the applied doses. Proper waste management contributes to reducing food waste, and in this study, the results obtained were promising, as it was possible to add value to the discarded carrot, obtaining carrot flour with improved functional properties. This product can be used, along with other flours, to prepare foods, such as flour by products, among others.

Keywords: daucus carota; discards; functional flour.

USE OF COLLAGEN OBTAINED FROM THE WET BLUE PROCESS IN THE ORGANOMINERAL FERTILIZERS GRANULATION

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The bovine leather industry generates significant waste, with approximately 45% of the leather being discarded as trimmings. Collagen-rich waste is frequently deposited in landfills, creating potential environmental concerns including metal leaching and the loss of valuable nutrients. Annually, the leather industry produces around 600,000 tons of solid waste. The wet blue process, which involves alkaline hydrolysis of leather in a single step alongside dechroming, yields a liquid material rich in nitrogenous compounds (approximately 12% nitrogen) with an average production of 400 mL per kg of waste. The collagen particles obtained measure around 166 nm. In other hand, the organomineral fertilizer (OMF) industry is continuously seeking new nutrient sources from agricultural and agro-industrial waste. Collagen not only provides nitrogen in the form of amino acids but also enhances granule formation during the granulation process due to its colloidal properties. In this experiment, the OMF composition (dry weight) included 61% poultry litter, 30% monoammonium phosphate, 4% bentonite, 3% magnesium oxide, and varying collagen levels (0%, 1%, 2%, 3%, 4%, and 5%), resulting in a 05-20-02 NPK. Collagen was produced using the wet blue process at the Chemistry Department of Minas Gerais Federal University. The dry materials were mixed and homogenized, and the collagen solution was applied together with the granulation water during granulation using an Eirich E-05 mixer for 3 to 5 minutes at the Embrapa Solos Fertilizer Laboratory in Rio de Janeiro. Granules were dried at 65°C and sieved between 2 mm and 2.4 mm for the pot experiment. Formulations with higher collagen content started the granule formation faster than others. The addition of collagen partially replaced the water volume required during granulation representing environmental and economic advantages. Corn was used as the testing plant in pot experiments in two 45-day crop cycles (October to December 2024 and March to May 2025) in a greenhouse at the Rio de Janeiro Botanical Garden. A red-yellow Latosol, highly responsive to phosphorus, was limed, incubated for 60 days, then air-dried and sieved to 2 mm. The experimental design was randomized blocks (DBC) with eight treatments: zero P control, triple superphosphate (STP), and OMF (05-20-02) with varying collagen concentrations, applied in a dose of 100 mg kg-1 P in four replicates, totaling 32 two-liter pots. After harvesting the plants were dried and extracted for total nutrients. Shoot biomass and nutrient accumulation were determined as agronomic parameters. Although corn plants responded to phosphate fertilization, no significant differences were observed between the fertilizer sources. OMF showed the same agronomic performance as STP. Higher collagen levels in the OMF did not improve agricultural results or leave residual effects in the second crop cycle. The addition of up to 5% liquid collagen solution (12% N), recovered from the wet blue process to OMF formulation did not impact their agronomic properties. However, collagen improved the granulation process by reducing water usage and accelerating granule formation. This study highlights the potential of collagen from leather waste as a sustainable additive in fertilizer production, offering environmental benefits by recycling industrial by-products.

Keywords: organic residues; leather residues; recycling; fertilizer additives; maize; phosphorus.

PHOSPHORUS AVAILABILITY FROM ORGANIC AMENDMENTS: FIELD-BASED DETERMINATION OF THE B COEFFICIENT IN A MOLLISOL

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The application of livestock-derived by-products as organic amendments (OA) to agricultural soils is a sustainable strategy to recycle nutrients and promote circular nutrient economies. The OA application rates are commonly based on crop nitrogen (N) demand, despite their N: phosphorus (P) ratios often being lower than required by crops, leading to P overapplications. Effective nutrient management, particularly of P, requires accurate information on the increase in soil extractable P per unit of P applied—referred to as the b coefficient. However, this parameter remains poorly studied for OAs. The objective of this study was to estimate and compare the b coefficient of different OAs under field conditions. A field trial was conducted on a clay loam Mollisol in Balcarce, Buenos Aires, using a randomized complete block design with four replicates, testing three OAs: (i) chicken litter (CL), (ii) pig slurry (PS), and (iii) anaerobic digestate (DIG) from a digestor working with CL and PS, applied at four rates equivalent to 50, 100, 150, and 200 kg N ha^{-1}, based on total N concentration. A control treatment without OA was included. Amendments were applied 15 days before wheat (Triticum aestivum L.) sowing. Soil samples (0–10 cm) were collected at the crop sowing and harvest, and Bray-1 extractable P was determined. The total N to total P (Pt) ratio of the amendments was 3.6:1 for CL, 4.5:1 for PS, and 5.6:1 for DIG, with DIG showing the most favorable ratio relative to cereal crop needs (~6:1). Soil extractable P increased linearly with the amount of P applied, though the magnitude of increase varied among OAs. PS led to the greatest increases in extractable P per unit of P applied, with b coefficients at sowing and harvest of 0.70 and 0.56 mg kg^{-1} per kg ha^{-1} P applied, respectively. In contrast, CL and DIG exhibited lower b values of 0.39 and 0.22 at sowing and harvest, respectively. Based on harvest values, when soil P pools had stabilized, the P requirement (kg P ha^{-1} needed to increase 1 mg kg^{-1} of extractable P) was 1.8 for PS, and 4.8 for both CL and DIG. This latter value was similar to that reported for synthetic P fertilizers. These results suggest that OAs have contrasting impacts on soil P availability, likely due to differences in P chemical forms. This was further explored by quantifying the concentration of water-soluble P (WSP) in the OAs, which confirmed that the WSP:Pt ratio was 0.5 for PS and 0.3 for CL and DIG. Furthermore, when calculating the b coefficient based on WSP, no differences across OAs were observed at sowing and harvest: 1.4 and 1.0 mg kg^{-1} per kg ha^{-1} WSP applied, respectively. The observed variability among OAs should be considered for nutrient management in cropping systems receiving OA applications. Further research is needed to validate these findings across a wider range of OA types and soil conditions.

Keywords: digestate; pig slurry; chicken litter.

RECYCLING OF AGRICULTURAL WASTE IN THE CULTIVATION OF LAVENDER AND LAVANDINS

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The need to convert idle rural spaces and reduce the environmental impact of agricultural waste is driving the search for sustainable production alternatives. This paper presents an experience with the planting of lavender (Lavándula angustifolia) and three types of Lavender x Intermediate (Lavandin 'Abrial Grosso', Lavandin 'Super', and Lavandin 'Argentino') in a previously unused plot located on the Experimental Farm of the Faculty of Agronomy in Azul, Buenos Aires. Two objectives were set for this work: first, to revalue agricultural waste that was previously eliminated from the system through burning or discarding. Second, to evaluate the adaptation and productive potential of lavender and lavandin under sustainable management. The lavenders and lavandins used come from different productive areas of the country, allowing observation of their behavior and adaptation to the specific soil and climate conditions of the central Buenos Aires region. The planting was spaced 1 meter between plants and 1.2 meters between rows for lavender, and 1.2 meters between plants and 1.2 meters between rows for lavandin. Planting was done on ridges with mechanical intervention, without the use of synthetic chemicals, and using agricultural waste as cover. The residues used were: pea stubble, soybean stubble, fine crop threshing, and straw from livestock pens; from the farm and nearby farms. The residues applied as mulch and organic amendment contributed to conserving moisture, reducing weed emergence, and improving soil structure in the long term. Preliminary results show good adaptation of all the planted varieties, with expected differences in vigor, growth habit, and response to management. Among the hybrids, Lavandin "Super" produced the highest percentage of essential oils (%/100g of Fresh Weight, obtained by steam distillation) in its first year of harvest. "Super" also yielded 5.38 times more essential oils than Lavandula angustifolia. These initial results suggest that lavender could potentially be used for the production of dried flowers in this area. The experience demonstrates the potential of lavender and lavandin cultivation as a productive diversification strategy, with potential for added value through products such as dried flowers, essential oils, and natural cosmetics.

The residues applied as mulch made water use more efficient, reduced stress from high temperatures, contributed to the progressive regeneration of previously unproductive areas, and generated increased biodiversity. An increase in soil biological activity was observed, as well as the presence of beneficial insects and pollinators, particularly bees. Thus, agricultural waste could be considered strategic for a circular economy approach and territorial regeneration.

Keywords: agricultural waste; lavandula angustifolia; lavandins; super; biodiversity.

SOLARIZATION WITH RECYCLED POLYETHYLENE: A SUSTAINABLE AND INNOVATIVE ALTERNATIVE FOR SUBSTRATE DISINFECTION IN THE COMMERCIAL PRODUCTION OF TAGETES ERECTA AS AN ORNAMENTAL PLANT

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Substrate disinfection is essential in ornamental plant production to reduce phytopathogenic organisms and weeds. Solarization, which uses solar radiation to raise substrate temperatures, is an eco-friendly alternative to chemical disinfectants. Its effectiveness depends on the type of polyethylene used as a covering material and the temperatures achieved during the process. This study evaluated the effectiveness of solarization with recycled polyethylene and the feasibility of reusing disinfected substrates in the commercial production of Tagetes erecta, a widely cultivated ornamental species. The experiment was conducted using discarded substrate from ornamental crops at the Floriculture Institute (INTA, Buenos Aires), primarily composed of peat, composted pine bark, and perlite. Three treatments were applied: T1, solarization with new transparent polyethylene (50 microns); T2, solarization with recycled polyethylene from greenhouse roof replacements; and T3, non-solarized discarded substrate as a control. Solarization was performed in wooden boxes placed in the field at the end of summer, following a completely randomized design with three replications. Physical, chemical, and phytopathological characteristics of the substrates were measured. After solarization, substrates were used to grow Tagetes erecta in a greenhouse, adding a fourth treatment (T4), which consisted of a commercial substrate of similar composition with no prior use. Growth parameters (height, width, biomass, and chlorophyll, SPAD index) and weed incidence were recorded. Statistical analysis was performed using ANOVA and Tukey's test ($p<0.05$). Solarization treatments (T1 and T2) reached significantly higher temperatures than the control, reaching up to 45°C, about 15°C above ambient temperature, suitable for effective pathogen and weed control. No significant differences were found in pH, electrical conductivity (ds/m), or nutrient content (mg/l) among solarized treatments, with average values of pH 6, 5.9 and 6; EC 1.2, 1.1, and 1.2; $N\text{-}NO_3^-$ 134, 145, 160; P 25.4, 24.6, 22.9; Ca 3.09, 3.25, 3.04; Mg 4.62, 4.95, 5.23; K 75.56, 75.64, 81.42; Na 297.75, 291.85, 320.34 for T1, T2, and T3, respectively. No significant differences were observed in physical properties such as bulk density, porosity, or water retention, which remained within typical ranges for similar substrates. Organic matter decreased in all treatments, from 70% pre-solarization to 64% in T1, 62% in T2, and 60% in T3, likely due to mineralization accelerated by high temperatures. Phytopathological analysis showed no pathogenic fungi in solarized substrates, while beneficial fungi such as Trichoderma spp., Mucorales, and Paecilomyces sp. were more abundant and diverse in T1 and T2 than in the control. This indicates that solarization eliminates harmful microorganisms while preserving or enhancing beneficial microbiota. Plant growth was comparable in solarized and commercial substrates, with no significant reduction in morphological traits. Weed incidence was substantially lower in solarized treatments—40% in T1, 27% in T2—compared to 80% in the control and 0% in the commercial substrate (T4). In conclusion, solarization with recycled polyethylene is an innovative, effective, and sustainable technique for disinfecting reused substrates without compromising their suitability for commercial Tagetes erecta production. This method helps reduce agricultural waste, lowers production costs, and promotes circular economy practices in ornamental horticulture.

Keywords: solarization; substrate disinfection; recycled polyethylene; ornamental plant; reuse; circular economy.

POULTRY LITTER EFFECTS ON SOIL HEALTH AND CROP PRODUCTIVITY IN A VERTISOL FROM ARGENTINA

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Poultry litter (PL) is emerging as a strategic alternative to chemical fertilizers in Entre Ríos province (Argentina), showing both immediate and residual positive effects on crop productivity and soil quality. This study aimed to evaluate the impact of PL application on selected soil quality indicators and crop productivity within two crop sequences in a Vertisol from Entre Ríos. The experiment was conducted at the “El Tacu de San Cayetano” farm, near the town of Gilbert, on a Peludertic Argiudoll. A maize–cover crop (oat)/soybean sequence was compared with an alternative sequence including giant sorghum (Agri-002e)–soybean. For sorghum, two residue management strategies were evaluated: with and without residue incorporation through tillage. As a second treatment factor, PL was applied at three rates: 0X (control), 1X (6 tons ha^{-1}), and 3X (18 tons ha^{-1}), each with three field replications. Aerial biomass, maize grain yield, and forage quality (digestibility, metabolizable energy) were measured in maize and sorghum. Soil physical, chemical, and biological properties were assessed at the beginning and 14 months after the start of the experiment. PL application did not significantly affect maize grain yield, but it improved biomass production and forage quality in maize, oat, and sorghum. In soybean, both grain yield and biomass were 16% higher on average in PL treatments, regardless of the preceding crop, indicating a residual effect. While no major short-term changes were observed in most soil indicators, PL improved structural stability and showed trends toward increased microbial biomass carbon and anaerobic nitrogen in the non-incorporated sorghum treatment. These findings highlight the potential of PL as a valuable organic fertilization and management strategy for improving soil health and crop productivity in Entre Ríos agricultural systems.

Keywords: organic amendments; maize; sorghum; forage quality; soil quality.

VALORIZATION OF SUNFLOWER CAKE AS AN ENHANCER OF HYDROCARBON BIODEGRADATION IN THE TREATMENT OF CONTAMINATED EFFLUENTS

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The management of bilge water from ships, which contains high concentrations of hydrocarbons (HC), demands effective and sustainable solutions. Biological treatments emerge as a viable alternative due to their low cost and good efficiency, although they often require longer treatment times. In this context, the valorization of agricultural by-products such as sunflower cake—rich in protein and widely available in Argentina—offers an innovative approach to enhance biodegradation. This study evaluates the use of a protein extract obtained from sunflower cake as a medium supplement to enhance microbial growth and HC degradation. The extract was prepared by aqueous extraction (1:10 w/v, pH 7), agitation, and centrifugation, followed by lyophilization, yielding a concentrate with 32% protein content. An autochthonous microbial consortium, isolated and enriched from bilge water of ships and previously characterized as hydrocarbon-degrading, was used. It was cultured in sterile marine salt medium (pH 8) with varying concentrations of HC (0–2% v/v) and the protein extract (0–1% v/v) for 15 days at 25 °C. Microbial growth was monitored by OD600 nm and HC degradation was assessed using infrared spectroscopy. The consortium showed growth in all tested conditions. Without the extract, the maximum specific growth rate (μ_{max}) was 1.3 d^{-1} with a doubling time (DT) of 12.6 h. With 0.05% extract, μ_{max} increased to 1.7 d^{-1} (DT: 9.7 h), and with 0.2%, μ_{max} nearly doubled to 2.8 d^{-1} (DT: 5.9 h). At 0.5%, μ_{max} was 2.1 d^{-1} (DT: 7.8 h), indicating a clear kinetic improvement. Regarding HC removal, on day 5 the control (no extract) reached 52.9% ± 1.6 degradation, while 0.05% and 0.5% extract treatments showed 71.7% ± 5.7 and 80.2% ± 6.3 respectively. By day 10, these values increased to 63.0% ± 5.6, 80.9% ± 6.3, and 90.0% ± 4.7, displaying a dose-dependent and statistically significant pattern ($p < 0.0001$). These results demonstrate that the protein extract acts as a source of carbon and nitrogen, improving both microbial growth and degradation. Additionally, its emulsifying potential could enhance HC bioavailability. This approach integrates agro-industrial waste valorization with clean technologies, promoting sustainable and cost-effective processes. Its application in marine effluent treatment plants could reduce the environmental footprint of the oilseed industry and operational treatment costs.

Keywords: sunflower cake; hydrocarbon; biodegradation; protein extract; bilge.

PRODUCTION OF CANNED CARROT PASTE: AN ALTERNATIVE TO OBTAIN A NUTRITIONAL AND SAFE FOOD FROM DISCARDS

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The carrot crop in Argentina, with an annual production of 50,000 tons, generates approximately 30 % discards, representing both a resource loss but an opportunity to develop value-added products, enhance food security, and reduce environmental impact. This study aimed to optimize processing and preservation of discarded carrots to obtain a functional ingredient with potential applications in food industry. Carrots from washing facilities in southeastern Buenos Aires province, were disinfected, peeled, diced, and treated as follows: blanching for 3 min at 100 °C (B3), 10 min at 100 °C (B10), or no blanching (B0). After that, samples were milled into a paste, weighed, packed in 800 g tinplate cans, and sterilized (115 °C, 80 min). Color (CIELab*, Minolta CR300 colorimeter), dry matter content (%DM), total carotenoids (TCa, spectrophotometry at 470 nm), total phenolics (TP), and antioxidant capacity (AC) by FRAP and ABTS assays, were evaluated at canning (t0) and after 12 months of storage at room temperature (t12). For each variable, treated samples were compared to a fresh carrot sample (C). Additionally, aerobic mesophilic bacteria, total coliforms, Clostridium spp., and Bacillus spp. were analyzed. All determinations were performed in triplicate. A generalized linear model ($\alpha = 0.05$) was used for variance and statistical analysis. The %DM decreased significantly with longer blanching times (B0: 11.73%; B3: 10.22%; B10: 9.14%), suggesting water absorption during processing. The redness index (a* value) was lower in all treated samples (B0, B3 and B10) than in fresh one ($p < 0.0001$), possibly due to degradation or transformation of β-carotene during thermal treatments. Brightness (L* value) decreased during storage ($p = 0.01$). At t12, B10 showed the least intense orange color (a*: 7.7 b*: 55.5), indicating that prolonged blanching times negatively affect color retention. The TCa values were similar between the fresh carrot and B3 samples, even after 12 months of storage. In contrast, B0 and B10 samples exhibited about 15% lower TCa levels. TP increased significantly following thermal treatments ($p<0.0001$), possibly due to greater availability of reducing compounds from cell rupture during processing. AC-ABTS and AC-FRAP values were significantly higher in all pastes compared to fresh carrot ($p < 0.002$), although they decreased moderately at t12. AC-FRAP was also higher in the pastes ($p < 0.001$), with B3 and B10 showing the best performance. At t12 compared to t0, reductions in TP and AC values did not exceed 25% (TP: $p < 0.04$; AC-ABTS: $p = 0.006$; AC-FRAP: $p = 0.001$). No microbial growth was detected in any treatment, confirming effective sterilization and safety after 12 months. Unexpectedly, the canned pastes exhibited superior nutraceutical properties compared to the fresh vegetable. However, in a preliminary descriptive sensory test conducted with a trained panel, a bitter taste was detected in B0 paste, possibly due to polyphenol oxidase activity, whereas B3 and B10 pastes were described as sweeter and more pleasant. Blanching for 3 min (B3) achieved the best balance of quality attributes, offering a safe, nutritionally valuable, and viable alternative to valorize carrot discards and promote a circular economy.

Keywords: valorization; canned foods; antioxidant capacity; blanching; sterilization.

SUNFLOWER HULLS AS LIGNOCELLULOSIC CARRIERS FOR THE IMMOBILIZATION OF HYDROCARBON-DEGRADING BACTERIA AND THEIR MONITORING VIA LASER SPECKLE IMAGING

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The global expansion of agricultural production is generating large volumes of lignocellulosic waste, which require sustainable recovery strategies. Beyond their traditional use in construction and energy, lignocellulosic residues are promising feedstocks for developing supports for enzyme and microbial immobilization. This technique consists of attaching biocatalysts to an insoluble matrix to enable their recovery and reuse. Suitable supports must be inert, mechanically stable, renewable, and low-cost characteristics well met by lignocellulosic materials. In this study, we investigated the potential of sunflower seed hulls as a lignocellulosic support for the immobilization of a hydrocarbon-degrading marine bacterium (Marinobacter sp.), with the aim of applying the resulting bio-carrier in bioremediation processes. Sterilized sunflower hulls (0.22 g) were incubated in 50 mL of artificial seawater supplemented with yeast extract (0.1% w/v), bilge hydrocarbons (0.25% v/v), and a bacterial inoculum. The number of colony-forming units (CFU) per gram of hulls was monitored over time. Maximum immobilization was observed between 24 and 72 hours (3,26 ± 8,53E+10 UFC/G), after which CFU counts declined, suggesting a passive immobilization mechanism predominantly governed by physicochemical interactions between the bacterial cells and the substrate. Subsequently, the immobilized biomass was lyophilized in the presence of mannitol (0.5% w/v) as a cryoprotectant. Although viable cells remained after lyophilization, a reduction of approximately three orders of magnitude in CFU counts was detected. In parallel, we evaluated for the first time the use of a non-invasive technique based on laser speckle analysis to detect microbial activity on sunflower hulls. The preliminary results indicate that this approach may serve as a promising tool for monitoring cell immobilization on lignocellulosic carriers. To monitor bacterial activity on the lignocellulosic support, we implemented laser speckle imaging (LSI) as a non-invasive optical technique capable of detecting dynamic changes at the microscale. Pseudocolor images generated from speckle pattern analysis revealed increasing activity over incubation time, consistent with the progression of bacterial adhesion and colonization. Time-resolved speckle activity curves indicated a temporal evolution in signal intensity, peaking between 24 and 72 hours—coinciding with the period of highest CFU recovery—although direct correlations have not yet been quantified. These results suggest that LSI can serve as a qualitative, real-time tool to assess microbial immobilization dynamics on complex natural matrices such as sunflower hulls. Further work will focus on establishing quantitative correlations between speckle signal and traditional microbiological parameters.

Keywords: sunflower; hulls; bacteria; inmobilization; laser speckle imaging.

STARCH EXTRACTION FROM RUMEX CRISPUS AND BIOPLASTIC PRODUCTION

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Rumex crispus is an invasive weed commonly found across a wide range of landscapes in Colombia. Due to its high reproductive capacity—both by seeds and vegetative fragments—it competes aggressively with crops and pastures. This study explores the potential of using this species, typically regarded as a problematic plant, as a source of starch for the development of biodegradable plastics. The objective was to extract starch from Rumex crispus roots and evaluate its potential for bioplastic production, focusing on its mechanical strength and water solubility. The roots were collected at the Marengo Agricultural Center (Universidad Nacional de Colombia, Bogotá). After selecting vigorous plants, roots were thoroughly washed, blended with distilled water, filtered through cloth, and left to settle for three hours. The sediment was dried at 40 °C for 24 hours, then ground into a fine powder.

Bioplastics were formulated using 10 g of starch, 60 ml of distilled water, 10 g of alginate, and 10 ml of vinegar. The mixture was heated to 150 °C and stirred at three different speeds (500, 800, and 1400 rpm) in 5-minute intervals to form a homogeneous paste. The paste was spread evenly on a vegetable-oiled tray and oven-dried at 40 °C for 48 hours.

The resulting bioplastics varied in hardness and resistance depending on their thickness, supporting weights of 2, 4, and 6 kg. One application included the creation of a mousepad, which has remained in daily use at the Universidad Nacional's herbarium for four months without damage. From 100 g of fresh roots, 20 mg of starch were obtained, representing a 0.2% extraction yield.

While this yield is lower compared to conventional sources like cassava, the ubiquity and persistence of Rumex crispus make it an accessible and low-cost alternative for sustainable material development. Moreover, harvesting this weed for starch extraction may contribute to its population control and reduce the need for chemical herbicides. This research highlights the opportunity to convert an invasive species into a valuable input for environmentally friendly bioplastic production.

Keywords: starch; bioplastic; rumex crispus; weed management; biodegradable materials.

VALORIZATION OF AGRO-INDUSTRIAL WASTE FOR THE DEVELOPMENT OF A SILAGE-BASED NUTRITIONAL CORE FOR ANIMAL FEED

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The bioconversion of biological industrial residues through acidification or ensiling can be achieved via anaerobic fermentation, resulting in lactic acid production. This process preserves the nutritional quality and palatability of the product at a low cost, making it a viable supplement for animal feed. Sorghum, an underutilized regional crop rich in proteins and carbohydrates, presents a valuable substrate for fermentation. The objective of this study was to compare the fermentation performance and nutritional contribution of mixtures comprising poultry industry residues (Re) and sorghum flour (S) as protein and carbohydrate sources, against mixtures containing powdered egg (Hue) and corn flour (M) as protein and carbohydrate standards. Fermentation progress was monitored in four formulations Re-M, Re-S, Hue-M, and Hue-S, at baseline (t0), 15 (t15), 30 (t30), and 60 days (t60). Poultry residues were autoclaved to eliminate pathogens and enhance protein digestibility. A commercial lactic bacteria inoculum was employed to initiate fermentation. Additionally, α-amylase and papain enzymes were added at the start to hydrolyze complex substrates into fermentable sugars and amino acids, facilitating microbial development. Enzymes were allowed to act for one hour prior to inoculation. Fermentation was conducted at 32 °C in a controlled chamber throughout the study period. At each time point (t0, t15, t30, t60), microbial analysis was performed via plate culturing (32 °C 24 h) to assess the presence of Salmonella spp., Staphylococcus aureus, Escherichia coli, total coliforms, Enterobacter spp., and lactic acid bacteria. Analytical assessments included : free amino acid quantification by ninhydrin method, carbohydrate (glucose, maltose, DP4—tetrasaccharides) and lactic acid content via HPLC, proximate composition using infrared spectroscopy (IR), along with moisture content and pH measurements. Results indicated that the treatment of Re effectively inhibited pathogenic bacterial growth, although fungal proliferation was observed from t60 onward. Lactic acid bacteria exhibited similar growth kinetics across all treatments, with gradual reduction over time, increased concentrations progressively, reaching values of: Re-S = 4.9, Re-M = 4.2, Hue-S = 3.3, and Hue-M = 3.1 g/L. Corresponding pH reductions were: 2.4 for Re and 1.5 for Hue treatments. Initial enzymatic hydrolysis generated combined glucose-maltose-maltotriose concentrations of 7.3 g/L (Re-S), 6.4 g/L (Re-M), and 6.9 g/L in both Hue formulations. These sugars were steadily consumed by lactic acid bacteria over time, with complete depletion of DP4 by t15. Sugar consumption was faster in sorghum-based samples (S), with complete utilization by t15, whereas corn-based samples (M) retained residual sugars up to t30. Correspondingly, lactic acid production was lower in M-based treatments. Moisture content and free amino acid levels remained relatively stable throughout the fermentation process. Nutritional analysis revealed that the silages exceeded murine requirements in fiber, total lipids, proteins, and omega-6 fatty acids, but were deficient in carbohydrates and omega-3 fatty acids. The Re-based mixtures aligned more closely with murine nutritional standards. In conclusion, acidification through fermentation was successfully achieved by day 15 and remained effective through day 30. These findings provide a foundation for subsequent studies on the acceptability and digestibility of this silage-based nutritional core in murine diet formulations.

Keywords: valorization of poultry waste; lactic fermentation; animal feed;.

OPTIMIZING DIGESTATE BIOCHAR FOR NUTRIENT-RICH HYDROPONIC FEED

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The increasing global food demand and environmental concerns have driven agriculture toward circular economic strategies, including the valorization of digestates from biogas plants. Although digestates can be used in agriculture, their direct application poses risks such as phytotoxicity, inconsistent composition, and potential pathogen presence. To address these issues, slow pyrolysis can convert digestates into biochar, a more stable and agronomically beneficial form. The properties and performance of biochar are influenced by both the feedstock type and pyrolysis conditions, particularly temperature. This study explored the use of biochar derived from different types of solid digestates—pork (DSP), bovine (DSV), and dairy (DST)—to enhance hydroponic maize fodder production. The objectives were to: (1) identify the optimal pyrolysis temperature balancing carbon stability and nutrient availability; (2) determine the most effective biochar treatments for hydroponic systems; and (3) assess how different doses of the best-performing biochar influence the nitrogen and crude protein content in forage.

Digestates were collected from biogas plants in Argentina, and pyrolyzed at 400, 500, and 600 °C for two hours. The biochars (BDSP, BDSV, BDST) were characterized by their ash content, volatile matter, fixed carbon, elemental composition (C, H, O), moisture, pH, and electrical conductivity. A factorial experiment tested the effect of biochar type, temperature, and dose (0, 1.25, 2.5, 6.25 g/container) on hydroponic maize grown under controlled conditions. After eight days, measurements were taken for fresh weight, dry weight, moisture content, and chlorophyll levels. The most promising treatment was further analyzed for crude protein and nitrogen content using the Kjeldahl method.

The results showed that biochar properties were influenced more by feedstock than by temperature. All biochars were alkaline and carbon-rich, but BDST-500 (dairy digestate at 500 °C) had the most favorable characteristics: low volatile matter and moisture, moderate ash content, low electrical conductivity, and high stable carbon. The agronomic performance of hydroponic maize forage varied significantly with biochar type, pyrolysis temperature, and dose. Biochar from dairy digestate (BDST) at 500°C, especially at the highest dose, showed the best results in chlorophyll, fresh and dry weight, and moisture. Also, BDST biochar had lower salinity and higher carbon content, promoting better nutrient uptake and growth. Significant interactions between digestate type, temperature, and dose highlight that biochar effectiveness depends on the specific combination of these factors rather than any alone. BDST-500 biochar was the best treatment, significantly increasing nitrogen and crude protein in hydroponic maize fodder as application rates rose. The highest dose (6.25 g/container) improved nutritional quality without causing salt stress, supporting better nitrogen assimilation and protein accumulation.

The study concludes that biochar from dairy digestate pyrolyzed at 500 °C and applied at 6.25 g/container is the most effective amendment for hydroponic maize fodder systems. It improves plant growth, moisture, chlorophyll, and protein content while maintaining environmental safety. These findings support the use of dairy-based biochar as a valuable component in sustainable, soilless agriculture and promote its integration into circular bioeconomy strategies.

Keywords: nutrient cycling; waste valorization; soilless cultivation; sustainable agriculture; organic waste management.

DEVELOPMENT AND ASSESSMENT OF COMPOST-BASED BIOPRODUCTS: EFFECTS OF COMPOST PELLETS AND TEA ON TOMATO YIELD AND SUBSTRATE PROPERTIES

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The reuse of animal production waste is a key strategy for developing bioproducts that can partially or fully replace the use of inorganic fertilizers, promoting more sustainable agricultural systems. Anaerobic digestion enables the transformation of these wastes into digestate, from which a liquid fraction—potentially usable as a biofertilizer—and a solid fraction—suitable for composting into a stable, nutrient-rich product—can be obtained. This study aimed to develop and evaluate bioproducts derived from composted pig digestate for application on tomato crops (Solanum lycopersicum). Compost pellets were produced using a flat-die pelletizer (100 kg/h, 150 rpm) with compost at 25% moisture content. The resulting 6 mm-diameter pellets were dried at 60 °C until reaching 10% moisture. Additionally, compost tea was prepared by mixing compost and water in a 1:3 ratio (50 L compost:150 L water), aerated for 24 hours, and stored at room temperature. Bioproducts were tested under greenhouse conditions using three application doses per input type and five replicates per treatment. The control treatment consisted of tomato plants irrigated with tap water. Compost was mixed with the substrate at 10%, 20%, and 30% (v/v); pellets were applied at 5, 10, and 15 g per pot; and compost tea was applied weekly at 1/3, 2/3, and full-strength (3/3) dilutions.

Results showed that, in terms of crop yield, significant increases in fresh plant biomass at harvest were observed with 15 g of pellets (107.8 ± 10.9 g), 2/3 compost tea (112.9 ± 3.77 g), and 10% compost (130 ± 13.01 g), compared to the control (74.5 ± 12.58 g). Regarding dry biomass, increases were also observed with 30% compost and full-strength tea (3/3). The number of tomatoes per plant was significantly higher with 10% compost (8.8 ± 0.84), 2/3 tea (10.6 ± 2.07), and 3/3 tea (10.2 ± 2.28), compared to the control (3.4 ± 0.55). Total tomato weight per plant increased with 15 g of pellets, 1/3 and 3/3 tea, and 10% compost.

Regarding substrate properties, pH increased with 2/3 tea, 20% compost, and pellets at 10 and 15 g (values between 8.3 and 8.4 vs. 8.1 in the control). Electrical conductivity increased significantly only with 10% compost (756.3 ± 209.6 vs. 310.1 ± 42.4 µS/cm). For available nutrients, soluble phosphorus levels were significantly higher in all compost treatments (194.5–267.9 vs. 8.2 ± 2.8 mg P/kg DM in the control), while nitrate levels showed no differences. Among soluble cations, Zn, Cu, Mn, Ca, and Mg concentrations did not differ significantly from the control. However, potassium increased with full-strength tea (106.4 ± 7.2 vs. 53.3 ± 4.8 mg K/kg DM), and sodium with 10% compost (4618.8 ± 894.9 vs. 2983.6 ± 184.9 mg Na/kg DM).

The results demonstrate that compost-derived bioproducts, when applied at appropriate doses, can improve tomato crop performance in both solid and liquid formulations. In particular, the treatments of 15 g of pellets, 2/3 and 3/3 compost tea, and 10% compost showed the greatest potential, positioning them as viable and sustainable alternatives to synthetic fertilizers.

Keywords: compost; bio-base products; compost pellets; compost tea; organic amendments.

EVALUATION OF THREE SUBSTRATES AND TWO CONTAINER SIZES IN THE PRODUCTION OF CANNABIS (CANNABIS SATIVA L.) SEEDLINGS FOR MEDICINAL PURPOSES

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A quality seedling is identified by a vigorous stem, adequate height, absence of chlorosis, good root development, and freedom from pests and diseases. When the root growing within a tray reaches the base of the cell, apical growth is inhibited and branching of the adventitious system is stimulated, reducing the movement of cytokinins and auxins toward the vegetative apex. The smaller the cell, the more quickly this situation is reached. This constitutes stress that affects the plant's potential yield. Furthermore, the substrate where the roots will develop must provide a favorable environment for root development and vegetative growth. The main functions of the growing medium are nutrient source, water retention and availability, adequate gas exchange, and plant support. Evaluating the interaction between growing medium type and container size would allow for optimized use of inputs and space under nursery conditions, favoring the production of vigorous and uniform cannabis seedlings. The objective of this study was to evaluate the interaction of three growing mediums and two container sizes on the growth and quality of cannabis seedlings from botanical seeds. The work was carried out on the NIRVANA SAS farm in La Virginia, Tucumán province. The cannabis seeds were sown and conditioned in a germination chamber with LED lights, with a 24:0 light cycle. Three substrates were compared: GrowMix® Multipro New, GrowMix® Multipro Recycled by solarization, and Kekkilä Professional, used in two container sizes (Forest Trays - 100 cc - and Disposable Cups - 200 cc). A completely randomized statistical design with a factorial arrangement was used. Data were subjected to analysis of variance, and differences between means were compared using the Fisher LSD test (□ = 0.05). The chemical characteristics of the substrates were analyzed and compared. Seven days after sowing, germination percentage was recorded, and after 34 days the following were measured on the seedlings: Height, stem diameter, fresh above-ground weight, dry above-ground weight, leaf area, and leaf chlorophyll content. No interaction between substrates and container sizes was detected for any of the variables analyzed. The germination percentage was higher with Kekilä, but the Recycled GrowMix® performed best in the remaining variables evaluated, significantly outperforming the New GrowMix® and, to a lesser extent, the Kekkilä. The presence of Ca and Mg played a fundamental role in the growth of the cannabis seedlings. It is suggested that the characteristics of the selected substrate be tailored to the requirements of the species to be propagated, considering adjustments such as flushing and/or supplemental fertilization to balance nutrients or adjust values such as pH and EC. Regarding container size, the germination percentage was higher in the Forestry Trays, but vegetative development was greater in the Disposable Cups for the remaining growth parameters.

Keywords: medicinal cannabis; substrate; seedlings; container size.

UTILIZATION OF WASTED KIWIFRUIT: PRODUCTION OF DEHYDRATED PRODUCTS AS A NATURAL SOURCE OF ASCORBIC ACID

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Globally, over 30% of fruits and vegetables are discarded during production. In Argentina, the southeastern Buenos Aires Province is the main kiwifruit production area (Actinidia chinensis var. deliciosa, cv. Hayward), a fruit rich in antioxidants. Annually, at least 130 tons—mostly healthy fruit that fails to meet commercial size standards—are discarded. This perishable by-product is a valuable source of bioactive compounds such as ascorbic acid (AA). In this context, thermal dehydration emerges as an effective, accessible technique to preserve and valorize this fruit for potential use as functional ingredients or natural preservatives.

The aim of this study was to evaluate the effect of different convective air-drying temperatures on peeled and unpeeled discarded kiwifruit in terms of AA content and microbiological quality, to identify the most suitable processing condition.

'Hayward' kiwifruits stored under refrigeration for one month—coinciding with the peak of selection and packing for export and fruit discard detection—were used. A total of 18 fruits with peel were sliced and dehydrated at 35, 50, and 70 °C to constant weight. The same procedure was applied to 18 peeled fruits. Dehydrated samples and a fresh control were ground and analyzed for AA content by UHPLC-MS/MS. All determinations were performed in triplicate. Microbiological quality was assessed through conventional methods by counting total mesophilic aerobic bacteria (TMAB), yeasts and molds (Y&M), psychrophilic bacteria, coliforms, Bacillus, and sulfite-reducing Clostridium.

The results show that no significant differences in AA content were observed among drying temperatures or between peeled and unpeeled kiwifruit ($p>0.05$). Dehydrated powders retained a 96% of AA content relative to fresh fruit, with a mean of 409±1 mg/100 g DW.

Microbiological analysis revealed no detectable colony-forming units (CFU) of psychrophilic bacteria, coliforms, Bacillus, or Clostridium in any sample. A significant main effect ($p<0.05$) of both fruit type (with and without peel) and drying temperature (35, 50, 70°C) was observed for TMAB and Y&M counts. Unpeeled fruits showed higher microbial loads (TMAB: $5.6\pm 0.5\times10^3$ CFU/g; Y&M: $3.1\pm 0.2\times10^3$ CFU/g) compared to peeled fruits ($1.5\pm 0.5\times10^3$ and $5.7\pm 0.2\times10^2$ CFU/g, respectively), showing the need for a prior disinfection step. Regarding temperature, fruits dehydrated at 35 °C had significantly higher TMAB counts than fresh fruits, while samples dried at 50 and 70 °C showed no significant differences. No temperature effect was found for Y&M counts. Although Argentine food regulations (Código Alimentario Argentino) do not have any specific microbiological criteria for this dried fruit, we found that counts of the different groups in the kiwi powders fall within the permissible limits, considering similar regulated products.

These findings support the use of convective dehydration as a feasible strategy to recover AA from wasted kiwifruit, even without peeling, thus saving time and processing resources. Moreover, our results demonstrated that kiwifruit, as raw material, has specific properties that confer the capacity of protecting AA against thermal degradation, enabling the selection of drying temperature and conditions based on energy efficiency without compromising nutritional quality. This approach allows for the production of natural, value-added powders and contributes to reducing food waste.

Keywords: vitamin c; food loss; value-added products; food safety.

SELECTION OF DEHYDRATION TECHNOLOGIES TO RECOVER ASCORBIC ACID FROM KIWIFRUIT DISCARDS

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The increasing volume of discards and loss associated with fruits and vegetables is driving the search for valorization strategies to transform these by-products into functional ingredients. In Argentina, the southeastern region of Buenos Aires accounts for the largest national production of kiwifruit (Actinidia deliciosa). It is estimated that at least 130 tons are discarded annually due to not meeting commercial size standards, despite being healthy fruits. Kiwifruit is rich in bioactive compounds, including ascorbic acid (AA), known for its antioxidant capacity and nutritional relevance. Recovering these discards through the production of dehydrated powders represents a sustainable alternative for obtaining value-added ingredients for potential use in the food industry.

The aim of this study was to compare the effect of convective thermal drying (70 °C), freeze-drying, and spray-drying on the AA content in discarded kiwifruit.

A sample of ‘Hayward’ kiwifruits with peel, stored under refrigeration (0°C, 95% HR) for one month, was selected. After a month of post-harvest cold storage, the largest volume of waste is detected. Convective drying (T1) was applied to fruits (slices) at 70 °C using a food dehydrator until constant weight was reached. For freeze-drying (T2), fruits were frozen at -80 °C and subjected to vacuum sublimation (Labconco™ FreeZone™ Freeze Dryer). The dehydrated samples from T1 and T2 were ground and stored under low humidity conditions. For spray-drying (T3), fruits were blended and used to prepare aqueous extracts (sample: solvent ratio, 0.6). Different encapsulating agents 30% (w/v) (maltodextrin, gum arabic, and their combination) were tested, and the samples were spray-dried (Büchi Mini Spray Dryer B-290; inlet temperature: 160 °C; feed rate: 25%). AA content was determined by UHPLC-MS/MS and expressed in mg/100 g dry weight (DW), in 3 replicates for all powders and a fresh control.

No significant differences were observed between the fresh control (424.6±11 mg AA/ 100 g DW) and powders from T1 and T2 ($p > 0.05$), with an average of 416±21 mg/100 g DW (range: 402.7±21 to 424.6±11 mg/100 g DW). Powders from T3 showed a significantly lower AA content (68.6±21 mg/100 g DW; $p < 0.05$). Despite the high biopolymer content in the spray dried powder, the process efficiency was evaluated and found to be 29.7%.

Both convective drying at 70 °C and freeze-drying preserved the AA content, at similar concentration to fresh fruit, highlighting the remarkable protective effect of the kiwifruit matrix on AA stability, even under intensive dehydration processes like T1. Although further studies are needed to evaluate AA stability a throughout the useful life of these powders, since spray-dried may have some advantages over the rest, the results suggest that recovering and stabilizing these discards through theese technologies is a promising option for the valorization of rejected kiwifruit, due to its lower investment requirements and greater scalability.

Keywords: vitamin c; valorization; thermal drying; freeze-drying; microencapsulation.

FROM BY-PRODUCTS TO FUNCTIONAL INGREDIENTS: VALORIZATION OF FLAXSEED EXPELLER AS A SUSTAINABLE SOURCE OF ANTIOXIDANT PEPTIDES THROUGH ENZYMATIC HYDROLYSIS

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The growing global demand for functional foods has encouraged the exploration of natural sources with bioactive properties that contribute to the prevention of chronic diseases. The oilseed industry produces agro-industrial by-products that are rich in nutritionally valuable compounds, such as proteins. A representative example is flaxseed (Linum usitatissimum) expeller, a solid cake obtained after oil extraction. This by-product is commonly used for animal feed or simply discarded, which not only increases the carbon footprint and contributes to environmental degradation, but also leads to the loss of a material with significant potential as a source of bioactive compounds. Its revalorization is in line with the principles of the circular economy and sustainable production, promoting a more efficient and responsible use of natural resources. The aim of this study was to evaluate the potential of flaxseed expeller as a source of antioxidant peptides, through its transformation by enzymatic hydrolysis using different strategies, for potential application in functional foods or nutraceuticals. A protein extraction process was developed using defatted flaxseed flour, obtained by ethanol treatment (85%) followed by grinding. Proteins were solubilized under alkaline conditions (pH 10) and then subjected to enzymatic hydrolysis at 55 °C for 4 hours (pH 7.5), with constant agitation (110 rpm). Four hydrolysis strategies were compared: individual use of Alcalase (A) or Flavourzyme (F); simultaneous combination of both enzymes (A+F-SI); and sequential combination (A+F-SE), applying Alcalase for 4 h followed by Flavourzyme for an additional 4 h. The degree of hydrolysis (DH%) was determined by the OPA method, and the in vitro antioxidant capacity (AA%) of the hydrolysates was assessed by the ABTS assay. Results showed that the combined strategies (SI and SE) led to higher degrees of hydrolysis (51.14 ± 2.5% and 53.16 ± 1.35%, respectively) compared to individual enzymes, with the simultaneous strategy standing out due to its lower operational complexity and shorter total processing time (4 h vs. 8 h). Regarding potential bioactivity, hydrolysates obtained with individual Alcalase exhibited the highest antioxidant capacity (up to 36.49 ± 1.5%), while Flavourzyme had a lesser effect. The combined strategies did not significantly enhance the in vitro antioxidant activity compared to individual Alcalase, suggesting that the hydrolysates released by this enzyme are responsible for the observed bioactivity. This study provides evidence of the feasibility of valorizing flaxseed expeller as a low-cost protein-rich raw material, proposing a low-impact technological strategy for its incorporation as a high-value functional ingredient. The valorization of by-products such as flaxseed expeller contributes to the development of more efficient and sustainable production systems, responding to the evolving demands of the food industry and the Sustainable Development Goals.

Keywords: flaxseed expeller; enzymatic hydrolysis; antioxidant peptides; waste valorization; circular economy.

EVALUATION OF POULTRY LITTER APPLICATION ON SOIL PHOSPHORUS AND NITRATE LEVELS IN AN AGRICULTURAL ROTATION SYSTEM IN ENTRE RÍOS

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The sustained growth of poultry production in Entre Ríos Province generates a large amount of organic residues that, if properly managed, can be used as amendments to improve the soil's physico-chemical properties. This study evaluated the effect of poultry litter, in two forms—composted and uncomposted—on the levels of available phosphorus (P-Bray) and nitrate (NO_3) in a corn crop.

Two treatments were evaluated: composted poultry litter (T1) and uncomposted poultry litter (T2), compared to an unfertilized control (T0). The application rate was adjusted to supply 3000 kg of organic carbon per hectare. For this purpose, 16,111 kg of dry matter (DM) were applied in T1 and 6,319 kg DM in T2. The macronutrient inputs were 328.7 kg N and 246.5 kg P in T1; and 215 kg N and 96.7 kg P in T2.

During the 2023/2024 growing season, seven soil samplings were conducted between November 29, 2023, and July 12, 2024, with increased frequency during January and early February. Sampling depth was 0–5 cm. P-Bray and NO_3 levels were analysed using non-parametric tests, as the data did not meet the normality assumption. The Kruskal-Wallis test was applied to each sampling date, followed by Dunn's test with Bonferroni correction for multiple comparisons when necessary.

Results showed statistically significant differences (P.adj < 0.05) in the levels of available phosphorus and nitrate. For P-Bray, significant differences between T1 and T0 were found on two dates: December 27, 2023, and February 14, 2024. These differences confirm the positive effect of composted poultry litter on phosphorus availability, although no significant differences were detected during January despite T1 consistently showing higher values. Regarding NO_3, significant differences were observed on December 27, 2023, and January 10, 2024, where both organic treatments showed higher concentrations compared to the control. In the other dates, although no statistical significance was found, a trend of higher NO_3 levels in T1 and T2 was evident. The higher nutrient availability at the beginning of the experiment may have been influenced by a 10.9 mm rainfall event recorded on December 24, 2023, which could have accelerated the mineralization of the organic fraction.

Overall, the results highlight the potential of composted poultry litter as an organic amendment to improve soil phosphorus and nitrate availability, without causing excessive increases in NO_3 levels. This type of evaluation contributes to the valorization of agricultural residues within the framework of sustainable nutrient management.

Keywords: poultry litter, soil amendments, nitrogen, phosphorus.

DEVELOPMENT AND VALIDATION OF AN ANALYTICAL METHOD FOR THE DETERMINATION OF PHYTOHORMONES IN SOIL TREATED WITH ORGANIC FERTILIZERS

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Organic fertilizers offer a sustainable alternative to synthetic fertilizers, providing benefits for both plant development and soil health. In addition to improving soil structure and enhancing microbial biodiversity, they exhibit high biostimulant potential due to the possible presence of natural plant hormones in their composition. Phytohormones in organic biostimulants are generated during composting or fermentation processes by the action of microorganisms, which synthesize compounds like auxins, cytokinins, and gibberellins. Moreover, plant residues can release natural phytohormones or their precursors. These substances contribute to root development, nutrient uptake, and stress tolerance, providing a biostimulant effect without the need for synthetic phytohormones application. In this context, the aim of the present work was to develop and validate an analytical method for the simultaneous determination of indole-3-acetic acid (IAA), abscisic acid (ABA), gibberellic acid (GA3), salicylic acid (SA), jasmonic acid (JA), trans-zeatin (tZ), and trans-zeatin riboside (tZR) in soil samples treated with the liquid biostimulant “Blonos,” produced by the company Bloemendaal SRL. To achieve this, various extraction strategies using different solvents were evaluated on fortified soil samples. The resulting extracts underwent several cleanup procedures, including the use of octadecylsilane (C18), primary-secondary amine (PSA), graphitized carbon black, and dilutions with distilled water at 1:5, 1:10, and 1:20 ratios. Sample analysis was performed using ultra-high-performance liquid chromatography coupled to tandem mass spectrometry with a triple quadrupole detector (UHPLC-MS/MS). For each extraction and cleanup combination, recovery percentages, matrix effects, reproducibility, and limits of detection and quantification were assessed. The results showed that the best extraction efficiency was achieved using acetonitrile with 1% formic acid, in combination with $MgSO_4$ as partition salt and C18 as the cleanup sorbent. Of all the phytohormones evaluated, IAA and ABA were detected at concentrations of 10 and 40 µg/L, respectively; while SA and JA were detected at 395 and 645 µg/L, respectively. The remaining phytohormones were not detected. The developed method proved to be robust and reproducible for soil matrix analysis, with good recovery rates, low matrix interference, and detection limits suitable for applications in environmental monitoring and control.

Keywords: phytohormones; organic fertilizers; uhplc-ms/ms; soils; extraction methods.

APPLICATION OF STABILIZED AGRO-INDUSTRIAL WASTES TO SOIL: EFFECTS ON ORGANIC MATTER AND CARBON STOCK

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This study aimed to evaluate the effects on soil organic matter and carbon stock through the application of stabilized agro-industrial waste in the soil. The experiment was conducted in a dystroferric Red Latosol at the experimental area of the State University of Western Paraná, Brazil. A randomized block design was adopted with three blocks and six treatments: C30 – waste stabilized for 30 days of composting; C60 – waste stabilized for 60 days of composting; CTA – waste stabilized until the composting process reached ambient temperature; CCM – waste stabilized by an industrial composting plant; CAF – poultry litter with uncontrolled stabilization; CTL – without waste addition.

Three treatments were carried out over a four-year. Soil organic carbon (SOC) concentration was determined annually during the period in the 0–10 cm layer. Soil carbon stocks (SCS) were determined based on SOC concentrations, soil bulk density, and the depth of the studied layer. In soil samples collected at the beginning and end of the experiment, chemical fractionation of organic matter and characterization of humic acid (HA) were performed using Fourier-transform infrared (FTIR) spectroscopy.

For the variables SOC and SCS, an analysis of variance was applied, and means were compared using Tukey's test. The initial SOC concentration did not differ statistically ($p<0.05$) among treatments, with concentrations ranging from 3.18% to 3.25%. After four years, SOC content was significantly affected ($p<0.05$) by the addition of organic composts. SOC concentrations for C60 (4.10%) and CTA (4.07%) were statistically higher than those of the other treatments ($p<0.05$). The SOC concentration for C30 (3.93%) was statistically different from the other treatments ($p<0.05$). The CCM and CAF treatments presented SOC concentrations of 3.84% and 3.77%, respectively. The CTL treatment, without organic compost application, presented SOC of 3.46%.

Initial SCS did not differ statistically ($p<0.05$) among treatments, ranging from 40.06 to 41.16 Mg/ha. SCS was significantly affected ($p<0.05$) by the addition of organic composts after four years. Treatments C60 and CTA presented SCS values of 50.13 and 49.69 Mg/ha, respectively. These results differed statistically ($p<0.05$) from the CTL treatment, which presented an SCS of 45.87 Mg/ha.

When comparing FTIR spectra of soil-derived HA fractions, the C60 and CTA treatments showed a reduction in absorption intensity at 2920 cm^{-1} for the final sample compared to the initial one. The signal near 2920 cm^{-1} can be attributed to C–H bonds. In HA samples at the end of the study, a reduction in the 2920 cm^{-1} signal was observed for the C60 and CTA treatments compared to C30, CCM, and CAF treatments. It is concluded that after four years of experimentation and three applications of treatments, SOC and SCS in the 0–10 cm layer were significantly affected by the addition of stabilized organic composts.

Keywords: broiler chicken; composting; humic acids; ftir spectroscopy.

BIOGAS PRODUCTION FROM DIFFERENT TYPES OF POULTRY LITTER WITH INOCULATION OF BOVINE DIGESTATE

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The accelerated growth of chicken meat production in Brazil in recent decades has resulted in a proportional increase in the generation of organic waste, among which chicken litter stands out. This litter is a mixture of feces, feathers, unconsumed feed, and vegetal material used as substrate, such as sawdust or rice husk. Improper disposal of this waste can cause significant environmental impacts, such as soil and water contamination, in addition to greenhouse gas emissions. On the other hand, when properly managed, chicken litter can be used as raw material for biogas production through anaerobic digestion, constituting a sustainable and energy-efficient solution. In this context, the present study aimed to evaluate biogas production from two types of chicken litter—rice husk and wood sawdust—innoculated with digestate from bovine waste. The experiment was carried out in a completely randomized design, in a 2×4 factorial scheme, with two types of litter (sawdust and rice husk) and four digestate concentrations. Biogas production was monitored every two days over 131 days of hydraulic retention time, by measuring the vertical displacement of the gasometer. The daily biogas volume was calculated by multiplying the displaced height by the internal cross-sectional area of the gasometer. The results showed that the treatment composed of wood sawdust with 100% digestate (SMB100A0) presented the highest accumulated biogas production, as well as an earlier start of generation, indicating greater efficiency in organic matter decomposition. A similar behavior was observed in treatments SMB50A50 (50% digestate and 50% water) and CAB100A0 (rice husk with 100% digestate), which also presented significant volumes and an early onset of production. It was verified that the type of litter directly influences biogas production: the sawdust litter generated approximately 22% more biogas compared to the litter composed of rice husk, highlighting the influence of the lignocellulosic composition of the materials on digestibility. Furthermore, the use of digestate as an inoculant proved to be effective, accelerating microbiological activity and favoring biogas production in all tested combinations. This study reinforces the importance of valorizing agricultural waste as a viable alternative for clean and renewable energy generation. The use of chicken litter, especially when associated with bovine digestate, proves to be a promising strategy for energy transition and for promoting environmental sustainability in the Brazilian rural sector.

Keywords: anaerobic digestion; renewable energy; environmental sustainability.

ULTRASOUND-ASSISTED EXTRACTION OF ANTIOXIDANT COMPOUNDS FROM RED APPLE BY-PRODUCTS FOR APPLICATION IN BEVERAGE FORTIFICATION

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The apple juice industry produces large quantities of by-products that represent a natural source of antioxidant compounds that could be reintroduced into the food industry. Globally, it is estimated that approximately 20 million tonnes of apple residues are produced each year, while in Argentina this figure is 16,500 tonnes. In response to this issue, the recovery of natural antioxidants is a sustainable way to make use of fruit-based by-products. Ultrasound-assisted extraction (UAE) is an efficient and environmentally friendly process that does not require the use of organic solvents. This study aimed to evaluate the aqueous extraction of antioxidant compounds from red apple by-products using direct ultrasound assistance. Frozen red apple pomace (-80 °C) was ground to a size of 1 mm² and homogenized with distilled water at a solid-to-liquid ratio of 1:10. Extractions were carried out using ultrasound (20 kHz) at amplitudes of 20%, 50%, and 100% for 2, 5, 10, and 15 minutes in an ice bath. The extracts were analyzed for pH, total soluble solids (TSS), total phenolic content (TPC using the Folin-Ciocalteu method) and total antioxidant capacity (TAC-DPPH using the DPPH method) for each treatment combination. All measurements were performed in duplicate. At 20% and 50% amplitude, ultrasound-assisted extraction (UAE) exhibited a comparable thermal profile (range: 4 °C ± 0.13 to 12 °C ± 0.2), with slight variations at 20%. In contrast, at an amplitude of 100%, temperature increased significantly after 15 minutes (from 4 °C ± 0.13 to 27 °C ± 0.3). The pH remained constant (average: 4.9) across all treatments. A similar trend was observed for TSS, except for the extract obtained after 15 minutes at 50% amplitude, which showed a significant decrease in this parameter. Regarding TAC-DPPH, the highest values were observed after 15 minutes of extraction at an amplitude of 100% (5.747 ± 0.20 µmol Trolox equivalents/g frozen pomace). In contrast, there were no significant differences at 20% amplitude across the time interval, while at 50% amplitude, there was a 26% reduction in antioxidant capacity after 15 minutes. For TPC, ultrasound at 100% amplitude demonstrated a consistent increase from 5 minutes onwards, reaching a maximum value of 1.84 ± 0.10 µg gallic acid equivalents/g frozen pomace after 15 minutes. This increase in yield may be related to the ultrasonic cavitation phenomenon, which causes cell lysis and enhances mass transfer. Similarly, controlled thermal increases may have favored the release of thermosensitive compounds without inducing degradation. In conclusion, UAE at 100 % amplitude for 15 minutes under temperature control proved to be an effective strategy for obtaining antioxidant-rich extracts in a short time. Further process optimization is planned for its application in beverage fortification.

Keywords: ultrasound; antioxidants; phenolic compounds; by-products.

VALORISATION OF BOTANICAL WASTES AS NITROGEN SOURCES FOR KOMBUCHA BACTERIAL-CELLULOSE PRODUCTION: INFLUENCE OF TEMPERATURE AND AERATION

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Turning agro-industrial by-products into high-value biomaterials is a key strategy in circular bioeconomy. This study assessed three locally abundant residues—spent coffee grounds (C), powdered yerba-mate (Y) and gin-botanical trub (G)—as substitutes for black tea in kombucha fermentations aimed at producing bacterial cellulose (SCOBY). We also quantified how incubation temperature and head-space aeration affect process metrics.

Experimental design: Batch cultures (4 g L^{-1} residue + 100 g L^{-1} sucrose, initial pH ≈ 5.2) were run in triplicate at 18, 25 and 30 °C for 21 days. Operational variables (pH, °Brix, turbidity, titratable acidity with 0.090 N NaOH) were recorded at multiple time-points; SCOBY wet and dry masses were measured at harvest. Four covers were compared at 30 °C: polyethylene film (FILM), hermetic lid with lateral holes (HOLES), gauze (GAUZE) and filter paper (PAPER).

Temperature effect (black-tea medium): At 30 °C the pellicle reached 56.1 ± 6.3 g L^{-1} wet (3.3 ± 0.4 g L^{-1} dry), about 65 % higher than the 18 °C (34.3 ± 9.7 g L^{-1}) and 25 °C (33.7 ± 18.5 g L^{-1}) sets. However, pH dropped to ≤ 1.7 and titratable acidity rose to 930 ± 30 meq L^{-1}, implying risk of over-acidification and lower cellulose crystallinity. The 25 °C runs maintained pH 2.3 ± 0.05 with smoother sugar consumption, suggesting a compromise between yield and product quality.

Residue effect (25 °C, gauze cover): All three residues supported comparable wet yields—coffee 34.8 ± 13.1, yerba 34.0 ± 14.1 and gin 31.0 ± 10.3 g L^{-1} ($p > 0.05$)—demonstrating their suitability as nitrogen/supplement sources. Yerba promoted the sharpest drop in °Brix (–3.5 units), while gin runs showed higher scatter, possibly due to terpenoid inhibition.

Aeration effect (30 °C): Cover choice strongly modulated oxygen supply. PAPER (80.0 ± 8.4 g L^{-1}) and FILM (75.5 ± 6.3 g L^{-1}) out-performed GAUZE (56.1 ± 6.3 g L^{-1}) and HOLES (55.6 ± 41.9 g L^{-1}). The perforated lid showed the widest variance, indicating unstable O_2 transfer; PAPER combined high permeability with good contamination control.

Conclusions: (i) Operating at 30 °C with high-permeability covers maximises wet SCOBY mass, but 25 °C ensures gentler acidification and potentially higher cellulose quality. (ii) Coffee, yerba-mate and gin residues can fully replace tea as botanical supplements, providing a direct valorisation pathway for local wastes. (iii) Filter paper proved the most reliable cover, balancing oxygenation and sterility. Ongoing work includes moisture-free mass balances, crystallinity analysis and scale-up in perforated-lid reactors.

Keywords: kombucha; bacterial cellulose; waste valorisation; fermentation.

EFFECT OF POULTRY LITTER APPLICATION ON EXTRACELLULAR ENZYMATIC ACTIVITY AND ITS RELATIONSHIP WITH SOIL PROPERTIES

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Argentina, as one of the world's leading poultry producers, generates large quantities of poultry litter (PL), an organic by-product used as a soil amendment. Traditionally, it has been applied without prior treatment, but currently, methods such as composting, self-heating, and pelletizing are being promoted, as they improve handling, reduce volume, and facilitate distribution. Various studies have shown that PL enhances the chemical, physical, and biological fertility of soil, with a notable impact on extracellular enzymatic activity (EEA), a key indicator of microbial activity and nutrient recycling. The objective of this study was to evaluate the effect of PL application on EEA and its relationship with soil physicochemical variables, six months after application. The study was conducted on an Argiudoll soil under no-till at the INTA Paraná Experimental Station. Four treatments were applied prior to soybean sowing (Nov 2023): an unfertilized control (To), composted and pelletized PL (PLc), non-composted PL (PLnc), and a fertilized control (Tf) with nutrients equivalent to those provided by PLc (N, P, K, and S). PL doses were calculated to supply 3 MgC ha^{-1}. Soil samples were taken from a depth of 0–5 cm six months after application, following crop harvest. EEA (nmol h^{-1} g^{-1}) was measured using fluorescence assays for enzymes related to the C cycle (CEL: β-D-cellobiosidase and GLC: β-D-glucopyranosidase), N (NAG: N-acetyl-β-D-glucosaminidase and LEU: leucine aminopeptidase), and P (FOS: acid phosphatase). Additionally, pH, electrical conductivity in dS/m (EC), extractable phosphorus in mg/kg (Pe), and nitrates in mg/kg (NO_3^-) were analyzed. Pearson correlation analysis showed significant positive associations between CEL-NAG, NAG-FOS, FOS-CEL, LEU-NAG, LEU-CEL, and LEU-FOS. Positive correlations were also observed between EC-FOS, EC-NO_3^-, and NO_3^--LEU. Using ANOVA with linear mixed models, it was observed that CEL activity was higher in PLnc (44.8) than in To (14.8), with no significant difference from PLc and Tf. GLC showed higher activity in PLc (348.9), with no differences from PLnc and Tf. LEU activity was higher in PLnc and Tf (90.95 vs. 63.1, respectively) compared to PLc and To (39.1). For FOS, PLnc (608.6) showed the highest value, differing from To (279.7). pH was lower in Tf (5.19), differing from the other treatments (average 5.6). EC increased by 47% in PLc, PLnc, and Tf (average 0.145) compared to the control (0.098). For Pe, Tf showed higher values than PLc (168.2 vs. 115.33), despite having the same P input. Finally, NO_3^- showed no significant differences (84.4 vs. 70.3) between PLnc and PLc, while Tf had the highest concentration (102.5). The study highlights the need for continued research into the complex interactions between soil microbiology and organic amendments to optimize their use in sustainable agricultural systems.

Keywords: composted poultry litter - argiudoll - microbial activity.

EVALUATION OF TRITICUM AESTIVUM RESPONSE WITH AN APPLICATION OF A FERTILIZER OBTAINED WITH AN ANAEROBIC DIGESTATE

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Anaerobic digestion is a valuable process for treating different organic waste, and it allows the production of bio-based fertilizers from the resulting digestate. The aim of this study was to evaluate the response of wheat plants (Triticum aestivum) to the application of different doses of biofertilizer (BF) or urea (U) applied along the sowing line. The experiment was conducted in pots. To compare the treatments, the percentage of plant emergence and the length of the first emerged leaf were measured. The treatments were: control (T: without fertilizer), and increasing doses of BF and U (1:15, 2:30, 3:60, and 4:120 kg N ha^{-1}). Plant emergence was recorded from the seventh day after sowing and monitored for 30 days. On days 30 and 37 after sowing, the length of the first leaf was measured. At 11 days after sowing, 100% emergence was achieved in both the control (T) and BF2. BF1 and U1 reached 100% at 14 days. BF3 and BF4 reached 100% at 15 and 24 days, respectively. At 24 days, U2, U3, and U4 showed emergence percentages of 89.39%, 92.42%, and 74.24%, respectively. Moreover, at similar nitrogen doses, BF did not show phytotoxic symptoms, unlike U3 and U4, where delayed emergence, weak appearance, and thinner leaves were observed. At thirty days, treatments BF1, BF2, and BF3 showed the greatest length of the first emerged leaf ($p<0.0001$) (24.6, 16.7, and 26.76 cm, respectively), while U1 and BF4 did not differ from the control (24.77, 25.03, and 22.79 cm, respectively). U2, U3, and U4 (19.44, 16.78, and 13.33 cm, respectively) exhibited shorter leaf lengths. At 37 days, a similar trend was observed ($p<0.0004$), with BF1, BF2, BF3, and BF4 showing greater leaf length (34.26, 35.39, 36.33, and 35.6 cm, respectively) compared to the control (28.18 cm). U1 and U2 (31.27 and 29.74 cm, respectively) did not differ from the control, whereas U3 and U4 exhibited reduced leaf length (23.88 and 23.07 cm, respectively). Based on these results, it can be concluded that the application of high N doses in the sowing furrow using the biofertilizer under study does not affect wheat germination and promotes early development, whereas the application of similar doses of urea reduces establishment efficiency and negatively affects seedling vigor.

Keywords: anaerobic digestate; biofertilizer; nitrogen fertilization.

PRODUCTION OF DRY MATTER FROM CORN IN POTS FERTILIZED WITH ORGANOMINERAL FERTILIZERS BASED ON PIG WASTE COMPOST

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With the increase in animal husbandry for meat production, such as pig farming, there is an increase in the production of waste with high nutrient contents. The use of pig waste as fertilizer has become an increasingly common practice in agriculture, aiming to reduce costs and promote the sector's sustainability. The production of organomineral fertilizers from pig manure compost is a suitable alternative for waste disposal and contributes to increased soil fertility and crop production. Two organomineral NPK formulations, based on pig manure compost, were prepared at the Fertilizer Technology Laboratory of Embrapa Soils: ORGMAP1 with the addition of ammonium monophosphate (MAP) and potassium chloride (KCl), and ORGMAP2 with the addition of MAP, KCl, MgO, and the micronutrients Zn, Cu, and B. The objective of this research was to evaluate the initial growth of corn grown in pots in a greenhouse with different fertilizers based on pig manure compost. The treatments consisted by application of a dose equivalent to 100 mg kg-1 of P from two organomineral fertilizers, ORGMAP1 and ORGMAP2, an treatment with MAP and a control (without added P), in a completely randomized design with four replicates. Each pot was filled with 1 kg of Planossolo Haplico soil, a sandy texture, originally deficient in nutrients and with an available P content of 8.7 mg kg-1. A nutrient solution without P was applied to all pots. The corn shoots were harvested 54 days after planting, and the wet weight and dry weight were determined after drying in a forced circulation oven at 65 °C until constant weight was reached. Based on the dry matter production of each treatment and the control, the agronomic efficiency of the fertilizers in relation to the amount of P applied was calculated. Dry matter production and agronomic efficiency were subjected to analysis of variance and comparison of means using the Tukey test ($P \leq 0.05$). The two organomineral fertilizers based on pig manure compost presented similar results to the MAP fertilizer, promoting increased fresh matter and dry matter production of the corn shoots. In the control, yield was 3.3 g per pot, while in the fertilizer treatments it ranged from 10.0 to 12.2 g per pot, differing statistically from the control. The agronomic efficiencies of the fertilizers did not differ statistically, being 65.5 g.g-1 in MAP, 47.3 g.g-1 in ORGMAP1, and 68.8 g.g-1 in ORGMAP2. The results confirm the potential use of swine manure compost in the production of organomineral fertilizers, which are a viable alternative for increasing crop production and contributing to the cycling and reuse of nutrients in agricultural production systems.

Keywords: p available; mehlich-1; agronomic efficiency.

BIOCHAR, ORGANIC COMPOST, AND BENEFICIAL MICROBIAL INOCULANTS: NITROGEN USE EFFICIENCY IN A POT LETTUCE TRIAL

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Nitrogen is one of the most important nutrients in agriculture; therefore, its conservation, use efficiency, and sustainable management deserve special attention. Practices such as biochar application, organic compost-based fertilizers, and plant growth–promoting microorganisms can significantly contribute to improving nitrogen dynamics in horticultural systems. In this trial, we evaluated nitrogen use efficiency in lettuce grown in pots using different waste-based management strategies. The experiment was conducted in a controlled growth chamber (FertiLab System) under a factorial design including: four fertilization types (unfertilized control, NPK, GVA259 compost pellet, and GVA259 compost pellet + NPK), two biochar doses (0 and 10 t ha^{-1}), and three inoculation treatments (control, Bacillus aerophilus, and a mixture of Azospirillum brasilense + Pseudomonas fluorescens). Treatments were applied prior to transplanting, and the crop was grown for 40 days. At the end of the cycle, yield (dry matter), soil NH_4^+ and NO_3^- contents, foliar nitrogen content, total nitrogen uptake, and nitrogen use efficiency (NUE) were evaluated. Data were subjected to analysis of variance (ANOVA) in a triple factorial model, and means were compared using the LSD test at a 5% significance level. Results showed that the use of biochar, organomineral fertilizers, and microbial inoculants significantly increased lettuce yield. The NPK treatment increased NUE by 122.36%, indicating high uptake efficiency, although with the risk of rapid nitrogen depletion and greater leaching potential. Therefore, the use of organomineral pellets is recommended as an alternative due to their more gradual nutrient release. Inoculation with B. aerophilus significantly increased nitrogen uptake, whereas biochar application reduced NUE by 30%, while increasing soil NH_4^+ content by 8%. This reduction in NUE is hypothesized to be related to biochar's affinity for NH_4^+, retaining it within its matrix due to its high C/N-related surface properties, as well as a possible dilution effect, since biochar application stimulated biomass increase, thereby lowering NUE values. These results contribute to the understanding of nitrogen dynamics in newly established horticultural systems and pot-grown crops using waste-based amendments and provide insights into the interaction between nitrogen use efficiency and horticultural productivity.

Keywords: ammonium; nitrate; plant biomass; horticulture; agro-industrial residues.

ORGANIC AND ORGANOMINERAL FERTILIZATION APROACHES WITH SPENT BUTTOM MUSHROOM SUBSTRATE: IMPACTS ON CHICKPEA NODULATION AND SOIL BIOLOGICAL QUALITY

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The use of spent mushroom substrate (SMS) is emerging as an innovative strategy to improve nutrient cycling efficiency and mitigate the environmental impact associated with its improper disposal. Although literature already recognizes its potential to enhance soil chemical properties, its effects on biological parameters remain poorly explored. Therefore, our objective was to evaluate nodulation in chickpea and soil biological quality under different fertilization strategies using SMS combined with *Mesorhizobium ciceri*. The study was conducted under field conditions with the following treatments: NPK fertilization 04-14-08 (320 kg ha^{-1}), SMS application (organic fertilization), and SMS + NPK application (organomineral fertilization); all combined with three different doses of M. ciceri: 0 mL (D0), 1 mL (D1), and 2 mL (D2) per kg of seed. The experiment followed a randomized block design, comprising 36 subplots. At the flowering stage, five plants per subplot were collected, and nodule number and nodule mass were evaluated. After grain harvest, a soil bioanalysis was performed, assessing arylsulfatase and β-glucosidase enzyme activities, soil organic matter (SOM), and the Soil Biological Quality Index (SBQI). Data were subjected to analysis of variance (ANOVA), followed by Tukey's test at a 5% significance level. The D0 inoculation treatment did not induce nodulation in chickpea, demonstrating that SMS residues alone cannot contribute to nodulation. The highest values for nodule number were observed under NPK with D2 (13.8), while the highest average nodule mass was obtained under SMS with D1 (0.96 g). Regarding SBQI, SMS + NPK combined with either D1 or D2 maintained high to very high levels of arylsulfatase, β-glucosidase, and soil organic matter. However, all evaluated treatments were classified as having a high SBQI (>0.61). It is concluded that *M. ciceri* is essential for nodulation in chickpea and that the use of SMS within an organomineral fertilization strategy enhances SBQI, indicating an improvement in soil biological quality.

Keywords: soil enzymatic activity; sustainable agriculture; arylsulfatase; β-glucosidase; microbiota.

EVALUATION OF AGRONOMIC USE OF LIQUID SWINE MANURE ON SOYBEAN CROP (2024–2025 SEASON)

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National pork production in Argentina grew by 41,7% between 2017 and 2024, increasing from 554.364 to 785.778 carcass-equivalent tons. This production increase occurred in the context of an intensification process involving the establishment of new farms, expansion of existing ones, and the adoption of improved input and process technologies, animal welfare practices, genetics, nutrition, health management, and staff training, among others. This evolution has not been exclusive to Argentina but reflects a global trend, also marked by growing environmental awareness related to production practices and sustainable development.

In this context, this production model results in a high generation of slurry over relatively small areas, which requires appropriate treatment systems to ensure stabilization and reduce environmental impact. When applied under an agronomic application plan, these byproducts can help mitigate soil nutrient deficiencies and improve crop yields, as they are sources of nutrients and organic matter.

The main objective of this study was to evaluate the effect of stabilized liquid swine manure application on soybean crop performance and soil chemical properties. The trial was carried out on a production field at Estancia Dos Ríos, in the locality of Despeñaderos (Córdoba), on a typical Argiustoll soil that had received slurry applications for the previous 7 years. The liquid swine manure, previously stabilized in treatment lagoons, was applied through a center pivot system over two adjacent circles. The evaluated treatments included two slurry doses (12,5 and 25 mm/ha) combined with 80 kg/ha of single superphosphate (E12,5+SSP and E25+SSP); and stand-alone slurry doses of 25, 37,5, 50 and 62,5 mm/ha (E25; E37,5; E50; E62,5), along with an untreated control (C). Crop yield and changes in soil chemical properties were analyzed before planting and after harvest.

After 8 years of evaluating the agronomic use of liquid swine manure, a positive response in soil chemical properties was observed when comparing pre-planting and post-harvest sampling results. This response was mainly associated with indicators related to the soil's potential fertility (OM and TN). Additionally, improvements were noted in the micronutrients analyzed (Zn and Cu).

Statistically significant yield differences were observed between the control and the rest of the treatments. Yield differences were also found between E25 and both E37,5 and E25+SSP. No significant differences were found between these two treatments and E12,5+SSP, E50, and E62,5. Likewise, no significant differences were observed between the latter three and E25.

It can be concluded that E37,5 is the recommended dose, as it produces the highest yield without the use of chemical fertilizer. The results demonstrate the positive effect of the proper agronomic use of liquid swine manure in productive systems, along with the associated economic benefits for farming operations.

Keywords: soybean; agronomic use; pig slurry; soil; yield.

EVALUATION OF RECOVERED CALCIUM PHOSPHATE FROM SWINE MANURE AS A PHOSPHORUS SOURCE FOR SOYBEAN AND CORN CROPS

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The sustainable management of swine manure is crucial for minimizing environmental pollution while maximizing its agricultural value. The SISTRATES system is a swine manure treatment process developed by Embrapa to address these challenges. In this system, phosphorus in precipitated and recovered as calcium phosphate sludge that can be processed into a granular fertilizer. This study evaluated the agronomic efficiency of this recovered calcium phosphate as a P source for soybean and corn crops grown in succession under greenhouse conditions at the University of Rio Verde. The experiment used 5 dm^3 PVC pots filled with dystrophic Red Latosol soil (P: 1.4 mg dm^{-3}) collected from a native Cerrado area, employing a completely randomized design with six treatments and four replicates: pure P sludge (13.71% P_2O_5), P sludge + Monoammonium Phosphate (MAP) (24.05% P_2O_5), P sludge + Triple Superphosphate (TSP) (23.57% P_2O_5), MAP (52.76% P_2O_5), TSP (45.38% P_2O_5), and a control with no added P. A dose of 100 mg kg^{-1} P was applied, with soybean cropped for 45 days followed by corn. Shoot dry mass of both crops, phosphorus content in plant tissue, and residual soil P after harvest were determined and analyzed using ANOVA and the Scott-Knott test at a 5% significance level. For soybean, mineral fertilizers (MAP and TSP) produced the highest shoot dry mass, foliar P content, and P uptake, indicating superior early-stage P availability, while sludge-based treatments (pure or blended with MAP/TSP) showed comparable but slightly lower efficiency, suggesting slower P release, and the control group exhibited significantly lower growth and P absorption, confirming P deficiency in unfertilized soil. In contrast, corn responded differently, with all P treatments, including sludge-based ones, performing similarly in terms of dry mass and P uptake, and only the control group underperforming, indicating that any P addition (organic or mineral) improved corn growth, likely due to benefits from residual P left by previous fertilization. Residual soil P analysis revealed that MAP and TSP treatments left higher residual P levels, suggesting potential long-term availability, while sludge treatments had residual P levels similar to the control, implying faster P depletion but still meeting short-term crop needs. These results demonstrate that calcium phosphate sludge from swine manure can work as an effective P source, particularly for corn cultivation where it performed comparably to conventional fertilizers, while soybean mineral fertilizers remained superior in early growth stages though sludge blends still provided adequate P nutrition. The findings highlight the potential of recycled swine manure P to partially or fully replace synthetic fertilizers in crop rotations, promoting circular agriculture and reducing environmental impacts, though further field trials are recommended to validate these results under real farming conditions. The comparable performance of sludge-based P sources for corn suggests immediate applicability in farming systems, whereas the slightly reduced efficacy for soybean indicates areas for further optimization of the recovery process or application methods to enhance early P availability for more P-demanding crops.

Keywords: pig farming; residue treatment technology; sustainability; p fertilizer.

VALORIZATION OF COTTON WASTE AS RAW MATERIAL FOR PARTICLEBOARD PRODUCTION

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This research addresses the feasibility of producing particleboard from residues generated in cotton production, particularly in ginning plants located in the northeastern provinces of Argentina. These residues, predominantly lignocellulosic in composition, are collected in large open-air piles with no planned applications other than emergency livestock feed, biomass addition to soils, or clandestine incineration to control their ample volume. Representing approximately 40 % of the cotton harvested in the country, they offer a low-cost alternative raw material for use in particleboard production, meeting international standards, and potentially replacing the forest resources currently used in this industry.

During the research, experimental boards were molded from two different particle sizes distribution of ground residue. Single layer boards, composed of coarse and fine particles, and three layer boards, composed of two outer layers of fine material and an inner layer of coarse particles, were evaluated. Urea-formaldehyde resin was used as binder, with contents varing from 11.9 % to 19.3 %.

Particleboards properties were evaluated according to argentinian and american regulations, and the results were compared with the requirements established by IRAM standard 9723 (2012) for particle boards used in Argentina and ANSI standard A208.1 (2022) in the United States. Density (IRAM 9705 – 2001 / ASTM D 1037 - 2020), static 3-point bending strength (IRAM 9706 – 2001 / ASTM D 1037 - 2020), and water resistance, characterized by absorption and swelling results upon immersion in water for 24 hours (IRAM 9720 – 1999 / ASTM D 1037 - 2020), were determined.

Results obtained demonstrate that it is possible to meet the standards required by national and international regulations. Better performance was observed in the three-layer panels, with greater bending strength and better water resistance, which is attributed to a more efficient combination of particle sizes and distribution of resin contents in each layer. In contrast, the single-layer boards showed more unfavorable and variable results.

Based on these results, it is possible to conclude that particleboards made from cotton ginning residue could offer a viable, low-cost alternative with suitable technical properties for use in furniture and non-structural construction, reducing the environmental impact associated with both the current disposal of waste in the cotton industry and the intensive use of forest resources by the panel industry, thus promoting more sustainable production and consumption practices.

Keywords: cotton gin wastes; urea formaldehyde resin; particleboards; single-layer boards; triple-layer boards.

ALPERUJO FROM THE CORONEL DORREGO DISTRICT, A RICH SOURCE OF PHENOLIC COMPOUNDS

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El partido de Coronel Dorrego es el principal productor de aceite de oliva de la provincia de Buenos Aires. En este distrito se concentra la mayor cantidad de industrias olivícolas del sudoeste bonaerense. En los últimos años, de la mano de importantes proyectos con sistemas superintensivos, se ha incrementado considerablemente la superficie implantada con olivos, y se prevé que esto siga aumentando en el corto plazo. A su vez se han establecido nuevas y modernas plantas elaboradoras de aceite equipadas con sistemas continuos con decanters de dos fases. Mediante este sistema de extracción se obtiene, además del aceite, un subproducto semisólido denominado alperujo. Por diversas razones (escaso valor, elevados costos para su traslado, etc.) los productores no le dan mayores usos (a excepción de algunos casos que lo compostan y/o le extraen el carozo para ser utilizado en las calderas de las propias plantas) y terminan aplicándolo sobre la superficie del suelo en las plantaciones próximas a la fábrica, o en algunos casos acumulándolo en cavas cerca de la planta, lo que puede generar problemas de contaminación ambiental. Por otra parte, la falta de datos precisos sobre su composición química y sobre su variabilidad dificulta el planteo de soluciones efectivas para su reutilización. En este sentido, con la intención de generar información necesaria para el posterior planteo de alternativas tendientes a dar valor agregado a este subproducto, se realizó un mapa de las plantas elaboradoras en este distrito, se relevó la cantidad de alperujo producido en el año 2025 y se determinaron algunos parámetros químicos para su caracterización cualitativa. Los resultados indicaron que en el distrito existen 6 plantas extractores de aceite de oliva, todas con sistemas de extracción de dos fases y presentan escasa dispersión territorial. La humedad promedio del alperujo de estas 5 plantas fue de 63,4 % (con una variación entre el 60 y el 70 %) y la concentración de compuestos fenólicos totales de 12656 ppm (con una variación entre 8090 y 14718 ppm). Los valores de humedad coinciden con resultados publicados en el país y en el exterior, mientras que en lo que respecta al contenido de fenoles totales se observaron valores similares a los reportados en trabajos de regiones de la cuenca del mediterráneo, y superiores a los observados en zonas cordilleranas de Argentina. Si bien se trata de resultados preliminares obtenidos en una única campaña, el elevado contenido fenólico observado es auspicioso para profundizar en su estudio y posible planteo de estrategias basadas en la recuperación de estos compuestos para obtener antioxidantes naturales y facilitar el manejo de las fracciones resultantes. En este sentido, trabajos futuros que incluyan el análisis de fenoles totales y perfil de compuestos fenólicos en alperujos de distintas variedades y estados de madurez permitirán conocer más sobre esta posibilidad.

Keywords: aceite de oliva; subproductos olivícolas; sudoeste bonaerense.

PERFORMANCE OF TAGETES PATULA FERTILIZED WITH PELLETS MADE FROM LIVESTOCK AND AGRO-INDUSTRIAL WASTES

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According to United Nations estimates, the global population will increase by 2 billion by 2050, which will demand a rise in agricultural and livestock production. However, this growth will not come with greater availability of non-renewable resources. Agricultural intensification relies heavily on synthetic fertilizers, and Latin America and the Caribbean import about 85% of what they use, making them highly dependent on external markets. In this context, promoting sustainable agricultural practices and the transition to a circular economy is essential. One strategy involves using renewable resources, such as organic waste, to produce bio-inputs. This study aimed to evaluate the performance of several bio-inputs derived from agricultural and agro-industrial waste in an intensive greenhouse system. Two solid anaerobic digestates from pig (PD) and cattle (CD) manure were used, along with two composts from agro-industrial waste (AC) and cattle manure (CC). These materials were physically and chemically characterized before being processed into pellets using a flat-die pelletizer (100 kg/h, 150 rpm) at 25% moisture. The 6 mm diameter pellets were dried at 60 °C until reaching 10% moisture.

The pellets were incorporated into a commercial substrate at four different doses: 1:2.5 g/L, 2: 5 g/L, 3: 7.5 g/L, and 4: 10 g/L. Tagetes patula plants were grown in 370 mL pots under greenhouse conditions, with ten replicates per treatment. Two control groups were included: one with inorganic fertilization (NPK 18-18-18, 200 mg/L N) and another watered with tap water (control C).

The inorganic fertilization treatment (F) significantly outperformed all others ($p<0.001$) in growth index (GI), SPAD index (leaf chlorophyll content), and shoot dry weight. For GI, the rest of the treatments showed no significant differences among themselves. In terms of SPAD index, some treatments (e.g., CD2, AC1, PD2) had intermediate values between the F treatment and those with the lowest readings (AC3, AC4, CC3, CC4). Regarding shoot dry weight, the lowest results were observed in CC2, CC3, CC4, AC3, AC4, and PD4, while the remaining treatments fell between these and the F group. The number of lateral shoots was significantly lower in the control (C) and PD4 treatments, while no significant differences were observed among the others.

By the end of the trial, the substrate's electrical conductivity remained within suitable ranges (0.19–0.33 dS/m), and pH values stayed within optimal levels (5.48–6.47) across all treatments.

In conclusion, the tested bio-inputs did not significantly alter the physical-chemical properties of the substrate. However, plant growth with bio-inputs, regardless of dose, was lower than with inorganic fertilization. This suggests that, in short-cycle crops, complete substitution of synthetic fertilizers with bio-inputs is not feasible. Therefore, combining bio-inputs with complementary fertilization strategies is necessary to ensure efficient crop performance in intensive systems.

Keywords: pellets production; bio-inputs; agricultural wastes; sustainable agricultural; wastes valorization.

AGRONOMIC BENEFITS AND CHALLENGES OF USING ANAEROBICALLY TREATED PIG SLURRY ON AGRICULTURAL SOILS IN CÓRDOBA, ARGENTINA

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Even though animal manures are used globally as fertilizers in agricultural soils, in Latin America this practice is relatively recent. In Argentina, Córdoba province was the first to regulate the agronomic use of animal manure (both slurry and solid) through Resolution No. 29/2017, “Agronomic Management and Application of Livestock Waste.” In line with this initiative, the state through the MINCyT financed the National Project “IMPACTAR No. 119,” that evaluates the effects of stabilized in anaerobic lagoons pig slurry applications on soil properties. In 12 pig farms located in Córdoba province, samples of raw pig slurry and anaerobic lagoons were collected to determine physical, chemical, and microbiological variables. Additionally, soil samples with and without pig slurry applications were collected at different depths (0-10 cm; 0-20 cm; 20-60 cm). Microbiological variables were determined for the 0-10 cm depth, while chemical variables related to soil fertility were determined for the 0-20 cm and 20-60 cm depths. Data analyses were performed using Infostat Professional statistical software. Anaerobic lagoons reduced total solids, volatiles, and chemical oxygen demand, and, to a lesser extent, nitrogen and phosphorus. In contrast, sodium, potassium, copper, pH, and alkalinity increased significantly ($p<0.05$). Regarding microorganisms, reductions were observed in thermotolerant coliforms (31%), E. coli (29%), Salmonella spp. (58%), and fecal streptococcus (24%). When evaluating the quality of agricultural soils with pig slurry, increases in organic nitrogen, mineral nitrogen, extractable phosphorus, potassium, zinc, and copper were observed—essential nutrients for crop growth. However, electrical conductivity and sodium increase were detected, which could be attributed to the salt content in the pigs' diet and/or the presence of salts in the groundwater used to wash the confinement facilities. Regarding microbiological parameters, Escherichia coli and Salmonella spp. were not detected. However, a 27% and 37% increase in total coliforms and fecal streptococcus, respectively, was observed in soils with pig slurry applications compared to control soils. Animal slurry is a valuable source of inorganic and organic matter as nutrients for agricultural soils, however, it may also contain microorganisms that can be pathogenic to humans and/or animals and accumulate potentially toxic metals. Therefore, it is crucial to stabilize it before use and manage it properly to minimize food chain and environmental impact.

Keywords: nutrient recycling; manure; anaerobic lagoon.

VALORISATION OF SEWAGE SLUDGE FOR EROSION CONTROL AND SOIL QUALITY IMPROVEMENT IN A MEDITERRANEAN AGROECOSYSTEM

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Soil erosion is a key factor of land degradation in Mediterranean agroecosystems, especially in those with soils of sandy textures, undulating topography, and variable rainfall patterns. This study evaluates the use of treated sewage sludge as an organic amendment to reduce soil erosion and improve soil quality in a 13.4-hectare permanent pasture under a Mediterranean oak forest in Ribatejo, Portugal. the pasture is grazed in a rotation system by cattle and wild bulls, and has received 6 $t{\cdot}ha^{-1}$ of sewage sludge in October 2022, as part of a strategy to improve soil organic matter and physical properties.

The Universal Soil Loss Equation (USLE) was applied from 2022 to 2024 to model soil loss dynamics. The rainfall erosivity factor (R) was estimated using the Arnoldus method with local precipitation data. The soil erodibility factor (K) was calculated following Wischmeier & Smith (1978), incorporating USDA texture class corrections and a unit conversion factor. Slope length and steepness (LS) were derived from field data. A cover-management factor of $C = 0.02$ was adopted based on national guidelines for permanent pastures, and no conservation practices were assumed ($P = 1$).

Results show an 85% reduction in modelled soil loss between 2022 and 2024, alongside a progressive increase in soil organic matter (SOM) from 4.5% to 6.8%. However, and despite the reduction in soil loss, the SOM has decreased to nearly the same % as in the experiment starting value, after 3 years from sledge application, revealing a contribution of easily mineralizable OM, with small SOM build up in the soil. These improvements reflect the positive impact of sludge incorporation on soil stability and vegetative cover, even under varying rainfall conditions. The findings support the integration of organic waste valorisation strategies in soil conservation planning, particularly under Mediterranean climatic constraints.

Keywords: soil erosion; sewage sludge; soil amendment; usle; mediterranean agroecosystem.

LEGUME ADAPTATION AND PASTURE DIVERSITY IN A MEDITERRANEAN MONTADO FOREST SYSTEM, FOLLOWING PIG SLURRY APPLICATION

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Mediterranean agro-silvo-pastoral systems, such as the montado landscapes of southern Portugal, face increasing pressure to reconcile productivity with ecological resilience. This study investigated the effects of pig slurry application on a long-established natural pasture grazed by cattle and left unmanaged for over three decades. Slurry was selectively applied to degraded areas outside tree canopy cover, aiming to stimulate growth in nutrient-poor zones without disturbing overall plant community dynamics.

Despite the organic fertilization, the general floristic composition of the pasture remained stable, showing no significant species loss or invasive spread. Still, some noticeable changes were observed within the legume species. Prior to fertilization, clovers (Trifolium spp.) were the predominant legumes. Following slurry application, serradella (Ornithopus sativus L.), a native species well adapted to acidic soils, increased significantly in both frequency and biomass. These results suggest that serradella may be better aligned with the acidic and fertilized soil, supporting similar forage value with greater adaptability.

In treated areas, vegetative vigour and overall biomass improved substantially, particularly during dry seasons. As a result, the grazing period was extended by approximately one month, demonstrating both the productivity gains and the resilience of the system. Importantly, these benefits were achieved without compromising plant diversity.

In conclusion, the results point to a change within the plant community driven by legumes, highlighting the role of species like serradella in strengthening the resilience of Mediterranean pastures under acidic soils and nutrient input pressures. Continued botanical monitoring is recommended to assess the long-term balance between productivity and ecological integrity in these multifunctional systems.

Keywords: montado; legumes; organic fertilisation; serradella; agro-silvo-pastoral systems.

USE OF HYDROLYSATES FROM LIGNOCELLULOSIC BIOMASS FOR BIOPLASTICS PRODUCTION BY BACILLUS MEGATERIUM

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Plastic consumption is a widely discussed topic and one of the concerns of humanity due to its contribution to environmental pollution and the use of fossil resources. One of the most promising alternatives for replacing conventional plastic is the use of biopolymers produced by microorganisms. Among these alternatives, polyhydroxyalkanoates (PHAs) are one of the materials that have gained the most importance in recent years. Agro-forestry and industrial activities generate enormous quantities of waste annually constituting one of the largest waste streams worldwide one of the largest categories globally. Rice husk (RH) is a lignocellulosic residue that poses a challenge for the agro-industry: it represents about 20% of the total weight of the rice harvest and is often stockpiled in large quantities or discarded. Nevertheless, RH consists mainly of carbohydrates that can serve as a raw material for the production of high value-added products. The aim of this study was to evaluate the use of RH hydrolysate as a substrate for PHA production and to examine the effect of selected variables. The microorganism selected was Bacillus megaterium, a PHA-producing bacterium under conditions of carbon excess and nitrogen limitation. RH was hydrolyzed with formic acid with chloridric acid as enhanced to maximize monosaccharide (xylose) release and minimize furfural formation, which inhibits bacterial growth. For the growth and PHA-production stages, the influence of hydrolysate concentration in the medium (25, 50, and 75%, v/v) was assessed. Sugar and furfural concentrations were determined by HPLC; bacterial growth was monitored by optical density at 600 nm (OD_{600}); and PHAs were quantified by chloroform extraction, sulfuric-acid conversion, and spectrophotometric determination at 240 nm. The greatest PHA concentration (1.78 g PHA per 100 g dry biomass) was obtained using the 120-min hydrolysate diluted to 50%. This lower yield can be attributed to the complexity of the real residue and to inhibitory compounds formed during hydrolysis, such as furfural. In conclusion, rice husk represents a practical substrate for bioplastic synthesis, but further work is required to refine operating conditions and boost PHA yields.

Keywords: rice huck; biorefinery; microorganisms; phas.

BIOFERTILIZER BASED ON AGROINDUSTRIAL WASTES FOR CROP PRODUCTION IN THE CONTEXT OF CLIMATE CHANGE

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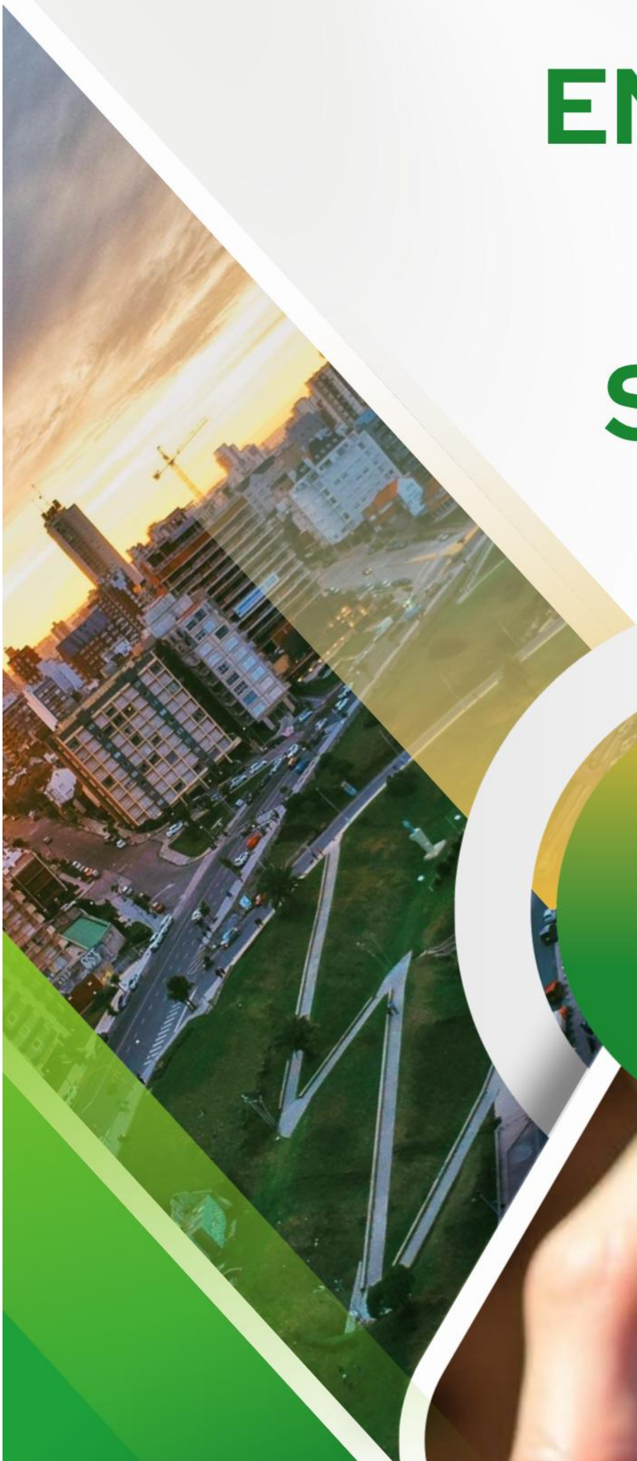
In response to the growing challenges of climate change, such as desertification and drought, innovative materials are needed to sustain food production in the face of a growing world population. Adequate agricultural production on degraded soils requires improving the water-holding capacity of soils, optimizing soil microbiota, and increasing fertilizer efficiency. In this context, the use of agro-industrial residues as soil amendments has been proposed as a sustainable solution to improve soil quality and mitigate the effects of drought. Globally, agriculture-based industries generate around 1.3 billion tons of waste annually. The Araucanía region of Chile generates more than 2.3 million tons of agricultural, agro-industrial, and forestry wastes annually, with great potential for reuse. Among the residues, biochar from biomass boilers, diatomaceous earth from brewery industry have shown that improve physical, chemical, and biological properties of the soil. This study aimed to formulate a biofertilizer using agro-industrial wastes to improve water holding capacity (WHC) and therefore Lolium perenne production under drought conditions in a Sandy soil.

A granular biofertilizer was developed from agro-industrial wastes (biochar and diatomaceous earth), using three materials as binders (A1, A2 and A3). The effect of the granular biofertilizer on soil properties and Lolium perenne production was evaluated under different water regimes (100 to 30% of WHC). The soil used in this study has pH of 5.5 and low organic matter content (2%). The formulated biofertilizer was characterized respect to their particle size distribution, attrition resistence and bulk density. The main results showed that the addition of the agro-industrial wastes significantly increased WHC (>50%) of the soil, especially with the combination of biochar and diatomaceous earth (5% v/v) addition. The granular biofertilizer developed under optimized conditions with A1 and A2 binders showed yields of 90% and 83%, respectively, with a size between 2-6 mm. in diameter. The granules produced with A1 binder exhibited a higher bulk density (0.270 g/mL) compared to those formulated with A2 (0.255 g/mL) and A3 binders (0.232 g/mL). Attrition resistance tests showed that granules made with A1 and A2 binders maintained nearly 100% integrity after agitation, while those made with A3 displayed resistance of only ~60%. The biomass production of Lolium perenne compared to the control soil without chemical fertilization was more than six times higher. It is noteworthy that the productivity of this crop remained stable even when irrigation levels were reduced from 100 % to 50% of the WHC. This study demonstrates that the development of a granular biofertilizer with combinations of biochar and diatomaceous earth showed great potential as a sustainable and scalable biofertilizer.

Keywords: granular biofertilizer; biochar; diatomaceous earth; wastes; drought.

ENVIRONMENTAL IMPACT AND SUSTAINABILITY



MULTICRITERIA ASSESSMENT OF NUTRIENT AND WATER USE EFFICIENCY IN BRAZILIAN DAIRY PRODUCTION SYSTEMS

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Brazilian dairy production systems lack comprehensive environmental assessments related to nutrient and water use efficiency. This study aimed to evaluate the relationship between production intensity and environmental indicators related to nutrient balance and water footprint through a multicriteria approach to support decision-making in dairy farm management. Data were collected from 67 dairy farms via semi-structured questionnaires administered to producers and technical managers. Nutrient use efficiency (NUE for nitrogen and PUE for phosphorus) and surplus were calculated using the Nutrient Balance approach, considering fertilizers and feed as inputs and milk as the output. The Water Footprint methodology was applied to estimate green, blue, and grey water consumption and to derive a product-based water efficiency indicator. A Productivity Efficiency Index (IP) was constructed through Principal Component Analysis (PCA), incorporating milk yield per hectare per year, stocking rate (LSU/ha), and milk yield per cow per year. Multiple Correspondence Analysis (MCA) was used to examine associations between IP, nutrient balance indicators, and WF. Data analysis was conducted using Python 3.11 and relevant scientific libraries (NumPy, Pandas, SciPy, Matplotlib, and Seaborn). The findings show that farms with the lowest IP have the lowest nutrient use efficiency and surplus and a medium-high water footprint. On the other hand, farms with the highest IP had the lowest water footprint and the highest nutrient use efficiency and surplus. The results suggest a synergy between IP and nutrient and water use efficiencies, but with greater potential for environmental risk in the form of N and P available as surplus. N surplus shows more distributed clusters in the vertical dimension, while the P surplus shows greater compaction in low and medium IPs. This indicates that the type of nutrient affects the structure of the association between the variables, suggesting that both nutrients should be considered together for more complete diagnoses. The study indicates that more productive systems tend to be more efficient in their use of nutrients and water, but it has an environmental price that is the high surplus. In addition, the heterogeneity in the intermediate systems and the discrepancy between the results with N and P highlight the need for multivariate and multicriteria evaluations with different environmental indicators to support more effective decision-making in dairy environmental management. The approach proposed in this study reinforces the importance of integrating environmental methodologies to understand the dairy production systems more holistically.

Keywords: dairy; nutrient balance; principal component analysis; productivity index; water footprint.

GROUNDWATER MONITORING IN FEEDLOT SYSTEMS OF NORTHWESTERN BUENOS AIRES PROVINCE

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In feedlot systems, one of the main environmental risks is the localized contamination of soils and both groundwater and surface water due to the accumulation of manure and runoff water. On the other hand, animals return between 60 and 80% of the nitrogen and phosphorus consumed through urine and feces. This may result in point-source contamination by nitrates near water troughs and phosphorus accumulation in areas surrounding feed bunks. Nitrogen, in the form of nitrate, has a high potential for surface runoff toward lower landscape positions or for leaching and infiltration through the soil profile. The degree of leaching is generally greater in sandy soils than in clayey soils. The objective of this study was to monitor the dynamics of groundwater chemical properties in contrasting intensive livestock systems and to evaluate the influence of soil texture and stocking rate on these parameters. Analysis of variance and mean comparison tests were performed to determine the association between soil textural class, stocking rate, and groundwater chemical variables, including pH, electrical conductivity, nitrate, ammonium, and phosphate concentrations. A total of 446 groundwater samples collected from monitoring wells at six sites between 2019 and 2024 were analyzed. Regarding nitrate concentrations, 52% of the samples showed values below the threshold level (≤ 45 ppm), whereas 28% exceeded 90 ppm. For phosphates, 44% of the samples were below the threshold value (≤ 0.2 ppm), while 39% exceeded 0.4 ppm. Ammonium concentrations were above 0.4 ppm in 83% of the samples, whereas only 13% of the samples were below the threshold value of 0.2 ppm. For electrical conductivity, 59% of the samples were below the threshold level of 2 dS m^{-1}, while 16% exceeded 4 dS m^{-1}. Soil textural class significantly affected groundwater chemical properties ($P < 0.001$), with lower nitrate (13 ppm) and phosphate (0.5 ppm) concentrations associated with silty clay soils containing a calcareous hardpan layer. Although statistically significant differences were detected for stocking rate ($P < 0.001$), no clear trend or consistent association was observed between stocking rate and groundwater chemical variables. In fact, sites with higher stocking rates (16,500 head-year) exhibited lower nitrate, ammonium, and phosphate concentrations than sites with lower stocking rates (850 head-year). This response may be related to the more frequent cleaning and maintenance of pens in high-stocking-rate feedlots, reducing nutrient accumulation and subsequent infiltration into deeper soil layers. It is concluded that feedlots located on soils with subsurface restrictive layers can prevent the evaluated chemical constituents from reaching deeper groundwater tables.

Keywords: feedlot, groundwater, soil texture, nitrates, stocking rate

EFFICIENCY IN THE REMOVAL OF CONTAMINANTS PRESENT IN WASTEWATER FROM THE USE OF SPIRULINA PLATENSIS

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Growing concern over environmental pollution has driven the search for sustainable and efficient alternatives for wastewater treatment. Spirulina platensis is emerging as a promising microorganism for this purpose. This microalga possesses a high phycoremediation capacity, meaning it can eliminate or biotransform chemical contaminants present in various effluents, by capturing them within its biomass. The objective of this study was to evaluate the performance of Spirulina platensis in removing contaminants from a dairy farm's collection pond effluent. Analyses were conducted in a column photobioreactor with a final volume of 2 L, maintained at 24 °C with aeration at 2.25 L/min, continuous illumination of 2500 lux, and an initial cell concentration of 200 mg L^{-1}. The photobioreactors were filled with a mixture of the dairy effluent and water, at dilutions of 25, 50, and 75%. Samples were collected at regular 24 h intervals and characterized for cell concentration, temperature, pH, dissolved oxygen, conductivity, and salt content. Chemical oxygen demand (COD), total nitrogen (N), and total phosphorus (P) were determined at the beginning and end of the experiment. Analysis of the results showed that Spirulina platensis had an average cell productivity of 1.7, 1.2, and 2.4 mg $L.h^{-1}$, a maximum productivity of 4.18, 2.36, and 6.12 mg $L.h^{-1}$, and a generation time of 210, 288, and 192 g/h^{-1} for the 25, 50, and 75% dilutions, respectively. Presenting parallel efficiencies in the removal of COD (67%), N (99%), and P (88%) at the 25% dilution, COD (82%), N (100%), and P (86%) at the 50% dilution, and COD (85%), N (99%), and P (84%) at the 75% dilution. The pH values ranged from 8.52 to 10.28 at the 25% dilution; 8.67 to 10.39 at the 50% dilution; 8.70 to 11.13 at the 75% dilution throughout the analyses. The results indicate the high efficiency of S. platensis in reducing COD, N, and P under autotrophic conditions for the evaluated dairy effluent. This process not only improves the quality of the treated effluent but also allows for the valorization of the obtained microalgal biomass, leading to more sustainable and environmentally friendly processes. Furthermore, this approach facilitates the generation of biofertilizers and other value-added compounds, thereby promoting principles of the circular economy.

Acknowledgments to the R&D Department of the Technological University of Uruguay, and INIA-FPTA project 394. Josh 1:9

Keywords: effluent; microalgae; treatment; biomass; cyanobacteria.

ENZYMATIC POTENTIAL OF TRICHODERMA KONINGIOPSIS FOR APPLICATION AS A BIOHERBICIDE IN THE PRESENCE OF SYNTHETIC

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This study evaluated the growth and enzymatic production of the fungus Trichoderma koningiopsis in the presence of synthetic herbicides with glyphosate as the active ingredient. The fungus was cultivated in a liquid medium with and without the addition of three commercial herbicides (Roundup Original, Roundup WG, and Zapp QI 620) at concentrations of 50% and 100% of the recommended dose. The activities of the enzymes peroxidase, laccase, amylase, cellulase, and lipase were analyzed throughout the cultivation period. The results showed that T. koningiopsis maintained its growth and ability to produce enzymes even in the presence of herbicides, with notable increases in biomass with Roundup Original and in peroxidase activity with Zapp QI 620. The absence of laccase activity was attributed to the lack of specific inducers in the medium. A preliminary test was conducted in a bioreactor using microalgae derived from biogas effluents, with prospects for co-cultivation with the fungus. The results indicate the potential of T. koningiopsis in the formulation of bioherbicides, contributing to more sustainable agricultural practices.

Keywords: microbiology; biological inputs; enzymes; agroecology.

EFFECT OF APPLYING ORGANIC AMENDMENTS ON NITROUS OXIDE (N_2O) EMISSIONS IN AN AGRICULTURAL PRODUCTION SYSTEM IN ENTRE RÍOS

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Population and economic growth have increased global demand for food, feed, fiber, and biofuels. As a result, various strategies have been implemented to minimize environmental impact and preserve soil health, such as the incorporation of organic amendments. In Entre Ríos, waste from poultry production (poultry litter and manure) is used as organic amendments due to their ability to improve soil fertility and physical properties, increasing soil carbon (C) and nitrogen (N) levels. However, N is lost in gaseous form from the soil through nitrification and denitrification in the form of nitrous oxide (N2O), a greenhouse gas (GHG). The magnitude of these emissions depends mainly on the availability of N, soil temperature, and moisture. The effect of surface application of composted residues on N2O emissions has been little studied. The objective was to evaluate the effect of adding composted and uncomposted chicken litter, compared to a synthetic fertilizer, on N2O emissions. A field trial was conducted in randomized complete blocks with the addition of organic amendments and synthetic fertilizers (2023/24 season) at INTA's Paraná EEA, under direct seeding prior to a soybean crop, in an aquic Argiudol soil of the Tezanos Pintos series. The treatments consisted of a control without fertilization (T0); addition of 16000 kg ha-1 of composted organic amendment (TC); addition of 6300 kg ha-1 of uncomposted amendment (TSC); and a control fertilized with 50+90+60+15 kg ha-1 of N, P, K, and S, respectively (TF). The C input from the amendments is the same (3000 kg ha-1), and the N input is 328 and 215 kg ha-1 for TC and TSC, respectively. N2O emissions were measured using static chambers between 9 and 12 a.m. at five times after application: at 6, 12, 20, 27, and 55 days. Simultaneously, soil samples were taken at 10 cm to determine the water-filled pore space (WFPS) and nitrate (NO3) content. No significant differences were found in the average daily N- N2O emissions between treatments or between the dates evaluated, with average N-N2O values of 0.32, 0.37, 0.38, and 0.38 gN-N2O ha-1 day-1 for T0, TF, TC, and TSC, respectively. The average NO3 content was 7.5, 6, 12.8, and 12.4 kg NO3 ha-1 for the same treatments, with no significant differences. WFPS showed average values of 61, 59, 62, and 68 % for treatments T0, TF, TC, and TSC, respectively, with no significant differences between treatments. When relating N-N2O emissions and applied N, TF differed significantly (p<0.001) from TC and TSC (0.0011 and 0.0016 g N-N2Oha-1day-1 kg-1 N), presenting higher emission values per kg of N applied (0.0077 g N-N2O ha-1 day-1 kg-1 N). When correlating these variables, we found that 76% of the cumulative emissions could be explained by the nitrogen dose. The addition of both composted and uncomposted chicken litter did not promote higher N2O emissions per unit of N input compared to inorganic fertilizer.

Keywords: waste treatment; poultry production; nitrogen gaseous losses; guano; soybean nutrition.

IMPACT ON SOIL ZN LEVELS FROM SUCCESSIVE APPLICATIONS OF COMPOSTED POULTRY MANURE AT HIGH AND LOW DOSES

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Zinc (Zn) is an essential micronutrient for plant growth and development. However, its management in agricultural systems presents particular challenges, especially when applying organic residues rich in this nutrient, such as Composted Poultry Manure (CPM). In animals, zinc is administered in high doses due to its limited intestinal absorption, leading to significant excretion in feces, which makes these residues a potentially concentrated source of zinc for agricultural soils. The objective of this study was to evaluate the dynamics of Zinc in the soil after successive applications of CPM. This trial was conducted under field conditions, using a RCBD experimental design with 4 replicates. Two contrasting doses of CPM were used: a high dose based on crop nitrogen (N) requirements (CPM-N) and a low dose based on phosphorus (P) requirements and supplemented with mineral N (CPM-P), in addition to a control without CPM. Treatments were applied successively over three crop cycles (wheat, second-crop soybean, and corn). Levels of available Zn, total Zn, and different Zn fractions in the soil were determined prior to sowing and at physiological maturity of each crop, quantified by atomic absorption spectrophotometry. Zinc balances were calculated for each crop and for the complete rotation. The results showed that the dynamics of this element varied according to the treatment and the crop. The total Zn level at the beginning of the trial was 51 mg kg-1 and increased at the end of the rotation in the CPM treatments (63 and 72 mg kg-1) while decreasing in the control (47 mg kg-1). The residual Zn fraction represented the largest part of the total Zinc, varying between 51 and 82%. The largest variation was observed in the CPM treatments, where it increased by 44% and 63% relative to its initial content in CPM-P and CPM-N, respectively. The extractable/exchangeable and moderately labile Zn fractions, considered more available, represented between 3-8% and 3-7% respectively. This indicates that after CPM application, Zn remains in stable forms, preventing accumulation. The soil Zn balance was negative for the control and positive after successive CPM applications; however, with the higher dose, only 20% of the amount of Zn allowed to be applied annually as compost to the soil was reached. Thus, Zn accumulation did not reach values that represented an environmental risk. On the other hand, it was observed that the high dose of CPM generated significant surpluses of other nutrients such as N and P in the surface layer of the soil, suggesting the need for careful management of the applied dose. In summary, the dynamics of Zn in the soil-plant system did not present contamination risks, which supports the viability of using CPM as a nutrient source in agricultural rotations, provided that recommended doses and current regulations are respected.

Keywords: zinc; poultry manure; sequential fractionation; nutrient dynamics; environmental impact.

SPREAD OF ANTIMICROBIAL RESISTANCE GENES AND PLASMIDS FROM POULTRY LITTER ACROSS AGRICULTURAL COMPARTMENTS: A ONE HEALTH PERSPECTIVE

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Poultry litter, the main waste product generated by poultry farming, is widely used as an agricultural fertilizer. However, owing to the extensive use of antimicrobials in animal production, this waste can accumulate bioactive antimicrobial metabolites, antimicrobial-resistant bacteria (ARB), and antimicrobial resistance genes (ARGs). Once applied to soil, these contaminants may reach crops and water bodies through runoff and erosion. Subsequently, these contaminants may return to the agricultural environment via irrigation, establishing a cycle that promotes the selection, dissemination, and persistence of antimicrobial resistance (AMR). This study, under the One Health framework, investigated the hypothesis of ARG and mobilizable plasmid dissemination from poultry litter to soil, the rhizosphere of Sechium edule (chayote), irrigation water, and sediment in two poultry-producing agricultural areas (farms A and B). The samples were collected in triplicate and subjected to total DNA extraction, followed by shotgun metagenomic sequencing (NovaSeq 6000, Illumina, paired-end). The sequences were subjected to quality control and de novo assembly using MEGAHIT v1.2.9. Gene prediction was performed using Prodigal v2.6.3, and functional annotation was performed using EggNOG-mapper v2.1.12 (eggNOG v5.0.2). Putative plasmids were identified with MOB-suite v3.1.9, and ARGs were detected using ABRicate v1.0.1 with the Comprehensive Antibiotic Resistance Database (CARD). Analyses revealed significant variations in the functional diversity and relative abundance of ARGs among the environmental compartments. The poultry litter presented the highest ARG diversity (119 distinct genes), 101 of which were exclusive to this matrix. KEGG Orthology-based annotation indicated that approximately 1% of all annotated genes in each sample were associated with AMR, including pathways conferring resistance to β-lactams, vancomycin, and cationic antimicrobial peptides (CAMPs). Genes such as sul2 (sulfonamide resistance), mtrA (macrolide and penicillin resistance), and rbpA (rifampicin resistance) were widely detected across compartments but presented significantly greater relative abundances outside poultry litter, suggesting accumulation and possible dissemination among environmental matrices. At least 25 distinct plasmids were identified in poultry litter from farm A (20 non-mobilizable, 5 mobilizable, and 1 conjugative) and 36 from farm B (28 non-mobilizable and 10 mobilizable). All the plasmids carried ARGs conferring resistance to multiple antimicrobial classes (e.g., sul2, ermB, aadA, dfrA, qnrB, qnrD, and tet) and were associated with bacterial genera such as Staphylococcus, Enterococcus, Escherichia coli, and Pseudomonas, which are listed as priority pathogens by the World Health Organization (WHO). The detection of the mobilizable plasmid pBC16 from Bacillus cereus, harboring the tet(L) gene in poultry litter, soil, and the rhizosphere, suggests horizontal gene transfer across compartments. These findings highlight poultry litter as an environmental reservoir of ARGs and mobile genetic elements with the potential for dissemination in agricultural systems. The presence of critical ARGs on mobilizable plasmids associated with priority pathogens underscores the risk to public and animal health. Environmental monitoring and proper waste management practices in animal production are essential to mitigate the spread of AMR.

Keywords: poultry farming; antimicrobial resistance genes; organic fertilizer; chicken manure; mobile genetic elements.

BIOGAS GENERATION USING TYPHA LATIFOLIA FROM PHYTOREMEDIATION TRIALS OF LEAD-CONTAMINATED WATER

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T. latifolia exhibits significant potential for the phytostabilization and phytoimmobilization of Pb in contaminated media. The plant effectively reduced Pb concentrations in aqueous solutions, particularly at high concentrations (1,000 and 10,000 µg Pb L^{-1}), achieving reductions exceeding 60%. Pb accumulation was predominantly observed in the roots, with limited translocation to aboveground tissues. This suggests that T. latifolia immobilizes Pb in the root system, potentially reducing its toxicity in the environment.

Given the plant tolerance and good remediation capacity, we sought an alternative pretreatment for the contaminated biomass by using it in an anaerobic digestion trial for biogas production. We considered that the effect of lead on the response to biodigestion would be more evident at high contamination levels (1,000 and 10,000 µg L^{-1}), while simultaneously evaluating the behavior of the control treatment, without lead contamination. Biogas production was tested on a batch scale in root and leaf exposed for 48 and 168 hours, and at three lead concentration levels: 0 - 1,000 - 10,000 µg Pb L^{-1}. No differences were observed in the milliliters of biogas generated by grams of volatile solids (organic matter) with respect to exposure time in any of the treatments. Biogas production was much higher in those plant materials with higher lead content and even higher than in control treatment. Roots exposed to 10,000 µg Pb L^{-1} for 168 hours, containing 2,962 mg Pb kg-1 of dry matter yielded 39% more biogas than their control counterparts, which contained 6 mg of Pb kg-1 of dry matter. When biogas yield was tested in leaves of plants exposed to lead-contaminated water, materials from the treatment of exposure to 1,000 µg Pb L^{-1} for 48 hours (and lead content of 10.2 mg Pb kg-1 of dry matter) yielded 19 % more than its control counterpart (3 mg of Pb kg-1 of dry matter).

To describe the biogas production in root and leaves, a first-order kinetic model was followed. The kinetic prediction models for biogas production both in roots and leaves were significant to estimate the Ymax (maximun biogas yield) and the hydrolysis constants in all treatments.

The results of this study suggest that the macrophyte T. latifolia can be used for phytoremediation of lead-contaminated waters and that the biomass generated can be used to generate bioenergy. This pretreatment does not remove lead from the digestate, so it would be appropriate to treat the digestate with this same phytoremediation species, or to use a dry biodigestion technology -with reduced moisture content- that would concentrate the lead in solid digestates that can be dried for final disposal.

To confirm the conclusions, a pilot scale study -continuous or semi-continuous feeding- must be carried out to elucidate the real operating conditions of a digestion process by evaluating the optimal organic loading rate -kg of volatile solids per cubic meter of biodigester per day- that must be adjusted based on the hydraulic retention time, the degradability rate of the biomass under study and the possible inhibition of lead under the conditions tested.

Keywords: biogas; contaminated biomass; lead; phytoremediation.

X-RAY DIFFRACTION (XRD) CHARACTERIZATION OF BIOCHAR PRODUCED FROM TWO HIGH-BIOMASS GRASSES GROWN IN CADMIUM-POLLUTED OXISOL

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Phytoremediation is an environmentally friendly technology that can be used to reduce cadmium (Cd) concentrations in polluted areas. However, due to the toxic effects of Cd, only a limited number of plant species are suitable for phytoextraction or phytostabilization. Additionally, the biomass produced during phytoremediation may become a secondary source of contamination if not properly managed. In this context, we produced and characterized biochar from two high-biomass grass species—Pennisetum glaucum cv. Purpureum Schum and Panicum maximum cv. Mombaça—with the goal of using the resulting biochar as a soil amendment to enhance the overall effectiveness of phytoremediation strategies. The grasses were cultivated in an Oxisol moderately contaminated with Cd (7.5 mg kg^{-1}), and their biomass was subjected to pyrolysis at two temperatures: 500 and 800 °C. X-ray diffraction (XRD) analysis revealed distinct differences in the crystalline phases of the biochar. At 500 °C, both grasses produced biochar with low-intensity peaks and a diffuse background, indicating predominantly amorphous structures. The main mineral phases detected were silica (SiO_2) and calcite ($CaCO_3$), with possible traces of phosphates and metal oxides. Raising the pyrolysis temperature to 800 °C resulted in significant structural changes. Biochar produced at this temperature displayed sharper, more defined peaks, reflecting increased crystallinity. Notably, the formation of graphite was observed, with peaks around 26.5°, 43°, and 50.2°, particularly in the biochar from P. maximum. Peaks associated with iron oxide (Fe_2O_3) and calcium phosphate [$Ca_5(PO_4)_3OH$] were also evident, especially in the biochar derived from P. glaucum. These results indicate that both the type of biomass and the pyrolysis temperature strongly influence the development of crystalline phases. While the 500 °C biochar retained a greater proportion of poorly crystalline residual minerals, the 800 °C biochar—especially that produced from P. maximum—underwent greater structural reorganization, forming more ordered carbonaceous materials. These transformations may enhance the capacity of the biochar to retain Cd through mechanisms such as precipitation with carbonate or phosphate groups. This study demonstrates that both biomass source and pyrolysis temperature play a decisive role in properties of biochar derived from grasses grown in Cd-contaminated soils. These findings support the strategic integration of phytoremediation and biochar application as a circular and effective approach to mitigate Cd contamination in soils, contributing to both environmental sustainability and soil health.

Keywords: circular phytoremediation; environmental sustainability; poaceae; soil pollution.

RETENTION AND INFILTRATION OF PESTICIDES IN SOILS OF THE PAMPAS LANDSCAPE IN CARMEN DE ARECO (BUENOS AIRES, ARGENTINA)

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The current agro-industrial production model in the Argentine Pampas plain relies heavily on pesticide use. These compounds, applied directly to crops, inevitably reach other environmental compartments such as water, soils, sediments, plants and biota (Aparicio et al., 2013; Pizarro et al., 2024). However, few studies have addressed cultivated soils and their interaction with wetland soils embedded within agricultural landscapes. The geomorphological and functional heterogeneity of these ecosystems regulates their capacity to retain and transport contaminants (Brinson, 1993).

This study aims to analyze pesticide retention and infiltration in one cultivated soil and two wetland soils with distinct hydrological dynamics and edaphic properties. The study area is in northeastern Buenos Aires Province, approximately 5 km southwest of Carmen de Areco. The landscape consists of an agricultural matrix interspersed with wetlands occupying low-relief areas. The agricultural matrix (CF) is a loess plain under rotational wheat-maize-soybean-pea cultivation, with seasonal pesticide applications. Wetlands are represented by floodplains (FW), elongated features ~400 m wide linked to fluvial systems, and depressional wetlands (PW), circular features 100–300 m in diameter, hydrologically isolated.

Three representative sites (CF, FW, PW) were selected. FW and PW are situated within 200 m of sprayed areas and maintain hydraulic connectivity, posing potential contamination risks. 90 cm soil pits were excavated at each site, collecting samples for physical and chemical characterization (% moisture, pH, texture, electrical conductivity, organic matter, CEC). Pesticide sampling occurred two weeks after seasonal spraying in two hydrologically contrasting ENSO years (November 2022 and 2023). Pesticides were quantified using a Waters Acquity UPLC-MS/MS system, analyzing 42 samples and detecting 28 pesticide compounds.

Results indicate:

The CF soil is an aquic Argiudoll, silty, well-drained, with total pesticide concentrations of ~5,000 ppb at the surface and ~100 ppb in deeper horizons.

The PW soil is a mollic Epiacuaf, clayey, prone to waterlogging, with high surface organic matter, showing ~1,000 ppb at the surface and ~10 ppb at depth.

The FW soil is a typical Natraqualf, silty-clayey, also waterlogged with poor drainage, sodium accumulation, carbonates, and expansive clays, containing ~50 ppb at the surface and ~10 ppb at depth.

Preliminary conclusions reveal three soils with distinct structures, pedogenic processes, and pesticide retention capacities. The contrast between PW and FW may be attributed to differing hydrological regimes that promote contaminant accumulation in PW. FW and PW were not directly sprayed yet containing pesticides, indicating transport from adjacent areas. Detection in deeper horizons suggests vertical movement through percolating water.

Vertical pesticide profiles generally declined with depth, though in 2023 relative increases were noted below 50 cm, coinciding with higher precipitation. While PW showed greater surface accumulation, FW exhibited stronger evidence of infiltration to deeper horizons. CF also displayed signs of leaching.

Keywords: soils; water; pesticides; wetlands; leaching.

INSIGHTS OF NITROGEN AND PHOSPHORUS USE EFFICIENCY INTO BEEF CATTLE PRODUCTION AT SÃO PAULO STATE, BRAZIL

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Beef cattle production systems in Brazil are heterogeneous. São Paulo state, a major consumer and exporter of beef, illustrates the gradient of intensification of livestock systems, ranging from improved pastures to feedlots. Input Intensive systems are characterized by a dependence on fertilizers and animal feed rising environmental concerns particularly regarding nitrogen (N) and phosphorus (P) cycles. Material Flow Analysis (MFA) was used to quantify N and P flows across breeding, rearing, and finishing phases in different beef production systems. Our aim is to compare efficiencies of N and P use from 2011 to 2021 in diverse livestock production systems in Sao Paulo state. This study combined several datasets, zootechnical indicators and feed software to calculate animal feed, manure and animal production from different production systems. Herd was categorized into 5 animal groups (calf 0-1 year, heifer and calf 1-2 years old, cow and bull) and 6 productions systems (2 for the initial phase: cow-calf phase, rearing period and 4 for the finishing one: extensive pasture, improved pasture, semi-intensive and intensive). Each animal category has its own dietary needs (composition and quantity) and productive performance (daily weight gain). Production was estimated based on culling rate (for Bulls and cows), age at slaughter (for heifers and calves) and live weight of animals. Nutrient Use Efficiency (NUE) was computed as the ratio of carcass production to inputs for each nutrient. In 2011, the total herd size was 6,509,632 heads, whereas in 2021, it had declined to 5,888,994 heads. Additionally, there was a strong increase in the proportion of animals finished in intensive systems from 38.5% to 73.5% in 2021. There was a reduction in feed inputs. Beef cattle production in São Paulo consumed 268,884 tons of N and 33,273 tons of P in 2011. In 2021, these values were 258,299 tons of N and 28,904 tons of P. However, there was an increase in the use of corn-derived feeds (as silage and meal). Regarding carcass production, 13,062 N tons and 5,899 P tons were produced in 2011, whereas in 2021, these values increased to 13,854 N tons and 6,257 P tons. NUE improved in Sao Paulo state over the years. In 2011, N and P use efficiencies were 7.6% and 21.7% respectively. By 2021, N and P efficiencies had risen to 8.7% and 25.8%. This increase in NUE can be attributed to the shift in herd dynamics towards more intensive systems. Some hypotheses can be raised regarding this change: high land value in the region, competition with other agricultural crops (such as citrus and sugarcane), and vertical integration of the slaughter industry. However, higher nutrient use efficiency might not lead to a lower environmental impact. Intensification of production in a given region leads to a higher concentration of animals, more energy and protein richer feedstuffs consumption and additional manure that can exacerbate environmental issues such as greenhouse gas emissions, nutrient leaching, waterway eutrophication, and soil pollution.

Keywords: material flow analysis; use efficiency; beef cattle system.

LINK BETWEEN ROOT GROWTH DYNAMICS AND CHANGES IN SOIL ORGANIC CARBON FRACTIONS WITH AND WITHOUT RESIDUE REMOVAL IN SUGARCANE

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Sugarcane (*Saccharum* spp.) is one of the world's most effective carbon (C) fixing crops. However, the impact of post-harvest residue removal for energy purposes on root growth and, consequently, on soil organic carbon (SOC) fractions has been scarcely explored. Our objective was to evaluate the effect of sugarcane residue removal on root growth dynamics and the physical fractions of SOC: particulate organic carbon (POC) and mineral-associated organic carbon (MAOC). It was hypothesized that maintaining residue enhances root growth and increases POC and MAOC fractions. An experiment was implemented in an irrigated sugarcane field in Northwestern Argentina. The evaluated treatments (0% and 100% residue removal over two consecutive cycles) were arranged in a randomized complete block design with three replications. Root biomass (0-30 cm) was sampled and quantified during stalk elongation (SE, late March) and maturity (M, late July) in each cycle. SOC and its fractions were determined before establishing the treatments and at M in each cycle, at depths of 0-5, 5-10, 10-15 (only second year), and 0-30 cm. In the first cycle, root biomass increased from SE to M under both treatments ($p = 0.04$), being consistently higher ($p = 0.005$) under the 0% removal treatment. On the contrary, in the second cycle, biomass decreased from SE to M in both treatments ($p = 0.03$); at SE, biomass was, on average, higher under 0% removal. By the end of the second cycle and at a depth of 10 cm, SOC increased by 1 Mg ha^{-1} under 0% removal, while remaining unchanged under 100% removal. There were no significant differences in MAOC between treatments. However, MAOC decreased from the beginning to the end of the first cycle, increasing afterwards (without exceeding initial values), reflecting C inputs from root death in the second cycle. After two years, significant differences in POC between treatments were only observed at 0-5 cm depth. Avoiding indiscriminate residue removal could enhance root growth and root-C inputs for MAOC formation. POC reflected residue removal or retention, and maintaining residue increased SOC at a rate of 0.5 Mg ha^{-1} yr^{-1}.

Keywords: bioenergy; belowground biomass; climate change; green harvest; rhizodepositions.

NITROUS OXIDE EMISSIONS FOLLOWING BIOSOLID APPLICATION ON FOREST SOIL UNDER WATER DEFICIT CONDITIONS

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Biosolids are organic waste products derived from wastewater treatment. Their application as a soil amendment in forest soils is a valorization strategy but carries environmental risks, such as nitrous oxide (N_2O) emissions, a greenhouse gas with a global warming potential 273 times higher than carbon dioxide (CO_2). N_2O is primarily produced through nitrification and denitrification, both microbially mediated processes. The co-application of biosolids with zeolites has been proposed as a mitigation strategy for N_2O emissions. Zeolites are microporous minerals with high cation exchange capacity. This study aimed to quantify N_2O emissions and analyze their key regulatory factors (temperature, water-filled pore space (WFPS), and soil nitrate (NO_3^-) content) over a 27-day period following soil application of biosolids, either alone or mixed with zeolites.

The experiment was conducted in a willow (Salix sp.) forest plantation. A completely randomized block design was implemented, with three blocks and three treatments: control (T), biosolids (B), and biosolids with zeolites (BZ). Biosolids were applied at a rate of 8.34 t dry matter/ha, and zeolites at 2.09 t/ha. N_2O emissions were measured on 15 dates using static chambers. Additional measurements included air and soil temperature, soil NO_3^- content, WFPS, cumulative N_2O emissions over the sampling period, and precipitation records.

Cumulative N_2O emissions for each treatment were: B: 129.8 ± 69.16 g/ha; BZ: 85.65 ± 20.89 g/ha; T: 42.89 ± 30.15 g/ha, with no statistically significant differences. Although zeolites showed mitigation potential on 4 of the 15 measurement days, their effect on cumulative N_2O emissions was not statistically significant. An N_2O emission peak was observed seven days after treatment application, with emissions 19–29 times higher than the average of the first six days. This peak occurred after the first precipitation event (13.2 mm) during the study period, suggesting that moisture stimulated microbial processes linked to N_2O emissions. No significant correlation was found between N_2O emissions and regulatory variables (WFPS or soil NO_3^- content), likely due to drought constraints.

Exceptionally dry conditions during the study period, associated with the La Niña phenomenon, likely constrained N_2O emissions. In comparable studies conducted under wetter conditions, cumulative N_2O emissions over six months were up to 75 times higher than in this study. The peak in N_2O emissions that occurred after the first precipitation event provides evidence of the sensitivity of microbial processes to changes in soil moisture. These results underscore how local climatic conditions, particularly the increasing frequency of droughts in the context of climate change, can strongly constrain microbial processes driving N_2O emissions, even in soils amended with nitrogen-rich residues. This finding reinforces the need to account for local environmental variables when designing biosolid management strategies.

Keywords: organic fertilizers; waste valorization; drought; zeolites; greenhouse gas emissions.

IMPACT OF MANURE APPLICATION ON SOIL PROPERTIES IN A SILVOPASTORAL GOAT-BASED FORAGE SYSTEM IN A SEMIARID ENVIRONMENT

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Agricultural activity in semiarid regions poses a challenge to the sustainability of production systems. In this context, soil organic matter (SOM) is considered a key indicator of sustainable management, as it regulates the intensity of soil conservation and restoration processes. One of the most commonly used practices to enhance SOM reserves and nutrient availability is the application of organic amendments such as manure. However, crop type and soil management strategies also play a crucial role. At the experimental field of INTA EEA Santiago del Estero (LS 28° 01´11,07”; LO 64° 14´20,36”), under irrigated conditions, the effect of manure application on soil physical and chemical properties was evaluated. Three types of organic amendments were tested: poultry litter (GG), fresh goat manure (GCN, collected six months before application), and aged goat manure (GCV, stored in piles for over a year). The manures were applied on October 2, 2023, at a single rate of 5 $t \cdot ha^{-1}$ and incorporated superficially five months prior to sowing. The treatments (GG, GCN, GCV, and an unamended control) were arranged in a completely randomized design (CRD) with three replicates, totaling 12 plots of 144 m^2 each. Initial physical and chemical analyses of the manures and soils were conducted. All plots were irrigated before sowing. On March 18, 2024, a forage mixture was sown, consisting of hairy vetch (Vicia villosa), triticale (x Triticosecale Wittmack, INTA Molle), and forage barley (Hordeum vulgare, Guadalupe INTA), planted in alternating rows (vetch-barley-triticale) within each plot. At the end of the growing cycle, bulk density (BD) in the top 15 cm of soil was not significantly affected by the treatments compared to the control (mean: 1,03 $g \cdot cm^{-3}$). However, significant differences were observed between GG and GCV treatments, with BD increasing by 15% under GG compared to GCV. Regarding electrical conductivity of the saturation extract (ECe), no treatment effects were detected (0,5 $dS \cdot m^{-1}$). Soil pH was significantly higher under GCV, being 2.5 times more alkaline than the control. Total organic carbon (TOC) and total nitrogen contents showed no significant differences among treatments, averaging 22.2 $t \cdot ha^{-1}$ and 2.1 $t \cdot ha^{-1}$, respectively. Total phosphorus levels did not differ significantly between the control and amended plots (537.6 $kg \cdot ha^{-1}$), although GG showed a 54% increase over GCV. These findings underscore the importance of selecting appropriate organic amendments and application timing according to soil conditions and production objectives. This study highlights the need for further long-term evaluations to better understand the dynamics of organic amendments in semiarid forage systems. Generating local data on manure management can support the development of sustainable strategies for silvopastoral production systems.

Keywords: fertility; manure; forages; sustainability.

MESOPHILIC STABILIZATION AND BIOREMEDIATION OF MIXTURES WITH PETROLEUM HYDROCARBONS POLLUTED-SOIL, ACTIVATED SLUDGE AND AGRICULTURAL RESIDUES

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Composting is extensively used as a technique to obtain amendments and fertilizers from organic residues derived from anthropogenic activities. In addition, it can be applied as an ecotechnology to remediate polluted soils for a wide spectrum of contaminants, like petroleum hydrocarbons, with relatively low costs, short time periods and elemental equipment. Thus, the aim of this work was to stabilize mixtures with hydrocarbon polluted-soil, activated sludge and agricultural residues in order to obtain a high-quality final product. Soil (S) was spiked with 3500 mg/kg of commercial diesel and mixed with activated sludge (AS) and wheat straw (WS) following three different ratios (wet mass %): 80.25% S:18.25% AS: 1.5% WS (MS_80); 70.25% S:28.25% AS: 1.5% WS (MS_70); and 60.25% S: 38.25% AS: 1.5% WS (MS_60). Each mixture consisted of 40 kg of materials disposed in plastic boxes and exposed to environmental conditions but shielded from heavy rains. Temperature profile was performed daily for the first two weeks and then registered weekly for a total of 67 days, along with mechanical blending. The total petroleum hydrocarbons (TPH) concentration was measured through GC-FID. Samples were taken to evaluate physical, chemical and microbiological parameters, as well as thermogravimetric analysis (TGA) and scanning electronic microscopy (SEM) observations. Pathogens content was evaluated by total and fecal coliforms determinations recommended by EPA (2003). Finally, germination indexes (GI) were determined at the end to assess the maturity of the mixtures in aqueous extracts at two dilutions (25 and 50%) using soy (Glycine max), corn (Zea mays) and tomato (Solanum lycopersicum). At the end, all the mixtures registered values of TPH under the quantification limit (i. e. 500 ppm) revealing removal percentages within 82.19 to 84.57. Pathogens content was also reduced 60.4 and 69.71% in the mixtures MS_70 and MS_60, respectively. In the mixture MS_80, coliforms increased 10.66%. Nonetheless, the three mixtures registered final pathogens contents below the class A biosolids threshold (1000 MPN per total solids gram). TGA studies revealed an increasing mass loss rate related to increasing proportions of AS. Stabilization mixtures presented the following initial and final values, respectively: 6.898% - 5.422% (MS_80); 5.868% - 7,159% (MS_70); 7.985% - 10.71% (MS_60). In general, a higher mass loss rate indicates a higher degree of maturity of the mixture. SEM scanning revealed the presence of amorphous masses from AS, which significantly increase the organic matter content of soil, predominantly formed by siliceous crystals and inorganic compounds. At the end, the matrices showed smoother and partially fragmented textures due to microbial metabolism. All three mixtures indicated maturity (>80% GI) for soy at 25 and 50% dilutions, as well as the mixture MS_60 for corn and MS_80 for tomato. The mixtures MS_70 (both dilutions) and MS_60 (50%) indicated no phytotoxicity (>60% GI) for corn and tomato. Maximum registered temperatures ranged from 36 to 40 ºC, marking a process with mesophilic stabilization, where it was possible to obtain decontaminated materials with mature amendment quality and to be used for ornamental purposes, in accordance to local and national legislation.

Keywords: biodegradation; organic wastes; soil with diesel; phytotoxicity.

PRELIMINARY INSIGHTS INTO ANTIMICROBIAL RESISTANCE DISSEMINATION: ESCHERICHIA COLI DYNAMICS IN SWINE EFFLUENT TREATMENT SYSTEMS

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Swine production has experienced sustained growth worldwide in recent decades. In Argentina, although traditional consumption was dominated by beef, pork production has also grown significantly. In these production systems, the abuse and misuse of antimicrobials has accelerated the spread of antimicrobial-resistant bacteria.

A considerable proportion of the antimicrobials administered to pigs are excreted into the environment in an unmetabolized state through urine and feces, while bacteria from the gastrointestinal tract are also eliminated. Increasing effluent volumes challenge the proper management of these wastes and the spread of environmentally resistant pathogens and bacteria. In this context, the adoption of adequate effluent treatment systems becomes relevant not only as a sanitary and environmental measure, but also as a long-term sustainability strategy.

This preliminary study assessed the presence of Escherichia coli as an indicator microorganism to analyze its antimicrobial resistance profile across different stages of effluent treatment systems commonly used by small- and medium-scale pig producers in Buenos Aires. Effluent samples were collected at three key stages: raw effluent, effluent after solid–liquid separation, and effluent from anaerobic treatment lagoons. This sampling strategy enabled the evaluation of the system's efficiency in reducing bacterial loads and its potential role in selecting resistant strains during the treatment process.

Serial dilutions were performed for enumeration, isolation, and detection of total coliforms. Colonies compatible with E. coli were selected and confirmed by biochemical tests. To consider the origin, ecology, and pathogenic potential of the isolates, E. coli strains were classified into different phylogenetic groups. Finally, a subset of colonies from each sample was selected for antimicrobial susceptibility testing using the disk diffusion method against 10 antimicrobials from different antibiotic families. Antimicrobial resistance (AMR) was evaluated as the percentage of non-susceptibility (% NS, resistant, and intermediate categories), following the interpretation criteria of CLSI.

Total coliforms recovered in the different stages were: raw effluent (3.6×10^5 CFU/mL); post solid-liquid separation (5.7×10^4 CFU/mL), and effluent from anaerobic treatment ponds (1.6×10^3 CFU/mL), indicating a progressive reduction in total coliform concentration across treatment stage. A total of 27 E. coli isolates were recovered, of which 20 (74%) were identified as belonging to phylogenetic group A and five (18.5%) to group B1, suggesting a predominance of commensal strains. Only two isolates were classified in groups B2 and D, typically associated with pathogenic intestinal strains.

Antimicrobial-resistant isolates were detected in all sample types. Among them, 13/15 (87%) were classified as multidrug resistant (MDR), defined as resistant to at least three different families of important antimicrobials. All isolates were NS to tetracycline, 93% to ampicillin, 80% to enrofloxacin, and 60% to ciprofloxacin.

This study reveals that, although effluent treatment systems reduce total coliform levels, they fail to eliminate antimicrobial-resistant E. coli. The high prevalence of MDR strains, even in treated effluents, underscores the potential environmental risk and highlights the need for improved waste management practices and prudent antimicrobial use in swine production.

Keywords: antimicrobial resistance; escherichia coli; effluents; pig production; waste treatment.

EVALUATION OF THE ACCUMULATION POTENTIAL OF RESIDUAL HERBICIDES IN EDIBLE PLANT ORGANS OF AGRICULTURAL CROPS

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The root absorption, translocation, and accumulation of residual herbicides from soil into plant organs depend mainly on the compound's availability in the soil solution, its mobility and ability to pass through roots, its physicochemical properties, and the type of crop. Therefore, it is essential to assess these processes under real field conditions using integrated indices that account for both the herbicide's availability in soil and its concentration in the edible plant organ (soil-plant index). This allows for a comparative quantification of the actual transfer potential of herbicide residues to agricultural products intended for human consumption. In this context, the objective of this study was to evaluate the relative accumulation of residual herbicides in edible plant parts of both extensive and intensive crops, depending on the type of herbicide and the harvested organ. A total of 22 production fields were sampled, located in both; intensive and extensive, cropping systems in the southeastern region of Buenos Aires Province, Argentina. The edible organs analyzed were: root (carrot), leaf (lettuce), tuber (potato), summer cereal grain (sweet corn), winter cereal grain (wheat and barley), and oilseed grain (sunflower). Soil samples were collected at two crop stages (sowing and harvest), and plant samples at two physiological stages (mid-cycle and harvest). At harvest, plant material was separated into edible organ and residue. Pesticide residue concentrations were determined using high-performance liquid chromatography coupled with tandem mass spectrometry (HPLC-MS/MS), covering a total of 59 active ingredients. Based on these data, a soil-to-organ accumulation index was calculated for each compound detected in soil at sowing and in edible organs at harvest. This index was defined as the ratio between the herbicide concentration in the edible organ (ng g^{-1} dry matter) and the corresponding soil concentration (ng g^{-1} dry soil). Finally, a two-way analysis of variance (ANOVA) was performed to evaluate the effects of organ type, herbicide compound, and their interaction on the accumulation index. Residues of six herbicides were simultaneously detected in soil and edible plant organs: glyphosate, its metabolite AMPA, atrazine, metolachlor, acetochlor, and flurochloridone. The soil-to-plant accumulation index showed no significant interaction between organ type and herbicide. However, there were significant differences among compounds, with some herbicides showing higher accumulation values compared to AMPA, which had the lowest index. No statistical differences were observed among plant organs. Nevertheless, potatoes showed accumulation indices close to zero, while the other crops had indices around 1.1. These results confirm that the relative accumulation of residues is mainly determined by the physicochemical properties of each herbicide or metabolite, rather than by the type of plant organ. This information helps to identify herbicide-crop combinations that may pose a higher risk to food safety. The evaluation of the soil-to-organ index allowed the identification of herbicides/metabolites and plant organs with a higher risk of residue accumulation. The potato crop and the metabolite AMPA stood out for their relatively low risk, suggesting a safer profile for food consumption.

Keywords: residual herbicides;soil-plant index; edible plant organs; herbicides residues.

VISIBLE SEEDS, SILENT RISK: NEONICOTINOID RESIDUES AS A CAUSE OF ACUTE TOXICITY IN WILD BIRDS

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Seed treatments with neonicotinoids are a widespread practice in South American agriculture. However, a proportion of seeds remains unburied after sowing and becomes accessible to wildlife. This study assessed the presence of neonicotinoid residues in seeds of maize, sorghum, and soybean after sowing, and in the gastrointestinal tract (GIT) of Eared Doves (Zenaida auriculata), a common granivorous bird in agricultural landscapes. We sampled 43 commercial fields in central-eastern Argentina and quantified unburied seeds immediately after sowing. Chemical analysis revealed the presence of imidacloprid, clothianidin, and thiamethoxam in maize and sorghum seeds, and imidacloprid in some soybean samples. Imidacloprid was the most frequently detected compound. Additionally, 200 Eared Doves obtained from hunting activities were dissected, and their GIT contents were analyzed. Residues of imidacloprid were detected in 5.5% of the birds, with maximum concentrations exceeding 6 mg a.i./seed kg in the digestive tract. In several cases, the birds had consumed maize or sorghum seeds prior to sampling. We estimated refined toxicity-exposure ratios (TER) using individual residue data and energy-based dietary models. The results indicated an acute risk (TER <10) for birds ingesting seeds containing imidacloprid, particularly maize and sorghum. This constitutes the first field-based evidence in South America of a direct pathway of neonicotinoid exposure to birds via consumption of treated seeds. Our findings underscore the need to enhance sowing techniques to reduce seed exposure and to revise pesticide risk assessment frameworks to consider realistic post-sowing scenarios. Reducing environmental residues is essential to avoid unintended effects on biodiversity in agricultural ecosystems.

Keywords: neonicotinoids; pesticide residues; seed treatment; avian toxicity; gastrointestinal exposure.

BIODIVERSITY MONITORING PLAN FOR THE CHUBUT RIVER: ASSESSING AN INVASIVE SPECIES FOR ITS USE AS A RENEWABLE ENERGY RESOURCE

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The Chubut River, which flows west to east across the province of the same name in Argentine Patagonia, constitutes a key ecological corridor for regional biodiversity, water provision for human consumption, and the well-being of local communities. However, it faces increasing anthropogenic pressures and the spread of invasive exotic species, which disrupt its natural dynamics and constrain the ecosystem services it provides. One of the persistent inquiries received by INTA (National Agricultural Technology Institute) concerns the utilization of woody species for thermal energy generation in the arid regions traversed by the Chubut River along its extensive 1,080 km course. Given the scarcity of information regarding the ecological dynamics of the river and its associated ecosystems, the Chubut Agricultural Experimental Station (EEA Chubut) proposed the development of a biodiversity monitoring protocol to serve as a technical input for the design of evidence-based public policies aimed at the river's protection and restoration. In September 2023, we facilitated the formation of an interdisciplinary technical team comprising institutions and agencies at both national and provincial levels to coordinate this initiative. The methodology adopted for the development of the project was the one known as the "Practical River Restoration Appraisal Guidance for Monitoring Options", originally developed in the United Kingdom. The work plan was structured into three stages: (1) pre-project assessment, (2) project design and implementation, and (3) post-project evaluation and adaptive management. During 2024 and 2025, progress was made on the first phase through the selection of a study site: the Los Altares Protected Natural Area (Category V – Protected Landscape), with the following objectives: (1) to characterize the Chubut River, (2) to characterize the flora and fauna associated with the river, and (3) to determine the interactions between both components. To characterize the flora, a plant species census was conducted in 2024 along the riverbank near the locality of Los Altares. The results confirm the presence of several invasive exotic species, such as Salix × fragilis. This species is classified as invasive due to its impact on biodiversity—e.g., by displacing the only native riparian tree species (Salix humboldtiana)—as well as its effects on hydrological dynamics of the river through processes of impoundment. Given that the management of Salix × fragilis is already governed by regulation, it is proposed that the Chubut River restoration plan include the development of management strategies that integrate selective removal and bioengineering techniques, considering biotic, abiotic, and socio-environmental criteria. For the latter, it is recommended to take into account the relationship between local inhabitants and their environment, in order to promote the use of biomass residues from Salix × fragilis removal for thermal energy generation—used for home heating and cooking—in Patagonian regions where firewood remains the primary energy source.

Keywords: biodiversity monitoring; biomass residues; bioenergy; exotic species reuse; public policies.

SUBSURFACE APPLICATION OF BIOSOLIDS IN A FOREST PLANTATION: EVALUATION OF THE USE OF ZEOLITES TO MITIGATE NITROUS OXIDE EMISSION

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Biosolids can be defined as by-products of effluent treatment, whose final disposal represents high operating costs. Due to their high content of organic matter and nutrients, they are used as an organic amendment in soils. In 2018, Resolution 410/18 was sanctioned in Argentina, which enabled its application in forest systems. However, there are still few studies that quantify their impacts and benefits. Due to its high nitrogen content, the application of biosolids in soils can increase nitrous oxide (N_2O) emissions. This is a greenhouse gas with a global warming potential 273 times greater than carbon dioxide and with the capacity to degrade stratospheric ozone. One possible strategy to mitigate N_2O emissions is to condition biosolids with zeolites. These are minerals with a high specific surface area, cation exchange capacity and adsorbent properties, capable of retaining ammonium (NH_4^+) and release it in a controlled manner, reducing the substrates required for N_2O-producing processes. The objective of this work was to study the emission of N_2O from a vertitic Argiudol soil in a willow (Salix sp.) plantation located at INTA Castelar, Province of Buenos Aires. A completely randomized design was used with three treatments: control (T), subsurface-incorporated biosolids (IB) and biosolids mixed with subsurface-incorporated zeolites (IBZ), both in 20 cm deep furrows between planting rows. The dose applied to biosolids was 8.34 t DM ha^{-1}, calculated to make up for a deficit of 100 kg N ha^{-1}, while 2.09 t ha^{-1} of zeolites (20% p/p) were added to the biosolid dose in the IBZ treatment. N_2O flux measurements were taken for 27 days using the closed static chamber method. The NO_3^- content in the soil, the water-saturated pore space, precipitation, and air and soil temperatures were recorded. High N_2O fluxes were observed in IB and IBZ treatments, due to high N availability and/or precipitation events, depending on the timing of the trial. The N-NO_3^- contents in IBZ tended to be similar or lower than those in the IB treatment, suggesting a moderating effect of the zeolites on N release. The N_2O emitted per amount of N applied was 2.9% for IB and 2.3% for IBZ, with no significant differences ($p > 0.05$). The T treatment presented the lowest cumulative emissions (0.048 kg N-N_2O ha^{-1}) ($p<0.05$) compared to IBZ (10.43 kg N-N_2O ha^{-1}) and IB (13.12 kg N-N_2O ha^{-1}). Cumulative N_2O emissions in IBZ were 20.5% lower ($p < 0.05$) than in IB. These results suggest a mitigating effect of zeolites on N_2O synthesis, possibly associated with the ability to adsorb the NH_4^+ released by biosolids. These findings are consistent with previous studies reporting reductions in N_2O emissions in agricultural soils amended with zeolites.

Keywords: salix sp; organic amendment; nitrification; denitrification; regulatory factors.

PERSISTENCE OF PATHOGENS IN SOIL AFTER BIOSOLIDS AMENDMENT IN SALIX SP. PLANTATIONS

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Globally, regulations on the use of biosolids in agricultural soils focus on the need to control the presence of pathogens to protect public and environmental health. In Argentina, Resolution 410/18 regulates the content of fecal coliforms and Salmonella spp. for application to soils under forestry use. The objective of this study was to evaluate the persistence of fecal coliforms and Salmonella spp. in soil after the application of anaerobically digested biosolids (B) to Salix spp. plantations. These biosolids were applied superficially (sup) and incorporated (inc) into 20-cm-deep furrows. A completely randomized block experimental design was established. The application rate of B was 8.34 t DM ha^{-1}, calculated to cover the crop's N requirements (100 kg N ha^{-1}). Soil sampling was performed 8, 15, 27, 83, 208, and 376 days after treatment application (ATA). The biosolids showed an initial fecal coliform concentration of 440,000 MPN g^{-1}, while Salmonella spp. was found below the detection limit (<3 MPN·4 g^{-1}), classifying it as a class B biosolid (fecal coliforms <2,000,000 MPN g^{-1}, no requirements for Salmonella spp.). By day 8 of ATA, which was preceded by 15.2 mm of rainfall, all surface-applied plots had elevated fecal coliform values (>2,000,000 MPN g^{-1}), whereas in the plots where the treatments were incorporated the values were considerably lower (600,000 to 1,500,000 MPN g^{-1}). Between days 8 and 83 ATA, a progressive reduction in fecal coliform concentrations was observed in most plots, typically reaching values below 1,000 MPN g^{-1} by day 83 (the threshold value for unrestricted application as class A). This convergence to low levels was observed after a relatively dry period, suggesting that sustained desiccation contributes to coliform inactivation, regardless of the initial application method. However, Salmonella spp. was detected more frequently on the surface, compared to incorporated treatments. After 208 days ATA, fecal coliform concentrations were uniformly low (50-550 MPN g^{-1}), and Salmonella spp. was detected in only one of the B sup replicates. On day 376 ATA, while most plots maintained low levels (50-260 MPN g^{-1}), high values were detected in one of the samples of B inc (26,400 MPN g^{-1}). Salmonella spp. was not detected in any of the final samples. These results demonstrate that pathogen persistence in soils amended with biosolids exhibits high spatial and temporal variability, regardless of the application method. From a regulatory perspective, the results validate the restrictions established by Resolution 410/18, which require limiting public and animal access for Class B biosolids for one year. While most plots reached low health risk levels within this period, the occasional detection of elevated fecal coliform concentrations at the end of the trial justifies maintaining these restrictions for the entire stipulated period.

Keywords: waste valorization; soil application methods; fecal coliforms; salmonella spp.

USE OF ECOTOXICOLOGICAL TOOLS TO EVALUATE WASTE TREATMENT SYSTEMS IN INTENSIVE LIVESTOCK FARMS

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The intensification of livestock farming in the province of Buenos Aires has led to an accumulation of excreta with high concentrations of bionutrients, pollutants and pathogenic microorganisms that have a negative impact on the environment. The most widely used technology to treat this waste is the stabilization lagoon, which allows aerobic, anaerobic and/or facultative decomposition. However, several studies have reported negative effects on aquatic and terrestrial organisms exposed to digestate treated with this technology. The aim of this study was to evaluate the effectiveness of removing and mitigating the toxic effects of livestock effluents treated with stabilization lagoons. For this purpose, a pig farm in San Antonio de Areco (Buenos Aires) was selected and effluent samples were taken before (pre-treatment) and after (post-treatment) passing through the stabilization lagoons. Physicochemical parameters (hardness, alkalinity, chlorides, nitrites, total nitrogen, ammonium, dissolved solids, soluble reactive phosphorus and total phosphorus) were measured and a standardized acute toxicity bioassay (120 h) was performed with Lactuca sativa seeds exposed to different dilutions of swine effluents (0; 12.5; 25; 50; 75 and 100%) in quintuplicate. At the end of the bioassay, the inhibition of germination and the inhibition of radicle and hypocotyl growth were evaluated. In particular, high nutrient loading was observed in the pre-treated samples with high concentrations of total nitrogen (1004.16 mg/L), total phosphorus (85.83 mg/L), ammonium (4.38x10^8 mg/L) and dissolved solids (20025 mg/L). The 50% dilution of the pre- and post-treated effluents inhibited seed germination in 100% of the replicates. The inhibitory concentration 50 (IC50) for germination was estimated using PROBIT analysis and was almost 30% for the pre-treated effluent and 60% for the post-treated effluent. Furthermore, ANOVA with Dunnet's post-hoc test showed significant differences ($p < 0.05$) between the control and some treatments, which allowed the calculation of the lowest observed effect concentrations (LOECs). The LOEC for radicle growth inhibition was 12.5% for both pre- and post-treated effluents. In contrast, the LOEC for hypocotyl growth inhibition was 25% for the pre-treated effluent and more than 25% for the post-treated effluent, indicating a slight decrease in toxic effect. Although this project is in a preliminary phase of implementation, a battery of reference bioassays (at least one plant, one invertebrate and one vertebrate species) is planned to fully characterize the potential impact of the treated effluents. The next stages will also be compare the efficiency of stabilization lagoons with that of biodigesters, a potentially more efficient and environmentally sustainable alternative for livestock waste disposal. The results of this project will make it possible to define quality criteria that will allow the development of guidelines and management strategies for the conservation of the province's natural resources.

Keywords: environmental assessment; toxicity bioassays; swine waste.

NITROUS OXIDE EMISSIONS FOLLOWING THE APPLICATION OF SWINE EFFLUENT AND THEIR MITIGATION BY DICYANDAMIDE

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The agricultural reuse of swine effluent (SE) as an organic fertilizer represents a key strategy for the sustainable management of livestock waste, aligned with the circular economy approach. However, its incorporation into soil can lead to significant emissions of nitrous oxide (N_2O), a greenhouse gas with a global warming potential 265 times greater than that of carbon dioxide. These emissions are associated with nitrification and denitrification processes carried out by aerobic and anaerobic microorganisms, respectively. In this context, the present study evaluates the impact of SE application and the combination of SE with dicyandiamide (DCD), a nitrification inhibitor, on cumulative N_2O emissions from a typical Argiudoll soil of the Capitán Sarmiento series. The experiment was conducted under field conditions using a completely randomized block design with three treatments: unfertilized control (C), SE, and SE+DCD, with four replicates per treatment. In each plot (3 m x 2.5 m), a dose of 15 liters of SE per m^{-2} was applied, equivalent to 150 kg N ha^{-1}. For the SE+DCD treatment, 7.5 g of DCD was added to the SE before application (equivalent to 10 kg ha^{-1}). Applications were carried out on December 17, 2024, and N_2O emissions were measured on 30 occasions during the first 100 days using non-vented closed chambers. Gas samples were analyzed by gas chromatography. Simultaneously, soil and climatic variables such as soil and air temperature, moisture, and precipitation were recorded during sampling. The highest emission rates occurred during the first few days after application, coinciding with high temperatures and rainfall events. Notably, on day 50, a peak in N_2O emissions was observed across all treatments, reaching the highest values of the period: 27 g N-N_2O ha^{-1} in C, 53 g N-N_2O ha^{-1} in SE, and 28 g N-N_2O ha^{-1} in SE+DCD. This peak coincided with an intense rainfall event of 73 mm, the highest recorded during the experiment. Preliminary results indicate that cumulative N_2O emissions from the control (834 ± 298 g N-N_2O ha^{-1}) were significantly lower than those from the other treatments ($p<0.05$), followed by SE+DCD (2449 ± 143 g N-N_2O ha^{-1}), which was 44% lower ($p<0.05$) than SE alone (4381 ± 303 g N-N_2O ha^{-1}). These findings align with previous results from our research group, which observed similar reductions in N_2O emissions (around 50%) when applying DCD with dairy effluent under comparable climatic conditions. The combined use of SE and DCD emerges as a promising strategy to mitigate N_2O emissions in agricultural systems aiming to replace synthetic fertilizers with organic sources. These results are expected to contribute to the development of more sustainable agronomic practices and to the environmental valorization of livestock waste.

Keywords: organic fertilizers; nitrification inhibitors; greenhouse gas emissions; circular economy.

LIFE CYCLE ASSESSMENT OF TECHNOLOGIES FOR DIGESTATE SOLID FACTION VALORIZING

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Biogas plants are often promoted as sustainable technologies for renewable energy production. However, their environmental viability depends largely on the appropriate management of digestate, a major by-product of anaerobic digestion (AD). In most cases, digestate is applied near the biogas plant, leading to nutrient accumulation in soils and increasing the risk of environmental damage. This scenario represents a significant barrier to the broader adoption of AD under increasingly strict environmental regulations. This study aimed to assess the environmental impacts of different technologies for the valorization of the solid fraction (SF) of swine digestate through life cycle assessment (LCA), identifying the main environmental hotspots associated with each treatment pathway. The analysis followed ISO 14040 and 14044 standards and adopted a cut-off approach to isolate the impacts and benefits of the SF. The scope begins with the solid-liquid separation from the digestate in settling tank fed by a covered lagoon biodigester. The solid fraction is then directed to five alternative valorization pathway: (i) fertigation by slurry tanker with and without energy self-sufficiency, (ii) thermal drying, (iii) composting, (iv) chemical precipitation of struvite, and (v) chemical precipitation of calcium phosphate. The results indicated that struvite precipitation had the lowest environmental impacts in most impact categories assessed, especially global warming, freshwater eutrophication, terrestrial acidification and terrestrial ecosystems. In contrast, calcium phosphate precipitation showed the worst environmental performance, especially in the categories of terrestrial acidification and freshwater ecotoxicity. This is mainly attributed to the avoided production of nitrogen fertilizers, whose industrial synthesis via the Haber-Bosch process is known for its high environmental burdens. Composting and drying presented intermediate performances but were strongly influenced by operational energy demand and emissions from organic matter degradation. Fertigation using biogas instead of diesel showed environmental benefits exclusively in two impact categories: global warming and terrestrial ecosystems. In these categories, the use of biogas reduced impacts by 23% (−2.45 kg CO_2 eq m^{-3} of digestate) and 300% (−0.03 kg NO_x eq m^{-3} of digestate), respectively, when compared to diesel-powered fertigation. These results reinforce the importance of integrating nutrient recovery strategies, with emphasis on those capable of replacing conventional nitrogen fertilizers, as a means to enhance the environmental sustainability of anaerobic digestion systems and ensure their alignment with circular economy objectives.

Keywords: nutrient recovery; circular economy; anaerobic digestion; environmental impacts; struvite precipitation.

AN OVERVIEW OF MANURE MANAGEMENT IN BRAZILIAN DAIRY FARMS

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Milk production in Brazil holds significant economic and social relevance, as it provides income and improves the quality of life for many families. However, the sector still faces substantial environmental challenges. The Water Performance Index for Dairy Farms (WPI_Dairy) is an indicator-based tool designed to diagnose and monitor environmental conditions on dairy farms across three dimensions: water quantity and quality, and manure management. This study aimed to assess the manure management conditions of selected dairy farms using the WPI_Dairy methodology. Data were collected from 34 dairy farms located in the states of Minas Gerais and Sao Paulo. The WPI_Dairy manure management dimension comprises 13 indicators grouped into three categories: infrastructure, operational practices, and fertilization. The minimum score required to meet acceptable standards in this dimension is 0.71. Among the evaluated farms, 44% operated with confined lactating cows and grazing systems for other animal categories; 35% adopted a pasture-based system with supplementation; 17% maintained full confinement; and 3% operated exclusively on pasture. The average WPI_Dairy score for the manure management dimension was 0.43, with values ranging from 0.00 to 0.77. Only three farms (8.8%) surpassed the minimum acceptable score of 0.71, indicating that the majority of farms lacked the necessary conditions for adequate manure management, considering both legal requirements and environmental best practices. Fifty-six percent of the farms had no manure treatment system, despite 82% washing the floor after each milking. Among those with treatment systems, 67% lacked proper impermeabilization, a requirement under Brazilian environmental regulations. Furthermore, 62% of the farms used pressurized water for floor cleaning, and 70% performed manure scraping prior to washing. This combination contributes to water conservation and reduces both the volume and pollutant load of generated manure. Only 13% of farms had an emergency response plan for manure-related accidents such as leaks or spills. Although 70% reported using manure as fertilizer, just 12.5% conducted nutrient analyses of the material. This suggests that the application of manure was carried out without essential information regarding its nitrogen, phosphorus, and potassium content, posing a considerable environmental risk. Among farms that applied manure to soil, 87.5% did so using surface application methods. In conclusion, the results indicate substantial environmental vulnerabilities among the assessed dairy farms, as the majority failed to achieve the minimum manure management score on the WPI_Dairy. The absence of treatment systems and inappropriate use of manure as fertilizer are critical issues requiring intervention. To improve the WPI_Dairy scores and reduce environmental risks, targeted investments in infrastructure and modifications to current management practices are necessary.

Keywords: fertilization; nutrients; treatment.

ENVIRONMENTAL ASSESSMENT AND MANAGEMENT TOOLS FOR A MORE SUSTAINABLE DAIRY INDUSTRY IN LA PAMPA, ARGENTINA

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The dairy industry in the province of La Pampa processes approximately 64% of the locally produced milk and constitutes a strategic pillar of regional economic development. Nonetheless, it faces critical challenges in managing liquid effluents, particularly due to inadequate disposal methods and poor handling of by-products like whey. In this context, the objective of the study was to conduct an environmental assessment of cheese production facilities, develop performance monitoring indicators, and evaluate the risk of water contamination. Based on these findings, the study proposes improvements in liquid effluent treatment and organic waste management to support cleaner and more competitive production practices.

Within the framework of a program focused on enhancing the productive and competitive capacities of the dairy sector—jointly implemented by the Ministry of Production of La Pampa, the Federal Investment Council (CFI), and the National Institute of Industrial Technology (INTI)—an environmental diagnosis was carried out across nine dairy plants collectively processing over 200,000 liters of milk per day.

Between 2023 and 2024, the study involved an in-depth analysis of production processes, measurement of water and effluent flow rates, and characterization of wastewater in accordance with IRAM standard 29012. The parameters analyzed included chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), total solids (TS), suspended solids (TSS), fats, nutrients, and turbidity. Groundwater contamination risk was assessed using the GOD index (Foster et al., 2002), incorporating hydrogeological variables such as water table depth, soil type, and lithology. Several management indicators were developed, including specific water consumption, organic load generation, and treatment efficiency.

Results revealed substantial variability in water use, averaging 1.9 liters per liter of milk processed, with values ranging from 1.25 to 3.2 L/L. On average, processing 5.5 liters of milk produced wastewater equivalent to the daily generation of one person. The average organic load was 16.14 g COD/L of milk, with peak values of up to 31.8 g COD/L. Facilities with higher loads exhibited poor whey recovery, raw material losses, and inefficient water use—factors contributing significantly to pollution. Groundwater contamination risk was classified as moderate to high in all cases, and extreme in one instance due to the aquifer's high vulnerability. Overall, treatment efficiency was low, with only one facility achieving a 73% COD reduction.

The study provided a comprehensive evaluation of the environmental performance of La Pampa's dairy industry and delivered practical indicators for ongoing monitoring and improvement. Opportunities were identified to upgrade treatment systems, optimize operational practices, and recover whey as a source of energy or animal feed. These strategies, aligned with cleaner production principles, offer the potential to reduce environmental impacts significantly, enhance the technical capabilities of the local industry, and strengthen its position in the face of growing regulatory and market demands for sustainability.

Keywords: dairy industrie; performance indicators; wastewater management; groundwater risk; cleaner production.

BIOREMEDIATION OF RESIDUAL HERBICIDES IN SOIL USING A COMMERCIAL PRODUCT OF CHICKEN MANURE COMPOST TEA

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Soil-persistent herbicides can cause phytotoxic effects on subsequent crops, particularly in sensitive species such as potato. Residues of fomesafen, sulfonylureas, and imidazolines have been shown to negatively affect potato sprouting and development. Fol Suelo® is a liquid organic fertilizer developed by Bloemen, obtained from composted poultry litter and chicken manure. Due to its high microbial content, it has potential as a bioremediation agent for soils contaminated with pesticide residues. In this study, the effect of Fol Suelo® on the degradation of fomesafen, chlorimuron-ethyl, and imazapyr was evaluated. Topsoil from an agricultural plot was sampled (0-10 cm). Physicochemical characteristics of soil were analysed (pH, electrical conductivity, organic matter, phosphorous, total nitrogen, nitrate and ammonium). Subsamples of 400 g of soil were divided into six flasks. All subsamples were spiked with a final concentration of 100 µg/kg of a mixture of fomesafen, chlorimuron, and imazapyr. After herbicide application soil samples were left 24 h to stabilize. Then, three replicates were watered with a Fol Suelo equivalent to 400 L/ha diluted in distilled water. The three remaining replicates were the control group and were only watered with distilled water. All samples were incubated in the dark under controlled temperature conditions (20ºC). Moisture content was monitored periodically. Herbicide concentrations were measured at 0, 2, 5, 8, and 15 days after application using an HPLC-MS MS. Experimental data was adjusted to a first order kinetic degradation model. Application of Fol Suelo® at 400 L ha^{-1} resulted in a 92% reduction of fomesafen concentration after 15 days and an approximately 80% decrease in its half-life, indicating a significant enhancement of degradation. In the case of chlorimuron, there was a reduction of 23% in half life in treated soil. No effect was observed in imazapyr. These results suggest that Fol Suelo® could be an effective bioremediation tool for soils with herbicide residues, such as fomesafen and potentially chlorimuron. More studies are needed to characterize the effect of Fol Suelo® on different soils and other herbicides.

Keywords: soil-persistent herbicides; organic fertilizer; bioremediation; uhplc-ms/ms.

PHOSPHORUS ACCUMULATION IN SOILS IRRIGATED WITH TREATED WASTEWATER IN RÍO NEGRO, ARGENTINA

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In the context of increasing pressure on water resources, the use of treated wastewater (TWW) for irrigation emerges as a promising alternative. It enables the reuse of water and nutrients for productive purposes, reduces freshwater demand for agriculture, and minimizes the environmental impacts associated with wastewater discharge into natural water bodies. This approach is especially relevant in arid regions, such as Ingeniero Jacobacci in southern Río Negro (Patagonia, Argentina), where irrigation-based production is extremely limited due to water scarcity. However, irrigation with TWW introduces nutrients into the soil, particularly phosphorus in both soluble and organic forms. Phosphorus dynamics in soil are complex, as it is relatively immobile and partially removed through crop harvests, but can accumulate over time if its input exceeds plant uptake, posing a potential risk of contamination to groundwater sources.

Since 2015, a multi-institutional project (INTA-Instituto Nacional de Tecnología Agropecuaria, UNRN-Universidad Nacional de Río Negro, DPA-Departamento Provincial de Aguas, MIJ-Municipio de Ing. Jacobacci, and COASyP-Cooperativa de Aguas y Servicios Públicos) has conducted experimental trials comparing irrigation with TWW and groundwater in alfalfa plots and naturalized vegetation systems following land leveling. The trial is located at the wastewater treatment facility in Ingeniero Jacobacci. The experimental design involves split plots, with annual monitoring of biomass productivity (kg DM/ha) and soil effects assessed through sampling at various depths (0–80 cm) and laboratory analyses.

This paper presents results on available soil phosphorus (Olsen method) from the initial sampling prior to irrigation and from the first (2016), third (2018), and eighth (2024) growing seasons. Results show significant increases in soil P (from 7 to 20 ppm) in TWW-irrigated treatments from the early years, especially in the topsoil (0–20 cm), both in alfalfa and natural vegetation systems. In subsequent years, increases extended down to 80 cm depth and across both vegetation types. However, the rate of accumulation was lower than expected, and even after eight seasons, maximum P levels did not exceed 35 ppm. While these values are markedly higher than the initial ones, they are still below thresholds considered environmentally hazardous. Crop phosphorus removal may contribute to stabilizing soil P levels. A comprehensive nutrient balance analysis is needed to better understand the dynamics observed, evaluate potential environmental risks, and determine the long-term sustainability of such irrigation schemes.

Keywords: treated wastewater reuse; phosphorus; irrigation; arid regions; soil monitoring.

IMPACT OF THE USE OF WASTE IN A CORN BIOREFINERY

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The bioethanol industry is continually seeking to minimise waste generation and reduce its carbon footprint to position itself in international markets and meet growing demands. With energy making up about 80% of the product footprint, any strategy to reduce its weight has a significant impact. A historical study was carried out in a real plant in Rio Cuarto, Córdoba and a prospective study on a plant to be built in Bahía Blanca, Argentina, evaluating technological alternatives for the use of light vinasse in biodigesters. The use in the generation of electricity and heat was studied, as well as its conversion into biomethane in the biorefinery. The methodological aspects of calculation and modelling were based on the ISO 14067 standard, which indicates that a specific PCR (Product Category Rule) should be used and relevant to the products under analysis. The study focused only on the climate change impact category, which includes the sum of greenhouse gases from all stages. Using standard 14064.3, which establishes the framework for environmental declarations. The partial HCP of bioethanol was calculated within the framework of a bioethanol plant integrated into biogas plants fueled by energy in a mixed form. The overall system was characterised by the use of an output current from the bioethanol plant for the generation of electricity, thermal and biofertilizers. Biogas was used in the operation of an internal combustion engine linked to a generator. The whole system was equipped with heat exchangers to recover the heat from the exhaust and cooling gases. In the case of the Rio Cuarto plant, three scenarios were compared,

- SCENARIO 1: Ethanol Plant Without Integrated Biogas Plant (Baseline)
- SCENARIO 2 A: Ethanol plant integrated with biogas plant, using the same for the generation of electricity and heat (present)
- SCENARIO 2 B: Ethanol plant integrated with a biogas plant, using it for burning in a boiler generating steam as thermal energy (hypothetical)

Scenario 1 yielded a value of 30.71 gCO2eq/MJ, while scenario 2A 24.55 gCO2eq/MJ (20% less) and 2B 23.51 gCO2eq/MJ (23% less than scenario 1). In all 3 cases, the stage with the highest proportion of emissions corresponds to the central/core processes (between 55 and 65%), followed by upstream (between 26 and 33%) and then downstream (between 9 and 12%). In turn, the reduction in emissions compared to scenario 1 is attributed to the central stage and, in particular, to the bioethanol plant. In the case of Bahia Blanca, several scenarios were constructed to advise investors on the incorporation of biorefinery residues, aiming to achieve GHG reductions compatible with EU RED III and ICAO requirements for SAF.

Keywords: biogas; residues bioethanol; saf; corn; wheat; biorefinery.

ANTIBIOTIC RESISTANCE IN SWINE WASTEWATER AFTER ANAEROBIC DIGESTION

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Swine effluents can contain antibiotic-resistant bacteria and antibiotic resistance genes (ARGs) as a consequence of antimicrobial use to maintain animal health and productivity. If untreated, animal husbandry wastewater may pose a significant risk for the environmental dissemination of antibiotic resistance. Anaerobic digestion is a technology that can be used in swine wastewater treatment, producing both biogas and biofertilizers. However, the potential of anaerobic digestion to attenuate ARGs remains poorly understood. This study aimed to assess the prevalence of antibiotic resistance in swine wastewater using a system consisting of an anaerobic digester followed by two sequential open-air lagoons. The final effluent is used as a liquid biofertilizer in extensive crop production. Effluent samples were collected by triplicate at different stages: untreated swine effluent (M1), digestate from the biodigester outlet (M2), and effluent from the final lagoon (M3). Total DNA was extracted from the samples, and gene quantification was performed by real-time PCR using SYBR Green. The targeted genes included the 16S ribosomal RNA genes from Bacteria and Archaea, the class 1 integron integrase gene (intI1), which is associated with environmental dissemination of antibiotic resistance, and the sulfonamide resistance gene (sul1). Statistical analyses were conducted to identify differences across effluent treatment stages. An increase in both the Archaea/Bacteria ratio and the abundance of intI1 and sul1 genes was observed in M2 compared to M1 and M3 ($p < 0.005$). In the final treatment stage (M3), reductions of 2.8-fold for intI1 and 4-fold for sul1 were detected compared to the untreated effluent (M1), although these differences were not statistically significant ($p = 0.053$ and $p = 0.06$, respectively). The abundances of intI1 and sul1 were positively correlated (Spearman's coefficient $R = 0.950$; $p < 0.001$). Further research is needed to better understand the dynamics of microbial communities and antibiotic resistance during anaerobic digestion, aiming to produce environmentally safe biofertilizers.

Keywords: key words: antibiotic resistant genes; swine effluent; anaerobic digestion; class 1 integrase.

VETERINARY ANTIBIOTICS IN EFFLUENTS TREATED BY ANAEROBIC DIGESTION

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The global demand for animal protein has driven the intensification of production systems. The confinement of animals in small spaces leads to the accumulation of effluents and creates favorable conditions for the spread of diseases, resulting in increased use of veterinary antibiotics (VAs). VAs are not completely metabolized within the animal and are released into the environment through feces and urine.

Effluents are commonly applied as amendments in agricultural fields either directly or after treatment using technologies such as anaerobic digestion (AD). AD stabilizes organic matter (OM), transforming it into biogas (a renewable energy source) and digestate. In Argentina, the regulation IF-2018-64926335-APN-DCAYR#SGP, which sets the parameters for determining the suitability of digestate for agricultural use, does not consider the presence of VAs. However, various VAs have been found in effluents, raising health concerns about the reuse of waste and its by-products. The objective of this study was to determine the presence of VAs at different stages of effluent treatment from a feedlot.

The presence of VAs was analyzed in effluents from a feedlot (3000 head of cattle) located in the southwest of Buenos Aires Province. There, effluent collection is performed mechanically over a concrete floor into a receiving chamber (RC), from which two mesophilic anaerobic digesters (MADs, 41 °C) are loaded, each with a capacity of 3000 m³ and a hydraulic retention time (HRT) of 41 days. After solid-liquid separation of the digestate, the liquid fraction remains in a stabilization pond (P) for 41 days before being applied to the field.

Sampling was carried out at each site (RC, MAD, and P) during the month of May. Total solids (TS) and OM content were determined according to Sluiter et al. (2008). The presence of VAs was determined using a modified liquid-liquid QUECHERS-type extraction, which included acidified acetonitrile, partitioning salts ($MgSO_4$/EDTA), and a cleanup step with C18, followed by analysis by UHPLC-MS/MS.

Table 1. TS, OM, and OXI content in effluent samples.

	TS (%)	OM (%)	OXI (µg/Kg)
RC	14.2 ± 0.1	11.2 ± 0.1	1.2 ± 0.6
MAD	6.6 ± 0.1	4.5 ± 0.1	1.4 ± ND
P	3.9 ± 0.1	2.5 ± 0.1	2.4 ± ND

ND: not determined

Both TS and OM decreased throughout the treatment process (Table 1). Only the presence of OXI was identified at all sampling points. Although OXI levels appeared to increase throughout the process and inversely with OM content, the low concentrations detected and the lack of replicates do not allow concluding that these differences are significant. It will be necessary to: i) conduct composite sampling over time in order to understand the dynamics of this compound in relation to the time of administration and processing, and ii) optimize and validate the analytical methodology to minimize the impact of OM on quantification and ensure method robustness for application in these complex matrices.

Keywords: keywords: anaerobic digestion; effluents; veterinary antibiotics; feedlot; digestate.

PRODUCTION OF TAPES (TAGETES ERECTA) ON A SUBSTRATE RECOVERED BY SOLARIZATION, WITH DIFFERENT WASHING DOSES

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Strawberry production on substrate is a rapidly expanding system in Argentina. At the end of each production cycle, there is a need to recover and reuse the substrate, not only because it represents an environmental problem but also because of its high cost. Solarization reduces the pathogen load in the substrate, facilitating its reuse. Furthermore, the accumulation of salt in a substrate can affect the development of new plants, so a washing strategy would ensure a safe and reusable growing medium for new production cycles. The objective of this study was to evaluate tappa production with a substrate used in a soilless strawberry production system, recovered through solarization and washing. The work was carried out at the Famaillá Agricultural Research Institute (EEA) – INTA. A GrowMix® substrate, recovered through solarization and used for four years in strawberry production in grow bags, was used. After solarization, the substrate was placed in 1-liter blown-out pots, into which crested seedlings were transplanted. The day before transplanting, two flushing treatments with irrigation water were applied (1 liter and half a liter, respectively), which were compared with an unwashed control. After flushing, pH, EC, macronutrients, and sodium were determined. During cultivation, the pots were watered once a week with a 1 g/liter solution of Hakaphos® Red. On the remaining days, irrigation water alone was applied. A Randomized Complete Block design was used with 3 replicates. Data were subjected to analysis of variance, and comparisons between means were made using the Fisher LSD test ($\alpha = 0.05$). Days to Flowering, plant height, growth index, stem diameter, number of buds, chlorophyll content, aboveground fresh weight, and aboveground dry weight were evaluated. The results showed that in the recovered substrate, washing reduced EC values at the expense of a decrease in essential nutrients, except for P. In the control without washing, the lowest or intermediate values were obtained in almost all variables, revealing that direct reuse of the substrate can limit the growth and productivity of the canopy. Washing with 1 volume improved plant height and stem diameter, but had lower chlorophyll content and aboveground fresh weight, while washing with ½ volume of water stood out as the most balanced and effective strategy, since it allowed adequate growth in height and diameter, promoted a higher chlorophyll content, and achieved the highest aboveground fresh weight value. The results show that the half-volume flushing treatment represents the best alternative for producing crested grass with reclaimed substrate, combining water efficiency with significant agronomic improvements.

Keywords: growing in substrate; solarization; substrate flushing; sustainability.

PUBLIC, ANIMAL, AND ENVIRONMENTAL HEALTH RISKS ASSOCIATED WITH COMPOST PROCESSING ON SMALL-SCALE PIG FARMS

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The proper management of manure from pig production represents both an environmental and a productive challenge for the agricultural sector. When stabilized through processes like composting, this waste can transform potentially polluting and hazardous materials into valuable resources for agriculture, livestock farming, and soil improvement, thereby establishing a circular economy within the farms. In Tandil county (Buenos Aires, Argentina), some small-scale pig farms pile a mixture of manure and bedding materials for composting. This study evaluated the quality of intended stabilized materials from "old piles" (longer stabilization time) and "fresh piles" (shorter composting time) across three small-scale pig farms named A, B, and C. Physicochemical parameters such as pH, electrical conductivity (EC), organic matter (OM), total nitrogen (N), the nitrogen-to-carbon ratio (C:N), N as nitrate (N-NO_3^-), N as ammonium (N-NH_4^+) and the N-NH_4^+/N-NO_3^- ratio were analysed. Microbiological characterization and parasitological examination included the detection of faecal coliforms, nematodes (eggs/larvae), cestodes (or tapeworms) eggs, and oocysts of Toxoplasma gondii. None of the intended stabilised material met the regulatory standards concerning the N-NH_4^+/N-NO_3^- ratio. The OM values ranged from 31.37% to 45.04% in the fresh piles and from 7.73% to 15.11% in the old piles. Only two samples from the old piles at farms A and B showed values compatible with maturity (C:N ratios of 10.6 and 15, respectively). All samples were within the acceptable pH ranges (6.28 to 7.56) and exhibited a N-NH_4^+/N-NO_3 ratio of more than 0.3, and absolute N-NH_4^+ values less than 400 ppm. In all farms, fresh piles showed EC values ranging from 5.1 to 11.5 mS/cm while in old piles the EC values ranged from 0.36 to 1.14 mS/cm, classifying the compost as saline and non-saline, respectively. Fecal coliform levels in all samples were below 1000 MPN per gram of total solids dry weight. Ascaris lumbricoides and Strongyloides stercolaris eggs were detected in some samples from farms A and B, while tapeworms were present in samples from farms A and C. Toxoplasma gondii (2-5 oocysts/field) was found in material from old piles across all three farms. Based on these results, the use of “stabilized” material as animal bedding or as a soil amendment is not recommended. While the raw materials (pig manure and crop hay) possess good physical properties for composting, the high N-NH_4^+/N-NO_3^- values of the compost indicate non-stable and immature materials, and the N-NH_4^+ content could cause phytotoxicity. Elevated EC values, particularly with the continuous use of fresh compost, pose a significant risk of soil salinization. Despite composting's known ability to reduce pathogens, the detection of viable parasitic eggs and T. gondii oocysts shows that current post-composting handling is inadequate. Consequently, the material remains unsafe for direct agricultural application and presents a zoonotic infection risk. Effective composting requires careful management, particularly with sufficient heat generation and stabilization, to significantly reduce pathogen levels.

Keywords: compost stability and maturity; innocuousness; compost physicochemical; characterization.

EMERGY ASSESSMENT OF THE IMPACTS OF THE 2024 FLOODS ON A FAMILY FARM IN CANGUÇU-RS: A CONCEPTUAL CASE STUDY

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This study proposes a conceptual assessment of the impacts of the 2024 floods on a family farming property in the municipality of Canguçu-RS, using Emergy Synthesis as the central evaluation tool. The approach seeks to integrate ecological, energetic, and social dimensions, which are often overlooked by conventional analyses focused solely on immediate economic losses. Located in the Pampa biome, Canguçu is composed mainly of small farms, making it particularly vulnerable to extreme weather events such as those recorded in that year.

The model developed analyzes three critical phases of the rural production system: (i) the energetic configuration of the property prior to the event; (ii) the impacts resulting from the interruption of resource flows and ecosystem services (such as soil erosion, infrastructure loss, and animal mortality); and (iii) the recovery processes, in which natural, social, and institutional resources are mobilized. Emergy allows for the quantification of both losses and the investments required for system restructuring, revealing how resilience is related to the quality of these supporting flows.

The results indicate that emergy contributes decisively to broadening the understanding of the socio-environmental impacts of floods, providing technical support for post-disaster planning. The assessment highlights paths for the sustainable reconfiguration of farms, such as productive diversification, infrastructure strengthening, and soil conservation management. The potential of the methodology to guide fairer public policies is also emphasized, particularly regarding financing and insurance mechanisms adapted to the realities of family farming.

Despite the technical complexity involved and limitations in local data, the study demonstrates that Emergy Synthesis, when combined with participatory strategies and rural extension, can be applied in different contexts, supporting the formulation of territorially appropriate and socially inclusive policies. It is concluded that this approach offers an integrative language between science, management, and communities, with the potential to strengthen the resilience of agroecological systems in the face of climate change. The work thus contributes to rural planning that unites ecological sustainability, food sovereignty, and territorial justice.

Keywords: family farming; floods; sustainability; emergy synthesis.

ASSESSMENT OF STABILIZATION AND PATHOGEN REDUCTION IN DAIRY WASTE IN FULL-SCALE OPEN AND COVERED (DIGESTER) LAGOONS

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Dairy industry is essential for food and milk production, however, it also produces enormous amount of waste. In large-scale dairy farms, dairy lagoons are often used for storing waste water produced in dairy farms by flushing flush lanes (i.e., sloped alleys). In flush lanes, water is used to flush manure, separate liquid-solid manures, and stored liquid waste in manure collection systems (i.e., lagoons). Manure poses significant biosafety issues mainly because of manure borne harmful pathogens such as E. coli, which affects water, human, animal an environmental health negatively. In this unique study, we attempted to enhance our understanding of pathogenic organism reductions in full scale lagoons which are either covered or open. Research was conducted in commercial dairy farms in full-scale lagoon systems. We evaluated the stabilization of waste, reduction of volatile solids, and reduction of pathogenic bacteria (E. coli). Results showed that dairy digesters (covered lagoons) play a role in reducing E. coli levels in effluent. In compare to closed lagoons, the reduction in open lagoons was relatively low. In addition, we compared the DNA reductions in open and closed lagoons. We anticipate that findings of this study will enhance the existing knowledge in terms of bacteria reduction and stabilization waste in dairy lagoons.

Keywords: dairy waste; pathogens; dairy digesters; lagoons; flush manure.

PREDICTING FULL-SCALE POULTRY DIGESTATE AGRONOMIC SUITABILITY: INSIGHTS FROM A PILOT STUDY

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In recent years, Argentina has significantly increased the implementation of biogas plants for energy production, generating substantial volumes of digestate as a byproduct. Resolution 19/2019 of the Ministry of Environment and Sustainable Development (MAyDS) regulates its agronomic use, promoting an integrated approach that recognizes the value of both biogas and digestate. However, improper application may lead to soil contamination and inhibition of crop growth. This study evaluated the treatment and quality of anaerobic digestate derived from poultry manure in a pilot-scale system designed to replicate full-scale conditions, to assess its potential as a biofertilizer and its environmental safety. A semi-continuous anaerobic reactor was fed with thermally hydrolyzed poultry manure. Whole digestate (P1) was separated into solid and liquid fractions. The liquid fraction (P2) was treated in a pilot-scale aerobic lagoon (P3), followed by an anaerobic lagoon (P4), replicating the hydraulic retention times (HRT) of full-scale systems. A sand filtration bed (P5) was added to enhance final effluent quality. Under steady-state conditions (2×HRT), key parameters were monitored across the treatment stages of the system (P1-P5), including pH, electrical conductivity (EC), total solids (TS), volatile solids (VS), FOS/TAC ratio, ammonia nitrogen ($N\text{-}NH_4^+$), total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD), total phosphorus (TP), residual biogas potential (RBP), metals (Cu, Zn, As, Cd, Pb, Ni, Cr), and pathogens (fecal coliforms, E. coli, Salmonella spp.). P1 exhibited high nutrient content, stable conditions, absence of Salmonella and total coliforms, and metal concentrations (Cr, As, Cd, Ni, Pb) below regulatory limits. However, E. coli was detected in 2/4 samples, and Cu and Zn concentrations exceeded the established thresholds. Lagoon treatment (P4) led to substantial reductions in ST (40%) and organic matter (50% VS and 55% COD), and eliminated pathogens, but also resulted in significant nutrient losses (80% TKN, 70% $N\text{-}NH_4^+$, 70% TP). Although Zn concentration decreased by 50% %, it still exceeded the regulatory limits. The sand filtration bed (P5) further reduced Zn levels by 43%, achieving regulatory compliance (<300 mg/kg dm) and improving the overall quality of digestate. The pilot-scale system proved effective in producing agriculturally suitable digestate. Results underscore the need to incorporate additional treatment stages in full-scale biogas plants to enhance digestate quality. This study provides critical data for optimizing biogas plant designs, maximizing the agronomic value of digestates, and minimizing environmental impacts. Pilot-scale studies are essential for predicting operational constraints and ensuring the sustainability of biogas technology.

Keywords: anaerobic digestion; manure; biofertilizer; metals; effluent treatment.

ACIDITY CORRECTION AND AGRONOMIC EFFICIENCY OF AGROSILÍCIO® PLUS ASSOCIATED WITH ALTERNATIVE SOURCES OF PHOSPHORUS IN TROPICAL SOILS

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Acidic tropical soils are generally characterized by high phosphorus (P) fixation, which limits agricultural productivity. The application of liming materials is essential to correct soil acidity, and the use of inputs derived from metallurgical wastes for this purpose promotes a circular economy and contributes to reducing greenhouse gas emissions. Furthermore, the soluble silicon present in these materials may positively interact with soil P, enhancing its availability to plants. This study evaluated the potential of fertilizer formulations containing Agrosilício® Plus (a steel slag aggregate) combined with different P sources derived from metallurgical wastes as a strategy for soil liming and P fertilization in soils of contrasting textures. The experiment was conducted in a greenhouse using a randomized complete block design in a 2 × 8 factorial arrangement with four replicates. The first factor consisted of two soil textures: sandy and clayey. The second factor comprised eight different combinations of P sources and/or liming materials, as follows: an absolute control; a control with P solution; limestone; Agrosilício® Plus; and four formulations containing 70% Agrosilício® Plus combined with 30% of a P source. These sources were: F1 – triple superphosphate; F2 – dicalcium phosphate; and F3, F4, and F5 – three distinct P sources derived from metallurgical wastes. Application rates were adjusted according to the soil liming requirement, and all treatments, except the absolute control, received 70 mg of P per kg of soil. Evaluations were conducted over three millet crop cycles, measuring the dry mass of the aerial part of the plants. In the first crop cycle, no interaction was observed between soil texture and liming inputs. Treatments with Agrosilício®, formulations F1 to F4, and the control with P solution resulted in higher productivity than limestone, while the absolute control showed the lowest productivity. In the second and third cycles, as well as in the accumulated data from the three cycles, there was a significant interaction between soil texture and liming materials. In the sandy soil, limestone, Agrosilício, formulations F1 to F3, and the P solution presented higher productivity. In the clayey soil, formulations F1 to F4 outperformed both controls. For the accumulated productivity in sandy soil, all tested inputs showed similar productivity and outperformed the control. In clayey soil, Agrosilício and the formulations containing it were superior to both limestone and the P solution, which, in turn, were superior to the absolute control. These results can be attributed to the higher P adsorption capacity of clayey soils, which limited the plants' response to the P solution. The beneficial effect of Agrosilício compared with limestone is likely due to its high content of soluble silicon, which can compete for adsorption sites, thereby reducing P fixation and enhancing its availability to plants. Overall, the findings suggest that combining Agrosilício® Plus with different P sources is an agronomically viable strategy for correcting soil acidity and supplying P in tropical soils, particularly those with higher clay content.

Keywords: liming; silicon; phosphorus; metallurgical waste; tropical agriculture.

AMMONIUM VOLATILIZATION FROM SOILS AMENDED WITH EFFLUENTS FROM THE SUGAR AND ALCOHOL INDUSTRY UNCOVERED AND COVERED WITH SUGARCANE STRAW

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Sugarcane processing generates by products like vinasse, filter cake, boiler ash and straws, which can be used directly in the soil and/or treated anaerobically generating biogas and biodigestates. The use of these residues in natura in soils is already established through studies, application protocols and current legislation. However, with the expansion of anaerobic treatment systems for biogas production, they are being used as raw material, producing effluent that requires standardization for agricultural use. This study aimed to quantify ammonium volatilization after surface application of urea, two biodigestates and vinasse, comparing treatments with and without sugarcane straw to determine nitrogen losses. The experiment was conducted in a completely randomized experimental design in a greenhouse conditions, with the following treatments: (i) urea at a dose of 50 kg N ha-1; (ii) vinasse; (iii) anaerobic effluent from sugar and alcohol waste, applied to the soil surface covered and uncovered with sugarcane straw in a quantity equivalent to 12 Mg ha-1, with 03 repetitions, totaling 18 plots. Pots containing 4,0 kg of soil and were fitted with a semi open collector holding two polyurethane sponges (15 cm diameter, 2 cm thick) soaked in 1.5 M phosphoric acid and 5% glycerin; the inner sponge trapped volatilized ammonia and the outer served as a atmospheric N2 trap. The volume of effluents applied was 100 m3 ha-1, to provide an average of 45 kg N ha-1, the maximum volume permitted by current legislation to supply 185 kg K20 ha-1 for a sugarcane crop cycle. Ammoniacal N receptor sponges were changed periodically for 28 days, and analyzed spectrophotometrically, and volatilization, cumulative loss and percentage of nitrogen volatilized were calculated. Results showed that urea volatilized about 25% of the applied nitrogen and straw had no effect on N losses, although the presence of straw delayed the volatilization peak by 3 days. N losses in soil treated with anaerobic effluent with straw were 72% and in soil without straw were 22%, rate similar to that of urea, while for soil treated with vinasse it was 9 and 7%, respectively. For vinasse the volatilization peak occurred in the first two days and for anaerobic effluent at seven days, perhaps due to the rapid decomposition of vinasse in the system. The significant losses of N to the atmosphere in soil covered with straw and treated with anaerobic effluent are due to the fact that the cover presents a barrier to its penetration into the soil, and, also the presence of urease in the straw accelerates the denitrification process. It is concluded that the behavior of ammoniacal nitrogen present in the anaerobic effluent in soil treated with straw differs from that in soil without straw and in treatments with urea and vinasse, indicating the need for further studies to prove this fact in different edaphoclimatic conditions, in order to define safe application rates for its agricultural reuse.

Keywords: sugarcane waste; anaerobic digestion; denitrification; nitrogen loss; agricultural reuse.

VALORIZATION OF AGRO-INDUSTRIAL WASTES INTO EFFICIENT BIOCHAR FOR OXYTETRACYCLINE ADSORPTION: BATCH-SCALE MULTIVARIABLE OPTIMIZATION

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Veterinary antibiotics such as oxytetracycline (OTC), widely administered in concentrated animal feeding operations, represent a growing environmental threat, as up to 90% of the administered dose is excreted unmetabolized and accumulates in swine wastewater. When this wastewater is mismanaged—via lagoon storage or agricultural application—OTC reaches ecosystems where, even in trace levels, promotes the dissemination of antibiotic-resistant bacteria and genes, threatening One Health integrity. Thus, developing efficient treatment strategies to eliminate this pollutant is imperative. Adsorption via biochar, which is pyrolyzed biomass under oxygen-limited conditions, emerges as a promising solution due to its simplicity, cost-effectiveness, and high pollutant removal efficiency. Moreover, if biochar is produced from biomasses like agro-industrial waste, this technique valorizes byproducts, supporting a circular economy. However, biochar efficacy for OTC adsorption critically depends on its physicochemical properties. The objective of this work is to evaluate the OTC removal efficiency and the adsorption capacity (q) of two biochars derived from agro-industrial wastes: brewer's spent grain (BSGB) and forestry residues (FRB). BSGB was produced using a laboratory-scale cylindrical pyrolysis furnace at 400 °C, while FRB was obtained from an industrial carbonization furnace operating at approximately 700 °C. Notably, FRB addresses a critical waste management challenge in Chaco Province, Argentina, where large volumes of forestry residues lack proper valorization. Both biochars were crushed, sieved (500-1000 μm), washed with deionized water and oven-dried at 70 °C. Characterization of biochars (moisture, volatile solids, ash content, fixed carbon, pH, electrical conductivity, elemental composition, SEM morphology and BET surface area) was conducted using standardized methods. Batch experiments consisted of preparing 50 mL of aqueous solutions with variable biochar doses (0.10, 0.55, 1.00 g) and OTC concentrations (2.50, 16.25, 30.00 mg·L-1) in 100 mL flasks, incubated at 25 °C and 140 rpm for 24 h. Residual OTC was quantified via UV-Vis spectrophotometry (λ=355 nm). Key variables (sorbent dose and OTC concentration) were optimized using Response Surface Methodology (RSM) with Central Composite Design (CCD). Targeted responses included OTC removal efficiency (%) and q ($mg \cdot g^{-1}$). Preliminary results showed that both biochars achieved the highest OTC removal efficiency at low concentrations: 60.39±8.53% for BSGB at 0.55g/2.50$mg \cdot L^{-1}$, and 53.40±23.30% for FRB at 1.00g/2.50 $mg \cdot L^{-1}$. In contrast, adsorption capacity exhibited the highest values at intermediate OTC concentrations, reaching a peak value of 1.10±0.23 $mg \cdot g^{-1}$ for BSGB at 0.10g/16.25 $mg \cdot L^{-1}$, and 0.63±0.32 $mg \cdot g^{-1}$ for FRB at 0.55g/16.25$mg \cdot L^{-1}$. In general, BSGB appeared to outperform FRB under most conditions. However, comprehensive coefficient of variation (CV) analysis reveals significant variability across assays, suggesting that particle size heterogeneity in both biochars causes substantial performance fluctuations, particularly affecting reproducibility at lower doses. In this regard, future research should prioritize increasing replicates at lower OTC concentrations and optimizing biochar processing to mitigate performance variability linked to particle heterogeneity. Additionally, incorporating particle size as a key variable in RSM-CCD designs could elucidate its influence on OTC adsorption mechanisms. Such refinements would strengthen the practical implementation of waste-derived biochars for sustainable antibiotic removal, aligning circular economy goals with One Health imperatives.

Keywords: biochar; antibiotic; waste management; circular economy.

OXYTETRACYCLINE RESIDUES IN SWINE FECES: IMPACT ON SOIL MICROBIOTA AND IMPLICATIONS FOR AGRO-ENVIRONMENTAL SUSTAINABILITY

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The widespread use of antibiotics in intensive livestock production systems is a recognized source of environmental contamination. A considerable proportion of these drugs is excreted in active form and reaches environmental matrices such as soil, surface water, and sediments. Oxytetracycline (OTC), a broad-spectrum bacteriostatic antibiotic, is extensively used in swine production for the treatment of bacterial infections. However, a large fraction of the orally administered dose is excreted unchanged, mainly via feces, which are commonly used as fertilizer in agricultural soils. Once deposited in soil, antibiotic residues may disrupt microbial community structure and function, including organic matter decomposition, nitrogen cycling, and mineralization, and may promote the selection of antimicrobial-resistant microorganisms. Although tetracycline residues have been reported in manured soils, limited experimental evidence exists under real environmental conditions regarding their direct effects on edaphic microbiota. This study aimed to evaluate the effect of swine feces containing OTC residues on total aerobic mesophilic bacteria (TAMB) counts in soil, considering seasonal variation as an environmental modulating factor. In addition, we sought to generate ecotoxicological data to inform sustainable waste management strategies in animal production under a One Health perspective. The experiment was conducted outdoors in a natural grassland plot (CIVETAN, FCV-UNCPBA, Argentina). Feces from untreated pigs were fortified in triplicate with realistic concentrations of OTC based on therapeutic dosages and oral bioavailability. Control samples contained no antibiotics. A total of 100 g of each sample were applied to the soil surface and exposed to ambient conditions for 30 days, repeating the assay during summer, autumn, winter, and spring. Soil samples (0–10 cm) were collected and analyzed using serial dilutions and pour plate techniques on nutrient agar, incubated at 28 °C for 24–48 h. Results were expressed as CFU/g of dry soil. A two-way ANOVA assessed the effects of treatment, season, and their interaction. Post hoc Tukey's test was applied when differences were significant ($p < 0.05$). OTC-treated soils exhibited significantly higher TAMB counts than controls ($p = 0.021$), likely due to selective pressure favoring resistant or adapted bacterial populations. Season also significantly influenced bacterial density ($p = 0.001$), with winter showing the highest counts, possibly due to increased soil moisture and reduced UV exposure, which may also enhance antibiotic persistence. No significant interaction between treatment and season was observed ($p = 0.335$), suggesting that the effect of OTC is consistent across different environmental conditions. These findings demonstrate that OTC residues in swine feces can significantly and consistently alter soil microbial density, regardless of season. Although TAMB counts alone do not provide information on community composition, they indicate a relevant microbial shift. Future research should assess the impact on other functional microbial groups (e.g., nitrifiers, nitrogen fixers) and quantify resistance gene profiles. Integrating microbiological monitoring into agricultural waste management is essential to mitigate ecotoxicological risks and preserve environmental health under the One Health framework.

Keywords: oxytetracycline; swine feces; soil microbiota; antibiotic residues; environmental impact.

INTEGRATED PRETREATMENT STRATEGIES TO ENHANCE DAIRY DIGESTATE QUALITY

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Anaerobic digestion is a well-established technology for dairy effluent treatment, generating liquid digestate (LD) that poses environmental challenges due to its high contaminant load, evidenced by elevated turbidity, chemical oxygen demand (COD), and ammonium (N-NH4+) levels. Recently, LD has emerged as a potential culture medium for microalgal growth. This study evaluated pretreatment strategies to enhance LD quality for potential use as a cultivation medium. Three experimental trials were conducted in triplicate using centrifuged LD (10,000 rpm, 4°C, 15 min). Trial 1 (T1) assessed KMnO4 effects at varying doses (3, 4, and 5 g/L) and pH levels (6 and 10) using jar tests, with negative controls at both pH values. Trial 2 (T2) evaluated LD treated with the optimal KMnO4 dose (P) from T1, combined with 0.2% PAMC flocculant (PF) to improve sedimentation. Trial 3 (T3) examined adsorption using forest residue biochar (7g) in LD (LD-B) and PF (PF-B) through batch systems (50 mL, 24°C, 140 rpm, 24h), including blanks (distilled water + biochar) and controls (PF and LD without biochar) for calculating removal percentages (%R) and sorption capacity (q). T1 results showed significant turbidity reduction (>80%) across all treatments compared to controls. Two-way ANOVA revealed significant effects of dose ($p < 0.001$), pH ($p < 0.01$), and their interaction ($p < 0.05$). At pH 6, 4 g/L achieved comparable turbidity removal to 5 g/L (82% vs. 86%, respectively; $p > 0.05$). At pH 10, all doses (3, 4 y 5 g/L) showed similar effectiveness (77, 82 y 89% removal; $p < 0.05$ vs. control), with 4 g/L at pH 6 identified as optimal. T2 demonstrated that PF reduced turbidity by 50% more than P alone and improved sedimentation time, though without significant effects on COD or N-NH4+. In T3, LD-B and PF-B showed similar N-NH4+ sorption capacities (2.96 and 2.30 mg/g, respectively) and turbidity reduction (9.95% vs. 9.36%). Notably, PF-B achieved 25.5% COD reduction, while LD-B showed no significant difference from controls. These findings support biochar as a complementary treatment to enhance digestate quality, particularly for organic matter reduction in flocculant-treated digestate (PF-B). Overall, these findings support the integrated use of oxidation, flocculation, and adsorption as effective strategies to enhance LD quality, particularly for COD reduction, and suggest potential for reuse in microalgal cultivation.

Keywords: biochar; chemical oxidant; effluent treatment; anaerobic digestion.

IMPACTS OF REPEATED SWINE EFFLUENT APPLICATIONS ON SOIL FERTILITY INDICATORS

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The application of porcine effluents to agricultural soils is a common practice on farms with available land for nutrient reuse. This strategy allows for the incorporation of macro- and micronutrients, as well as organic matter, into the soil. However, proper management is essential to mitigate environmental impacts and ensure sustainable use.

The objective of this study was to evaluate the impacts of repeated porcine effluent applications on soil chemical properties. Soil samples were collected from four farms in Arrecifes, Buenos Aires Province (Argentina), comparing two treatments at each site: one with more than four years of effluent application, and a reference treatment without application, under similar management and environmental conditions. Samples were taken from a depth of 0–15 cm and analyzed for electrical conductivity (EC), pH, organic matter (OM), available phosphorus (P), nitrate nitrogen (NO_3^--N), exchangeable sodium (Na^+), copper (Cu), and zinc (Zn).

Available phosphorus showed the greatest variation, with increases exceeding 300% in three of the four effluent-treated sites (reference values: 11–24 ppm). Organic matter content increased by 2% to 25% across all treated sites relative to reference sites. EC also increased consistently, ranging from 0.09 to 0.14 dS/m in treated soils, compared to 0.04 to 0.08 dS/m in reference soils. Exchangeable sodium remained at low levels and did not exhibit a clear trend.

Micronutrient concentrations were higher in treated soils, likely due to their presence in the effluents. Zn ranged from 2.66 to 7.69 mg/kg in treated soils and from 0.73 to 1.55 mg/kg in reference sites. Cu concentrations ranged from 2.52 to 4.34 mg/kg in treated soils and from 1.32 to 2.82 mg/kg in reference sites, with increases of 10% to 160%, depending on the site.

These findings highlight the potential of porcine effluents to improve soil fertility but also underscore the importance of site-specific monitoring and responsible management to preserve soil health and ensure the long-term sustainability of agricultural systems.

Keywords: effluents; soil; nutrient; reuse.

PHYTOREMEDIATION AS A GREEN TOOL TO REDUCE OF VETERINARY ANTIBIOTIC LOADS IN ANIMAL WASTEWATER

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Confined Animal Feeding Operations (CAFOs) are the main source of release of veterinary antibiotics (VAs) to the surface water ecosystems. The most commonly detected VA in the effluents and digestates of a swine CAFO in the southeast of Buenos Aires Province were enrofloxacin, ciprofloxacin, oxytetracycline, tilmicosin and tylosin. To reduce the load of VAs that reach surface water, phytoremediation using native wetland macrophytes serves as an environmentally friendly low-cost tool. Wetland macrophytes can remove, bioaccumulate and biotransform organic contaminants such as VAs, thereby reducing their load, while also tolerating these stressors. Previous studies by our research group showed great phytoremediation potential of organic compounds (e.g. human pharmaceuticals and pesticides) by the native wetland species Bidens laevis and Typha latifolia. Recent findings focused on exploring the phytoremediation potential of these two aquatic plants in terms of their capacity to remove, bioaccumulate and biotransform AVs. Hydroponically grown B. laevis and T. latifolia plants were exposed to environmentally relevant concentrations of oxytetracycline (0.05 to 100 µg/L) for acute short-term (48 h), and enrofloxacin (10 and 100 µg/L) for long-term effect (35 d), respectively. At the final exposure time, the plants were harvested and separated into roots and shoots (stems and leaves) in order to measure morphological parameters and physiological and biochemical biomarkers. Oxytetracycline and enrofloxacin and its metabolite, ciprofloxacin, were analyzed in plant tissues using LC-MS/MS (recovery rates between 70% and 120%). Oxytetracycline was found in B. laevis roots (16 – 1,080 µg/kg f.w.) and shoots (90 – 174 µg/kg f.w.). In this macrophyte, oxytetracycline inhibited oxidative stress biomarkers in the shoot at the highest exposure concentration. On the other hand, T. latifolia showed a high removal capacity for enrofloxacin, reaching ~90% after 7 days. Furthermore, high levels of enrofloxacin were bioaccumulated in the roots (943 – 515,076 µg/kg f.w.) and shoots (8 – 6,190 µg/kg f.w.) and also metabolized into ciprofloxacin. T. latifolia had high tolerance to enrofloxacin concentrations, showing the potential use in effluent phytoremediation. Nowadays, we are exploring the uptake capacity and tolerance to VA of other native wetland species, such as Cortaderia selloana, Sagittaria montevidensis, Schoenoplectus californicus. These studies will contribute to the design of constructed wetlands for CAFO wastewater treatment systems, as part of the nature-based solutions framework.

Keywords: veterinary drugs; livestock effluent; water recycling; nature-based solutions; biofertilizer.

QUINOA CROP AS A SUSTAINABLE STRATEGY FOR THE REMEDIATION OF MINING-DEGRADED SOILS

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Abandoned mine sites are a worldwide environmental problem. Mining waste causes a pollution plume generated by the release of high concentrations of metal(loid)s at a very acidic pH through erosion, runoff, and leaching processes. Chenopodium quinoa has become an interesting alternative for the phytoremediation of mining waste, as it has developed facultative halophyte strategies that could be used in the tolerance of metal(loid)s. In the town of La Planta, Caucete, San Juan, Argentina, a contamination plume has been generated because of the deposition of waste from mining activities, with As, Cu, Cd, and Zn being the most concentrated elements. The aim of this work was to evaluate the phytoremediation ability of two varieties of quinoa in soils with mining waste. In the study site of La Planta, an experimental plot was installed. An area of 64 m^2 was used for seeding two varieties of quinoa crop (Morillo and Hornillo). Two seedings were carried out during the years 2022 and 2023. After 120 days of exposure, the crop was harvested and the concentration of total metal(loid)s in soil at five depths before and after planting and the concentration in aerial organs were determined. The BAF and TF were estimated. The metal(loid)s determinations were carried out with ICP-MS after acid digestion of the matrix. As a result, the concentrations of the four most increased elements (As, Cu, Cd, and Zn) decreased after quinoa seeding between 10% and 64.7%, with a higher percentage decrease for Zn and As concentrations. Regarding the accumulation of metal(loid)s in the aerial organs of the crop, 1140 mg kg^{-1}, 6633 mg kg^{-1}, 518 mg kg^{-1}, and 1103 mg kg^{-1} of Cu, Zn, As, and Cd were obtained, respectively, resulting in FBA and FT values between 1 and 64, being the highest for Cd and Zn. From these results, it can be said that the quinoa crop is a good candidate for the remediation of environments contaminated with metal(loid)s not only because of its bioaccumulation ability, but also because of its rapid growth, ability to adapt to marginal environments, ability to carry out two annual seedings, rapid biomass production, and low water requirements.

Keywords: abandoned mine; heavy metals; crop; phytoremediation.

NATIVE MICROORGANISMS FOR AGRICULTURAL SOIL ENHANCEMENT

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The soil is a diverse ecosystem that harbors a large microbial biomass, which is key to biogeochemical cycles. Through their eco-enzymatic activity, fungi decompose organic matter and generate by-products that are useful to bacteria, which facilitates the biotransformation of elements such as phosphorus (P), nitrogen (N), sulfur (S), and carbon (C). However, intensive agricultural practices such as monoculture and the use of agrochemicals alter these processes, increasing erosion and salinization, which contributes to desertification and infertility. This translates into a loss of valuable fertile lands for crop growing, challenging future nutrition security. This problem is intensified when agricultural production is accompanied by inefficient waste management processes. The prospection for technologies to harness agricultural waste and produce biogas emerges as a promising alternative to mitigate these challenges, transforming waste into valuable resources. The conversion of residual biomass into biogas, coupled with the use of bio-fertilizers, not only reduces environmental pollution but also generates a source of renewable energy. In this way, the integrated management of agricultural waste becomes a fundamental pillar for agricultural sustainability, closing the nutrient cycle and improving soil health. This work presents results on the potential use of microorganisms (fungi and bacteria) from a soil managed with agro-ecological practices as bio-fertilizers, and presents a prospective for the management of agricultural waste. For this, the metabolic profiles of strains of interest were screened and greenhouse experiments were set up with chamomile plants (Matricaria chamomilla). The selected microorganisms showed extensive metabolic activity, with three of them showing a greater consumption of carbon and nitrogen substrates. Likewise, these microorganisms promoted the development of plant biomass and flowers in the plant when they were inoculated into the soil. The integration of these strategies not only optimizes the use of resources and reduces dependence on chemical inputs, but also promotes the resilience of agroecosystems.

Keywords: anaerobic process; biofertilizer; micoremediation; microfungi; mine tailings.

CIRCULAR ECONOMY AND REGULATORY FRAMEWORK

CITIZEN SCIENCE TO STUDY DECENTRALIZED COMPOSTING

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Organic waste represents approximately 50% of household waste. Its disposal in landfills not only requires transportation but also generates greenhouse gases and leachates, while valuable materials that could be used to produce organic soil amendments are lost. Decentralized composting (i.e. household and community initiatives) offers a low-cost, on-site treatment alternative with strong educational and participatory potential. This process engages citizens in waste management, raising awareness about their role in waste generation and their ability to take action. We launched the citizen science project Composta:Orgánicos (www.labciudadano.net) to promote composting practices and provide accessible information about urban composting in Buenos Aires (CABA), including the quality of the resulting product. Participants voluntarily completed a survey and gave a sample of their compost. Sixteen household and twelve community compost samples were analyzed according to the procedures required by national regulations (Resolution 1/2019 by SENASA and SCyMA) and tested against the established reference limits. Most compost complied with regulatory stability standards for microbial respiration (10.6 ± 7.4 mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$), water-soluble organic carbon (WSOC: 1.9 ± 2.6 $g \cdot kg^{-1}$), and the WSOC/total nitrogen ratio (0.13 ± 0.15). Regarding maturity, average values for ammonium (77 ± 121 mg $NH_4^+ \cdot kg^{-1}$), nitrate (2031 ± 1061 mg $NO_3^- \cdot kg^{-1}$) and ammonium/nitrate ratio (0.03 ± 0.04) were mostly within the limits. However, only 30% of the samples achieved a germination index above 60% for both species analyzed (tomato and ryegrass), as required by regulation. Most samples met the criteria for organic matter (39% ± 12.8%), C/N ratio (12.7 ± 2.3), and pH (8.1 ± 1). Nevertheless, electrical conductivity frequently exceeded the recommended thresholds, with average values of 8.3 ± 3.8 $dS \cdot m^{-1}$ for household compost and 4.8 ± 3.3 $dS \cdot m^{-1}$ for community compost. Nearly 30% of the analyzed samples exceeded the regulatory threshold for the presence of stones and clods, while 21% showed glass contamination. In no case did flexible plastics exceed the limit established by regulation. Finally, most samples reached moisture values within the acceptable range (53.8% ±14.1%). Compost quality is particularly relevant given that over 50% of community composters use compost to produce food, while household compost is mostly applied to ornamental plants. Elevated salt content and potential phytotoxicity could affect plant growth, especially in food crops. Urban compost should be evaluated not only for its quality as a soil amendment, but also for its potential to engage people in recognizing their waste generation and participating in its treatment. Urban composting is an effective way to reduce landfilled waste and greenhouse gases emissions, while producing a soil amendment that—despite some challenges—could be used in parks or for land remediation.

Keywords: organic waste; urban composting; compost quality.

BIOPRODUCT RECOVERY PROCESSES FROM MICROALGAE: METHODS AND SCALE

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Microalgae will consolidate themselves as a strategic alternative within the context of the circular economy, enabling the reuse of effluents as a cultivation medium and the production of high-value bioproducts. This review examines the potential of microalgae to integrate bioremediation and bioactive compound extraction processes, with a focus on industrial sustainability. Studies with Chlorella vulgaris demonstrate that, in addition to removing 71% of nitrogen and 67% of phosphorus from domestic effluents, the biomass generated can be converted into products such as omega-3 fatty acids, carotenoids, and antioxidants. Among the conventional methodologies, extraction with organic solvents stands out, as it is widely used for its efficiency in lipid recovery. Additionally, the review examines the use of new solvents with reduced environmental impact, including deep eutectic solvents (DES) and bio-based solvents. Scaling up these processes is essential to make their industrial application viable. Systems such as photobioreactors and open lakes were analyzed only for operational feasibility and contamination risks. The integration of waste treatment with the production of industrial inputs positions microalgae as allies in the transition to cleaner production chains, connecting biotechnological innovation with sustainable regulatory guidelines.

Keywords: biocomposites; microbiology; bioreactors; integrated processes.

CIRCULAR ECONOMY IN THE OLIVE OIL VALUE CHAIN: ASSESSMENT OF BY-PRODUCT GENERATION IN THE MAIN OLIVE-GROWING AREA OF ARGENTINA, SAN JUAN

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The Argentine olive sector has significant potential to adopt sustainable practices through the valorization of by-products: olive pruning residues and olive pomace generated during the olive oil extraction process.

Pruning residues can be valorized as a local renewable energy source or through composting processes to obtain organic amendments, among other technological alternatives. The selected option will depend on multiple technical, economic, and environmental variables.

Olive pomace, due to its high organic load and phenolic compound content, represents an environmental challenge that requires appropriate treatment. Different technologies make it possible to valorize this material by generating new products of commercial interest with significant added value.

The utilization of these materials not only provides environmental benefits, such as the reduction of greenhouse gas emissions through the replacement of non-renewable energy sources, the recovery of nutrients and bioactive compounds, and the mitigation of impacts on receiving water bodies, but also has a strong economic and social impact. It contributes to job creation, strengthens regional economies, and promotes technological innovation in rural areas.

A key aspect in promoting these processes is the generation of georeferenced information on the quantity and location of these valorizable materials over time. These data enable the design of technological solutions adapted to each region, the optimization of collection logistics, and a more accurate assessment of impacts.

The interview method was used to determine the amount of olives processed in 2024 and to estimate production for 2025. Based on these data, a factor of 0.8 was applied to estimate the amount of olive pomace generated, and a factor of 0.5 was applied to estimate pruning residues at each location.

A thematic map was developed to represent the geographical distribution of industries generating these materials and the main road networks, both of which are relevant when considering different valorization scenarios. The location of each company was represented by a graduated point symbol according to the average value, in tons, of the variable considered: 5760 generation and pruning residue generation. Since this is a quantitative variable, three equal-magnitude intervals were established according to ranges defined based on the annual production scale.

Regarding georeferenced information, this study presents the location of the 14 surveyed facilities and the average generation values of both by-products during the 2022–2025 production seasons in the olive-growing cluster of Sarmiento Department, San Juan Province. This information complements the surveys conducted during the 2022 and 2023 seasons, which have already been published, and extends the analysis to a four-year period. The variability in olive pomace generation among production seasons for each facility, as well as the annual total generated within the cluster during the study period, was also analyzed.

The promotion of circular economy models contributes to value addition within the national olive value chain and fosters sustainable productive development by transforming biomass into viable business opportunities.

Keywords: valorization; olive pomace; pruning residues.

BIOMASS SUPPLY FOR RENEWABLE ENERGY GENERATION IN THE AGRICULTURAL AND AGRO-INDUSTRIAL SECTORS OF SAN JUAN PROVINCE, ARGENTINA

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The Argentine energy system faces environmental and sustainability limits. Renewable energies, such as those generated from biomass processing, are proposed as a viable alternative. In this regard, prior to developing biomass energy valorization strategies, it is essential to understand the existing biomass supply in the province, considering its availability, quantity, and location.

The main objective of this study was to contribute to the development of renewable energy projects by determining and quantifying the direct and indirect biomass supply in the agricultural and agro-industrial sectors of the main productive regions of San Juan province. The study focused on the Tulum-Ullum-Zonda valley, discriminating three sub-zones: West, South, and Central-East, each with an approximate diameter of 30 km.

The methodology consisted of identifying and quantifying the biomass supply, differentiating between direct and indirect. Direct biomass included pruning waste from crops such as vines, olives, and pistachios, which cover 80% of the valley's surface area. Its quantification was based on cultivated area data and specific pruning factors according to crop type and production system. Indirect biomass, geographically concentrated, included waste and by-products from industrial processes such as wine production, raisins, olive oil, and pistachio cleaning. Based on publicly available production data, biomass generation was estimated considering production factors (biomass/raw material expressed in tons) and a moisture correction, adjusted to 10%. The geographical and temporal distribution of biomass was classified according to zones and management plans.

The study estimated a total biomass supply in San Juan province of 275,293 annual tons, with 74% corresponding to direct biomass (pruning wastes) and the remaining 26% to indirect biomass (agro-industrial by-products). Vine pruning represented the largest portion of direct biomass (75%), followed by olive pruning (17%) and pistachio (6%). These residues, with low moisture (<20%) and good fuel quality, are mainly distributed between the central-east zone (vines) and the southern zone (olives and pistachios). Indirect biomass, estimated at 70,372 t/year, consisted of alperujo (44%), pomace (29%), grape stems (12%), pistachio hulls (15%), and raisin cleaning waste (1%). It is more geographically and temporally concentrated, complicating its collection and transport.

Ninety-three percent of all available biomass was located in the southern and central-eastern zones, which favors the development of cogeneration projects by reducing transportation costs. However, seasonal availability presents a challenge: pruning is concentrated in winter (March to August), while agro-industrial biomass varies according to the processed crop. Between August and December, there is low biomass availability, which could limit the continuous operation of energy plants. This suggests the need for storage strategies or complementing biomass with other sources to ensure sustained energy viability throughout the year.

San Juan has high bioenergy potential thanks to 275,000 annual tons of biomass, mainly pruning residues. This biomass is distributed between the south and central-east, ideal for energy plants. Its low cost and environmental value are highlighted, although further studies on logistics and territorial optimization are required.

Keywords: agricultural residual biomass; renewable energy.

IMPLEMENTATION OF INNOVATION AND PROJECT MANAGEMENT BEST PRACTICES IN TECHNOLOGICAL DEVELOPMENT. CASE STUDY: NATURAL ANTIOXIDANTS FROM OLIVE POMACE IN THE MAIN OLIVE-GROWING AREA OF ARGENTINA

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This paper presents the progress achieved in the technological maturation process of an Olive Pomace Biorefinery model aimed at obtaining an Olive Biophenol Concentrate (OBC), a natural antioxidant. Both the process and the reference product constitute the first Minimum Viable Products (MVPs) of this line of work within the analyzed context.

The work is based on a systematic innovation process approach. The Technological Readiness Levels (TRLs) methodology was used to assess the maturity of technologies under development. Simultaneously, Project Management (PM) best practices were implemented, including schedule, scope, quality, stakeholder, resource, and risk management, as well as execution monitoring and control, and the integration of strategy and operations. Building on lessons learned from previous stages, product and process requirements were identified for the design of the MVPs. Business Analysis tools were applied to evaluate the business case. Agile planning methodologies were adopted due to contextual uncertainty, together with Lean PM concepts. This approach made it possible to optimize the innovation process dynamics with effectiveness, efficiency, and the expected quality, while navigating the complexity of different institutional cultures with adaptability and resilience.

The main results obtained include: 1) mapping of olive pomace generation in the San Juan olive-growing cluster during the 2024 season, continuing the series initiated in 2022; 2) laboratory- and pilot-scale production of a first MVP olive antioxidant; 3) physicochemical and functional characterization of the OBC and development of its product technical datasheet; 4) intra-institutional collaborations for the development of a solid product based on the OBC; 5) preliminary economic and financial feasibility assessment of the model; 6) partnerships with companies in the animal nutrition sector to conduct initial palatability trials in companion animals and other tests of interest to the poultry sector; 7) interaction with the corresponding regulatory agencies to evaluate the registration strategy for this first product and related products; and 8) design of the TRL labeling methodology and the risk and opportunity management methodology.

In conclusion, the application of best practices enabled the technological maturation of the model from TRL 2 to TRL 6–7, out of a total of 9 stages, in only six months. These latter stages involve validation of the concept in a relevant environment and the generation of viable products for future implementation at larger scales. The results obtained will have a significant positive impact on both the productive diversification process of the olive sector and the industrial sectors of animal nutrition and functional food production.

This development is part of an agreement between the National Institute of Agricultural Technology (INTA) and the National Institute of Industrial Technology (INTI), implemented in the provinces of San Juan and Mendoza to promote innovation within the framework of the circular economy.

Keywords: valorization, olive pomace, biorefinery, biophenols, antioxidants.

CIRCULAR ECONOMY AND THE REGULATORY FRAMEWORK IN BRAZIL: PROGRESS AND CHALLENGES FOR SUSTAINABILITY

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The development model based on a linear economy—characterized by extraction, production, consumption, and disposal—has shown clear limitations in light of worsening environmental crises and the depletion of natural resources. In this context, the circular economy emerges as a strategic alternative for the transition to a sustainable model by promoting the regeneration of natural systems, extending product life cycles, and reducing waste generation. In Brazil, the topic has gained increasing relevance, particularly within public policy and the strengthening of the regulatory framework.

The National Solid Waste Policy (PNRS), established by Law No. 12,305/2010, was a significant milestone by introducing the principles of shared responsibility and reverse logistics. However, the implementation of the PNRS faces structural, financial, and operational barriers. Data from ABRELPE (2023) indicate that, in 2022, over 35% of urban solid waste generated in the country was still disposed of inadequately, highlighting the need for more robust and integrated solutions.

In this context, the enactment of Decree No. 12,082/2024, which establishes the National Circular Economy Strategy, represents a major advancement. This strategy sets guidelines for incorporating circular practices into productive sectors, encourages sustainable business models, and coordinates actions among different levels of government. Additionally, the new Legal Framework for Basic Sanitation (Law No. 14,026/2020) has expanded opportunities for public-private partnerships and intermunicipal consortia, creating institutional conditions for developing regional solutions focused on the treatment and final disposal of solid waste.

Technological innovation emerges as a critical factor in enabling the circular economy in the country. Local initiatives—such as smart collection systems with sensors and real-time monitoring, automated sorting centers, and technologies for organic waste valorization (composting, biodigestion, and pyrolysis)—have shown potential for replication. Moreover, energy recovery from sludge resulting from wastewater treatment has emerged as an integrated solution for energy generation, fertilizer production, water reuse, and the mitigation of environmental and health impacts.

Despite the progress, significant challenges remain. Consolidating the circular economy in Brazil requires strengthening regulatory governance, providing incentives for innovation, investing in infrastructure, enhancing technical training, and, above all, adopting an integrated approach involving government, the private sector, civil society, and the informal sector. The coordination of these actors will be crucial for a just, inclusive, and effective transition.

Brazil has favorable conditions to lead this transition, provided there is strategic planning, regulatory alignment, and political-institutional commitment. The circular economy is not merely a new productive model but entails a profound and structural cultural shift aimed at building a sustainable, regenerative, and equitable future.

Keywords: circular economy - sustainability - regulatory framework - brazilian progress - waste valorization.

THE AGRO-INDUSTRIAL WASTE AS AN OPPORTUNITY TO BUILD UP A NEW TECHNOLOGY-BASED COMPANY: A CASE OF CIRCULAR BIOECONOMY

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In 1999 at the Chemistry Department of UNRC (Universidad Nacional de Rio Cuarto, Argentina) the Development Laboratory was establish. Today it is an interdisciplinary research group, which began its work by analyzing the technical and economic possibilities of existence of an oleo chemical development centre in the southern province of Cordoba, compatible with Mercosur and other markets as incipient contribution to circular bioeconomy concept. We conclude that there were excellent prospects for development because the prevailing international conditions in despite of an adverse local atmosphere.

Waste from oil industries introduces a number of problems: i)the waste storage and ii)that potential pollution. Its productive use could yield an important activity that would enhance the important existing oil industry solving at the same time the environmental problem. Our research process yields advanced production technology, with high added value products (Vitamin E for animal feed, fatty acids and derivatives like liquid soap) using as feedstock oilseed industry waste. Liquid soaps at the same time are an important market product and also we take as an social good. We propose to provide assistance to poor areas with vulnerable population with cleaning products expecting to impact on health budgets of public sector. The other product defined as Vitamin E is a tocopherol acetate concentrated in a percentage greater or equal than to 30% by weight. It is an intermediate good that can be used as input for several industries. As secondary products we have fatty acids fractions and a fertilizer in large amounts.

The industrial processes were supported by original well proved scientific and technological development condensed in the respective business plan. A patent application is being developed. The plants designed are flexible with an initial production of 120 tons/year of liquid soap and 50 tons of vitamin E. The projected plants are easily replicable and reproducible and relatively low initial investment with IRR and NVP excellent values. Thus the research group finally decides to create a spinoff company.Then, involving several non-university members, born Initia (Workers Cooperative) as technology-based company with a sui generis organizational form based on the Cooperative Capital. This last point could be a valuable tool in developing countries and also is presented here with all its innovative character. It is expected that the company created to cause a significant impact on the local economy and on the local university culture sometimes reluctant to participate in specific production processes.

From research to market was a way plenty of learning which change our minds and opened it to the world.

Keywords: industrial waste recovery; circular bioeconomy; vitamin e; liquid soaps; social good.

DESIGN AND MONITORING A COMPOSTING PROCESS WITH AGRICULTURAL AND AGRO-INDUSTRIAL BY-PRODUCTS FROM A HORTICULTURAL COMPANY

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Iceberg Agrícola S.A. is a company based in San Juan, Argentina, that produces, packs, freezes, and exports certified natural and organic vegetables. In addition to 60 hectares dedicated to primary production, the company operates vegetable cleaning and selection facilities and a modern frozen vegetable processing plant. These three sectors annually generate significant quantities of waste and discards, such as asparagus branches from primary production, broccoli stalks and pumpkin peels from the selection and cleaning process, and pumpkin pulp cubes from the freezing plant. To advance towards more sustainable production models, the company aims to replace raw animal manure in its primary production with compost obtained by processing its generated waste and discards. The objective of this study was to design and monitor a composting process adapted to the company's waste, with the goal of obtaining a final product suitable for use as an organic amendment in its crops. The main agricultural and agro-industrial wastes generated by the company were quantified, and relevant chemical properties for the composting process were characterized: organic matter, total organic carbon, total nitrogen, electrical conductivity, density, and pH. Goat and chicken manure were also characterized for use as process accelerators. Simultaneously, available water was analyzed to ensure its suitability as a moisture source. Based on the data obtained, theoretical calculations were performed to create compost piles 100 m long, 2 m wide, and 1 m high, aiming to maintain a C/N ratio close to 30. The process was monitored through technical visits every 48 hours during the first two weeks, and then weekly. Temperature, humidity, and visual observations were recorded, and adjustments were defined in collaboration with personnel. Finally, the chemical characterization of the finished compost was carried out. Based on the chemical characterization, the waste was classified into three groups. Firstly, asparagus branches, the main waste to be treated (approximately 200 m^3), had distinctive characteristics of low density (0.10 kg/L) and a high C/N ratio (69). The second group consisted of other horticultural discards with similar density values (0.35-0.44 kg/L) and C/N ratios (30-40). The third group comprised goat and chicken manure, with similar density values (0.50-0.55 kg/L) and low C/N ratios (11-17). Based on these results, piles were constructed with proportions of 2:1:1 and 2:1:2 v:v:v for asparagus Goup1:Group2:Group3. During the process, a progressive increase in temperature, reduction in volume, and signs of intense microbial activity were observed. Composting was concluded after 95 days. The final product showed good macronutrient content and acceptable physical parameters. Salt levels were above those recommended by applicable regulations but were considered normal for horticultural production under the local working conditions. Furthermore, it is considered necessary to further characterize the salts present and evaluate strategies to reduce their contribution, either through soil amendments or modification of the water source used. In summary, the implemented composting process allowed for the transformation of horticultural and agro-industrial waste into a product with potential as an organic amendment, replacing the use of raw animal manure and facilitating the certification of organic production standards.

Keywords: compost; horticultural wastes; cricular economy;.

SUSTAINABLE ORGANIC WASTE MANAGEMENT IN WINERY AND OLIVE OIL PRODUCTION: COMPOSTING AS A CIRCULAR ECONOMY STRATEGY

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The generation of organic waste in agricultural and industrial activities, such as viticulture and olive oil production, poses significant environmental sustainability challenges. In this context, this study outlines the experience gained at the Bodega Valle de La Puerta Winery (29° 25' 0.098" S; 67° 30' 13.77" W) during the initial compost production campaign in 2024. This campaign focused on the valorization of organic solid waste through on-site windrow composting, as part of the strategy for achieving in good agricultural practices certification. The main objective was to transform by-products generated at the winery and olive mill, such as pomace, alperujo, pruning wood chips and poultry manure, into a useful agricultural input that improves soil fertility while reducing environmental impact. A windrow composting system with mechanized turnings (EcoManagement®, Turner280) was implemented to ensure optimal aerobic conditions. The compost mixture was carefully formulated to achieve a carbon-to-nitrogen ratio of 25:1, taking into account the physicochemical characteristics of each component, while maintaining optimal moisture levels (50–60%) throughout the composting process. The total process duration was 150 days, comprising a 120-day active bio-oxidation phase and a 30-day maturation phase. During the evaluation period (April–November 2024), 3,200 tonnes of organic waste were processed, resulting in 1,500 tonnes of compost. Of this, 500 tonnes were ground and screened for pelletising, demonstrating the potential to diversify derived products and add value to the treated waste. Despite some logistical limitations arising from the implementation of new industrial-scale processes within the company, this was a successful endeavour, showcasing the dedication of the technical and operational team. The resulting compost met the stability and maturity criteria set out in current regulations (SENASA Resolution 01/2019), and preliminary analytical results suggest that it is suitable for use as a biofertilizer. This case study demonstrates the technical and economic feasibility of integrating composting processes into agro-industrial operations, in line with the principles of sustainability, comprehensive waste management and the circular economy. It also highlights the importance of having trained personnel, technical monitoring and continuous improvement strategies in order to scale up and replicate the process. Recommendations for the future include incorporating more precise monitoring technologies, expanding permanent infrastructure and operational capacity, and consolidating institutional partnerships to enhance local development. Ultimately, implementing composting as an on-site valorisation strategy is an efficient, replicable solution for treating organic waste in the agro-industrial sector, offering environmental and productive benefits.

Keywords: composting; organic waste; circular economy; biofertilizer; sustainable agriculture.

AGROINDUSTRIAL WASTE IDENTIFICATION, CHARACTERIZATION, AND QUANTIFICATION IN THE MUNICIPALITY OF LAPRIDA, BUENOS AIRES PROVINCE

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The design of an efficient waste management system, requires a thorough characterization of the waste to be managed. This involves not only its quantification, but also identifying its seasonality, location, and the management practices applied within the territory. This study presents a diagnostic assessment of the agroindustrial wastes generated in the municipality of Laprida, Buenos Aires Province. The analysis includes plastic, metal, end-of-life tires (ELTs), chemical liquids, manure, lignocellulosic, and organic wastes.

The aim of this work is to generate reliable information to support the development of waste valorization and energy recovery strategies, as well as the design of local public policies. Additionally, it intends to develop a survey methodology that can be applied in other municipalities across the province.

The methodology was developed in three stages: first, stakeholders involved in agricultural production and waste management were identified, and the Municipal Solid Waste Treatment Plant (MSWTP) was visited to survey equipment and current practices. Next, interviews were conducted with key stakeholders to gather quantitative information and to serve as a basis for designing a structured 10-question survey in Google Forms, which was applied in the final stage.

The results show that, although Laprida is predominantly a livestock district, the most frequently mentioned wastes were used silo bags, empty pesticide containers (EPCs), ELTs, and metals. Livestock manure was not considered waste by producers, as it is reused on the farms as organic amendments. While some participants reported proper composting practices, others simply collect, pile up, and store the waste. The interviewees indicated that most of the wastes studied are generated throughout the year.

A high percentage of the surveyed individuals (40%) do not manage their waste, attributing this to the lack of time and knowledge. Logistics and the absence of industries or technologies for treatment and/or recovery were identified as the main obstacles to proper agroindustrial waste management. Participants also reported a lack of collection centers, particularly for EPCs, which highlights an information gap, as a temporary collection center is currently operational.

The absence of specialized treatment industries is, in some cases, compensated by the operations of the MSWTP where producers who manage their waste take it for processing. However, the investigation reveals the existence of an informal market for wastes. EPCs are especially concerning, as they leave the formal management system, making traceability impossible and allowing contaminated plastic to end up in unauthorized uses, potentially posing health risks to the population.

Eighty percent of the surveyed individuals acknowledge that proper management of agroindustrial waste improves quality of life. This finding aligns with Laprida's profile as a municipality with a long-standing tradition of recycling, supported by local regulations on waste management in rural aeras. However, a significant percentage of producers still do not implement adequate management practices.

Regarding the methodology, preliminary interviews enriched and complemented the survey design. Despite dissemination efforts, digital channels were not the preferred option for producers. In many cases, surveys were completed in person during field visits, which proved more effective in the rural context.

Keywords: agroindustrial wastes; waste characterization; sustainability; waste management.

MANAGEMENT OF EMPTY PESTICIDE CONTAINERS IN LAPRIDA: CHALLENGES AND OPPORTUNITIES FOR A CIRCULAR ECONOMY APPROACH

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The management of empty pesticide containers (EPCs) poses significant environmental, logistical, and regulatory challenges for advancing towards circular economy models in the agricultural sector. This study presents a diagnostic assessment of the current situation in the district of Laprida, Buenos Aires Province, based on a methodology that combines producer surveys, interviews with key local stakeholders and document analysis.

The findings reveal a significant gap between existing regulations and actual practices. Although the district has a Temporary Collection Center (TCC), its limited operating hours (from 8 a.m. to 12 p.m.) overlap with the producers' working hours, making it difficult for them to deliver containers. This restriction, combined with a lack of accessible information and incentives, has resulted in inadequate practices such as open-field accumulation or container reuse, particularly among small-scale operations. Sixty-five percent of surveyed producers have never participated in training related to this issue. More than half delegate the tasks of transporting, rinsing, and perforating the containers to their pesticide applicators. Delays in the issuance of final disposal certificates were also identified as a relevant weakness of the system, as they hinder traceability and control. Additional logistical limitations were observed: 75% of surveyed producers are located between 15 and 30 km from the TCC, while the remaining 25% are between 35 and 60 km away.

Capacity constraints were also identified. During peak demand months (November 2023, February and May 2024), the TCC became saturated, forcing producers to leave containers without proper storage due to delays in collection by the authorized company. Another critical issue was the existence of an illegal market for EPCs, which poses health risks due to the reuse of contaminated plastic. Local authorities have acknowledged the problem and are taking initial steps to address it.

Regarding system efficiency, 55.5% of producers consider the current management system to be "sometimes" efficient, 27.8% view it as inefficient, and only 16.7% find it efficient. When asked about potential measures to promote proper container management, 32.3% suggested information campaigns, 27.8% proposed economic incentives, 22.2% supported on-farm collection, 11.1% supported stricter penalties, and 6.6% recommended improving access to the TCC.

The surveys also identified the most commonly used container types and active ingredients, findings that were corroborated through interviews with agricultural supply stores. Products such as Glyphosate, 2,4-D, and mineral oil are predominantly packaged in 20-liter containers, while Dicamba and Picloram are frequently available in 10-liter presentations.

Finally, from a regulatory standpoint, the recent publication of Resolution No. 343/24 by the Ministry of Environment mandates in Article 9 that distributors and retailers must establish, individually or jointly, at least one reception point for EPCs in each marketing area. If properly implemented, this measure could enhance both traceability and the overall efficiency of the system. In conclusion, the study proposes strategies to strength then the management system through a circular economy and shared responsibility approach. These include extending TCC operating hours, improving collection logistics, ensuring timely delivery of certificates, providing targeted incentives, and implementing educational workshops coordinated with enforcement actions.

Keywords: agro-industrial waste; empty pesticide containers; laprida; waste management system; sustainability.

CONCEPTUAL MODEL TO IMPROVE HOUSEHOLD SOLID WASTE MANAGEMENT THROUGH STAKEHOLDER COOPERATION WITHIN A TERRITORY

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Circular economy represents a strategic opportunity to rethink the management of municipal solid waste from a sustainability perspective. However, its implementation at the municipal level faces two major obstacles: the lack of local regulations and the limited allocation of technical, human, and financial resources for this purpose. This study analyzed these limitations based on a regulatory review carried out in municipalities of the province of Misiones, Argentina, through exploratory research with a mixed-methods approach. The methodology included the analysis of existing local ordinances and waste management plans, as well as semi-structured interviews with key stakeholders from the four sectors of the Quadruple Helix: government, academia, the productive sector, and organized civil society.

The results show that, in many cases, local regulatory frameworks need to be adapted to enable the transition to the circular model. This regulatory gap hinders the establishment of obligations, incentives, and control mechanisms that would allow the implementation of circular practices such as source separation, composting, or inclusive recycling in collaboration with key territorial actors, fostering win-win scenarios. In addition, there is a clear absence of municipal technical structures to support these actions, generally associated with a lack of resources.

Given this context, the State must play a leading role—not only as a generator of regulations and provider of resources but also as a facilitator of articulation among actors of the quadruple helix (government, productive sector, academia, and civil society). Only through this institutionally enabled synergy will it be possible to move toward effective household solid waste management models and close the existing implementation gap.

The objective of this study is to present a conceptual model to improve the management of household solid waste, in which municipal governments and academia assume a central role as facilitators of research, development, and innovation (R+D+I) processes. Through the design of clear public policies, participatory planning, and strategic allocation of resources, the aim is to institutionalize mechanisms of articulation with territorial actors that promote context-appropriate waste management plans.

Keywords: stakeholders; circular economy; management; household solid waste.

AGRICULTURAL AND AGRO INDUSTRIAL WASTE GENERATED IN GENERAL LOPEZ DEPARTMENT, SANTA FE PROVINCE: OPPORTUNITIES FOR ITS REUSE

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General Lopez Department is located in southern Santa Fe province. It ranks third in both population and surface area of the province. The region has excellent soils for agricultural activities, often combined with livestock farming systems. The agro-industry is linked to adding value to agricultural products. The most important activities include the production of balanced feed, inputs and tools for agricultural machinery, and the seed industry, which has been pioneer in the Pampas region.

These activities generate waste, that traditionally had not commercial value for the producer. However, in recent years, this paradigm has changed. What was once discarded, treated or outsourced is now being recycled or reused in other processes, as part of the Circular Economy of these systems. This can occur either within the context of the activity itself (especially in intensive livestock farming systems) or outside its boundaries, as seen in agro-industry. The aim of this study is to characterize and quantify current and alternative uses for the agricultural and agro-industrial waste, particularly that generated by intensive animal farming (pigs, beef cattle, and dairy cattle) and the seed industry.

The wastes considered in this study include husk, corncob, discarded seeds (from the seed industry), and bovine and pig manure. Data on waste quantities were obtained from SENASA database, agro-industries sources and INTA (National Institute of Agricultural Technology). The total amount of waste identified is 154,686 tons/year, 40% originating from the seed industry and the remaining from animal production. Currently, more than 65% of this waste is not utilized: it is either discarded in pits (such as pig and dairy effluent), in piled up (feedlot waste), dispersed in low-efficiency livestock feeding systems (husks, corncobs) or incinerated in high-temperature furnaces (discarded seeds).

What local options are today for improving waste management? Anaerobic digestion can be an important alternative for husk and cob, particularly by expanding the existing capacity of the regions of high-efficiency biogas plant. Dairy and pig effluents could be treated using medium-efficiency biodigesters to produce electricity and fertilizers in the areas where these activities are concentrated. Composting feedlot waste as a value-added process could also provide organic fertilizers to agricultural production.

What is the impact of this waste compared to other types of waste generated in the same area? And how does it compare to regions with similar activities? The full paper explores some of the answers to these questions in detail.

Keywords: adding value; anaerobic digestion; fertilizers; composting.

ENVIRONMENTAL DIAGNOSIS OF COMPOSTING IN DEEP-LITTER SWINE SYSTEMS

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The growing demand for animal-based products has intensified pig farming in Argentina. One of the most commonly used systems among small and medium-scale producers is the deep-litter tunnel system, which generates significant volumes of solid waste and poses major environmental challenges (Magri, 2020). This study aims to assess current waste management practices in these systems in the Central region of Buenos Aires Province, and compare with previous findings.

Three sources of information were used: records from periodic field visits between 2021 and 2025, an in-depth interview with one producer, and a structured survey carried out in 2025 with six of the eight members of APPORTAN (Association of Swine Producers of Tandil). The survey, adjusted after the interview, addressed production scale, system characteristics, types of waste generated, available and implemented treatment technologies and practices, final destination of materials, operational challenges, needed support, and perceived environmental impacts. The 2025 findings were compared with previous studies conducted in Tandil (Ferragine et al., 2019; Mestelan et al., 2023), focusing on recommendations regarding equipment acquisition and technical training.

In 2018, APPORTAN consisted of 29 producers (Ferragine, 2019); by 2025, the number had decreased sharply to 11—a 62% reduction—of which only eight still use deep-litter systems. Among the six surveyed, only two combined breeding and fattening on leased land. All producers reported reaching slaughter weights of 115–120 kg at six months from birth, with batches ranging from 25 to 100 animals per cycle. Five producers cleaned the tunnels after the animals were sold, and all stored waste outdoors without turning, repeating deficiencies identified in 2019. This practice hinders the achievement of sanitizing temperatures, limiting safe reuse of waste.

Following earlier research recommendations, APPORTAN acquired an RCO compost turner in 2021, which was first used in late 2024. However, most producers either do not know how to operate it or face limitations such as space constraints for proper storage, lack of towing equipment, transportation difficulties from farm to farm, or insufficient personnel. The interview and field visits confirmed that, due to other production priorities, composting is not a main concern, although awareness of its potential to free up space, reduce negative impacts, and generate a valuable byproduct is increasing. Only one producer tested compost quality, and visits revealed that most use it to fill in bumps in roads or to level flat areas. The lack of technical characterization limits broader reuse. All producers reported limitations in space and equipment and emphasized the need for financing, training, and technical assistance to improve their composting practices.

Composting represents a viable alternative for the sustainable management of solid waste from deep-litter systems. The comparison with earlier studies shows progress in awareness, though structural barriers persist that require enhanced technical support and training. The significant decline in APPORTAN's membership highlights the urgent need to design accessible and sustainable solutions that align scientific knowledge with producers' real-world conditions.

Keywords: swine production waste; comprehensive waste management; compost; limitations; support required.

INTEGRATED WASTE MANAGEMENT AND PRODUCTIVE SUSTAINABILITY IN A RURAL COMMUNITY IN NORTHERN ARGENTINE PATAGONIA

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Ramón Castro is a rural locality located in the center of the province of Neuquén, with an approximate population of 300 inhabitants. Its economy is based on extensive transhumant livestock farming, with chivito mamón (young goat) being the main commercial product, characterized by strong seasonality in sales. However, in recent years, the climate crisis has severely affected water availability, compromising tree cultivation, vegetable production, pastures, and animal husbandry.

In response to this scenario, small-scale broiler chicken farming (in batches of 150 to 200 animals per family) has been promoted, aiming to diversify production, ensure self-sufficiency, and generate income through sales in neighboring towns, thus providing a more stable economic income throughout the year.

In this context, the generation of organic waste from livestock activities (manure, fibers, poultry litter, slaughter residues, and mortalities) represents an opportunity for valorization through composting processes. This practice not only helps improve soil fertility and reduce the environmental impact of such waste, but also allows for the expansion of the local product basket, incorporating a circular economy approach in the rural setting.

Within this framework, the local government is moving forward with the implementation of sustainable strategies for climate change adaptation and mitigation. The aim is to prevent and control environmental degradation that negatively affects natural resources and agricultural production through integrated waste management, environmental education, and the promotion of resilient production practices that enhance soil water retention and increase biodiversity.

To achieve the proposed objectives, coordinated territorial planning was carried out in collaboration with provincial and national agencies. Among the activities developed were radio broadcasts, school talks, workshops, and pilot tests in producers' fields. One example is the implementation of composting units for the separate treatment of poultry slaughter residues and litter, later co-composted with other materials. Additionally, efforts were made to identify alternative markets for chicken feet and other offal, with the aim of reducing food waste.

Finally, local institutions (the local development commission, school, health post, and police station) have begun sorting solid urban waste at the source, promoting the recovery of recyclable materials and encouraging environmental education practices.

Keywords: circular economy; composting; resilient production system.

MAKE IT SIMPLE: INSTITUTIONAL CHALLENGES FOR UPTAKE OF MANURE MANAGEMENT IN DAIRY FARMS

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Manure management is a key challenge in intensive livestock systems driven by growing environmental concerns. Poor practices contribute to greenhouse gas emissions, water and soil pollution, and biodiversity loss. In contrast, sustainable technologies can turn manure into biofertilizer and bioenergy, contributing to a circular bioeconomy and reducing environmental impacts.

In Argentina, manure management regulation falls under provincial jurisdiction, leading to heterogeneous policy frameworks across regions. The province of Buenos Aires approved a specific regulation for dairy farms in 2018 after significant inter-institutional efforts, yet its implementation has been repeatedly postponed and adoption remains limited.

Mandatory implementation of advanced systems could disproportionately affect smallholders, creating unintended exclusionary effects. Our analysis frames manure management as an externality problem, emphasizing the need to create economic incentives to internalize environmental and social costs. The absence of real incentives (e.g., price differentials, financial support, or market recognition) currently hampers wider adoption.

This study examines the institutional and practical barriers to the adoption of manure management practices in dairy farms. We draw on primary data from 334 dairy farms in Buenos Aires province, surveyed between October 2024 and March 2025. This study builds on the results of (1) a discrete choice experiment that analyses producers' stated preferences regarding manure management practices and (2) an analysis of two key psychosocial factors driving dairy farmers' adoption of more sustainable manure management practices: their risk preferences and farm succession. We complement the work with quantitative data on farmers' knowledge of the regulation and perception of enforcement as well as information on farmers' access to advisors. Complementary insights are provided by qualitative interviews with key stakeholders in the dairy value chain.

Findings show that farmers generally favor simple systems, driven by a shortage of trained personnel and avoiding to engage in complex processes. Complex technologies often require dedicated labor, making them harder to adopt for small- and medium-scale farms. Adoption costs—including investment in appropriate technology, technical assessments, and general management—pose a significant challenge. Furthermore, behavioral factors such as risk aversion were found to negatively affect adoption decisions. Family dynamics and particularly inter-generational cohesion also play a crucial role in shaping producers' investments in manure management systems. Intergeneration transition phase is found to drive adoption of sustainable manure management.

Based on our findings we outline strategic lines of research and action to favor sustainable manure management adoption: (1) public-private cooperation schemes for local-specific solutions; (2) development of specialized training programs for advisors and technicians; (3) revision of the existing Manure Management Guide for dairy farms; (4) support for intergenerational transitions in family-run farms; (5) research of economic assessments of costs and returns associated with different manure management practices across scales and agroclimatic contexts; and (6) exploration of market-based mechanisms and development of risk-mitigating programs.

Keywords: policy incentives; risk preference; farm succession; farmer preferences; technology adoption.

SUSTAINABLE ORGANIC WASTE MANAGEMENT IN FRUIT AND VEGETABLES WHOLESALE MARKETS: THE EXPERIENCE OF THE MERCADO DE SAN MIGUEL (CÓRDOBA, ARGENTINA)

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The generation of municipal solid waste (MSW) is increasing globally, exceeding projections and contributing to climate change, biodiversity loss, and soil, air, and water pollution, with direct consequences for societies, the environment, the economy, and human health.

In Argentina, municipal waste management faces significant financial, technical, and institutional constraints. Currently, about 65% of MSW is disposed of in landfills, while the remaining 35% is dumped in more than 455 open dumps scattered throughout the country, occupying an area of over 6,174 hectares, with few examples of organic solid waste management.

This study analyzes the case of the San Miguel Fruit and Vegetable Wholesale Market, located in Malagueño (Córdoba), as a concrete example of comprehensive organic waste management in a central market.

Founded in 1989 and managed by a cooperative, the market plays a strategic role in the Agri-Food Region of Córdoba, ensuring the supply of fresh food to Córdoba Capital and its metropolitan area, while generating direct and indirect employment and strengthening the local productive fabric. Since 2012, the market has processed 100% of the organic waste and part of the inorganic waste it generates. The strategy combines source separation, food donations, and anaerobic digestion of organic waste. The treatment plant, with a capacity of 1,000 m^3, was accompanied by training for internal staff, improvements in logistics, and agreements with local institutions for food donations and the recycling of inorganic waste.

The study employed a mixed-methods framework that included both qualitative and quantitative analysis. Economic data provided by the market administration was collected, and in-depth interviews were conducted with key stakeholders involved in managing the system. This information enabled the construction of an economic comparison between a scenario with the management model and a scenario without intervention. Over 13 years, the market has managed to process and divert approximately 16,666 tons of organic waste from final disposal, representing an estimated reduction of 18,517 tons of CO_2 equivalent. In addition, the transport of 595 trucks equipped with 28 m^3 roll-off containers has been avoided, which, at current prices, represents an estimated savings of 576 million pesos over the 13-year project period. Upon analyzing construction and maintenance costs, it is estimated that the initial investment paid for itself in just three years, demonstrating that, in addition to environmental and social benefits, the model has generated significant economic savings for both the market and the municipality, establishing itself as a replicable model for other wholesale markets across the country. The San Miguel Market's experience highlights the potential of markets as key hubs for the circular economy and urban sustainability.

Keywords: anaerobic digestion, circular economy, sustainability, horticulture, marketing.

AN ORGANIC RESIDUES MANAGEMENT EXPERIENCE AT THE NATIONAL UNIVERSITY OF THE SOUTH, ARGENTINA

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In Argentina, approximately half of the urban solid waste generated is organic residues (OR). This OR can constitute a high-value agricultural resource for soil conservation and improvement if properly recovered. Within the framework of the Participatory Budget Program (Res. CSU-697/21), the Department of Agronomy was selected with its proposal "UNS COMMUNITY GARDENING," thanks to which a compost bin was built on campus. Since then, with the participation of faculty and students from the "Organic Residues Management and Recovery" course in the Agricultural Engineering program, more than 5,000 kg of OR have been composted, and approximately 800 kg of quality compost have been produced, which has already been used in the community gardening. In addition, highly relevant information was generated to make it possible for the departmental council to approve the internal OR management plan for the Department of Agronomy in 2024 (Res. CDA-212/2024), where all RO generated by the department's daily activities are composted within the campus itself. The OR management system considered the following areas: generation, storage, transportation, staff, as well as communication and dissemination options to achieve full program adoption. The plan integrates a collaborative effort between department management, teaching and non-teaching staff, students, and the cleaning service cooperative staff. Each day, the activity begins with the cooperative collecting the properly identified bins strategically located in different areas of the property. Upon removal, one is left empty and clean. This way, there is always a bin to deposit the OR. Upon completion of the rounds, the bins containing residues are stored in a temporary storage facility established for this purpose. From there, non-teaching staff collect the residues, take them to the composter, where they are weighed, added, cleaned, and returned to the temporary storage facility so that the cooperative staff can have them available the following day. The teaching staff, in turn, monitors the composting process and the proper functioning of the plan, and also coordinates communication with department management. The plan began in September 2024, and during its first period (September-December), approximately 1,900 kg of OR were recovered. Composting developed optimally, meeting the thermophilic stage and the agronomic quality requirements of Joint Resolution 1/19 (MA-SENASA). After the maturation stage, the compost was sieved for use in the community gardening. Synergies, collaborative work, and the commitment of the various stakeholders (teaching staff, non-teaching staff, administrators, cleaning staff, and students) were key to the adoption of OR management practices. This experience allows us to conclude that implementing an OR management system at the university level is operationally feasible, with its design and planning being very important to ensure its sustainability. Through these practices, it is possible to contribute to achieving a society that is conscious of and responsible for its residues in a sustainable manner, and the Public University must play a fundamental role in comprehensively promoting these types of practices.

Keywords: organic residues; composting; community gardening.

MALT BAGASSE: AN UNDERUTILIZED RESOURCE? PRELIMINARY FINDINGS FROM ONGOING RESEARCH

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In Argentina, craft beer production accounted for approximately 3.0% of total beer production in 2023, equivalent to 600,000 hl. The main by-product of industrial processing is bagasse, which is rich in fiber, protein, and vitamins. According to literature, 0.6 kilograms of bagasse are obtained per liter of beer produced. For 2023, the national production of malt bagasse from the craft beer sector reached approximately 360,000 tons. This by-product can be allocated to final disposal as waste, animal feed, composting, microbial cultivation, biogas production, and, more recently, due to its incorporation into the Argentine Food Code, human consumption.

For several years, the Atlantic coast region of Buenos Aires Province—particularly the city of Mar del Plata—has established itself as a key hub for craft beer production, concentrating approximately 35% of the province's breweries.

This work aims to contribute to the study of malt bagasse valorization within the craft beer sector in Mar del Plata. To achieve this, a survey of craft beer producers was conducted via semi-structured interviews. The dimensions addressed allowed for the quantification of bagasse volume, its local use, and the identification of limitations and challenges faced in its management and potential utilization.

Nine breweries were surveyed. The total production of liters of beer in 2024 was 6,885,400 l, with a range spanning from 18,000 to 4,000,000 l annually. On average, these breweries generated approximately 0.32 kg of bagasse per liter of beer produced. Based on an average annual production of 858,125 l per brewery, it is estimated that approximately 274,600 kg of malt bagasse are generated each year in Mar del Plata.

Bagasse production varies throughout the year, concentrating in the summer season, which coincides with higher consumption. In 89% of cases, bagasse is donated, while the remaining portion is either exchanged or otherwise valorized. In general, producers employ multiple disposal or reuse strategies rather than relying on a single modality. The majority of donated or exchanged bagasse is used as animal feed: 56% for pigs, 33% for chickens, horses, and cattle, and 11% for dairy farms. A minimal percentage is utilized for human consumption—primarily in the preparation of baked goods—or for composting purposes, and only in isolated cases.

In all surveyed cases, bagasse is utilized as an input for another productive process. Due to its rapid decomposition, timely collection from breweries is essential and must be carefully coordinated with production schedules—an aspect that is consistently managed among the respondents. Although its nutritional composition makes it suitable for human consumption, current regulations stipulate that it must be "dried in the brewery," a requirement that significantly limits its use due to the high associated costs.

Preliminary conclusions indicate that the malt bagasse obtained from craft breweries in the surveyed area is already integrated into the circular economy flow.

Keywords: craft beer; valorization; regulatory framework; mar del plata.

COMPOSTING EXPERIENCES: CHALLENGES IN THEIR CONSTRUCTION PROCESSES AND DEVELOPMENT DYNAMICS

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Agrifood waste represents a significant portion of the biomass generated throughout the food value chain, from agricultural production to final consumption. Approximately one-third of global food production is wasted, generating serious economic, environmental, and social impacts. The inadequate and inefficient management of this waste is a global problem, especially at the local level (southeastern Buenos Aires), where initiatives for the reuse of organic solid waste are limited.

The circular bioeconomy framework advocates for the transformation of waste into valuable resources within the scope of sustainable production and management. One example of circular bioeconomy practices is composting, an aerobic biological process through which waste biomass is converted into compost by microbial activity. Compost is a stable, safe, and value-added product suitable for application in both extensive and intensive agricultural systems. Nevertheless, composting remains a marginal practice in many local contexts.

In south-central Buenos Aires, an exploratory study was conducted using a qualitative and descriptive methodology to visualize the scope and limitations of processes of construction and development of composting experiences. During 2024, semi-structured interviews were conducted with the responsible of five initiatives identified in the circular bioeconomy case database constructed by CeRBAS INTA Regional Project (PER 030).

The five cases studied are predominantly recent, dating from 2018 onward. Three are privately managed, one is municipal, and one constitutes a community-led initiative. These projects were established with the objective of implementing strategies to mitigate inadequate organic waste management and they deploy multi-sectoral collaborations involving public and private stakeholders.

They utilize organic waste sourced from households, from the gastronomic and agro-industrial sector, from the large retail distribution of food, as well as those coming from agricultural production, complemented with dry residues.

The composting process varies according to the scale of the enterprise, its capitalization level, and degree of professionalization. Variations include methods of input supply, use of cement tanks, construction of windrows or compost bins, characteristics of infrastructure and logistics, as well as the extent of quality parameter monitoring.

The volume of waste processed ranges from 152 kilograms to over 8,000 kilograms per month. The enterprises produce thermophilic compost, and some also generate vermicompost, which is either marketed or distributed to users. Additionally, in certain cases, the composted waste is integrated into their own production activities.

Regarding the technical and productive dimension, limitations were identified in processes, product quality, logistics, and cost management, varying according to the type of enterprise. The interviewees also agreed in pointing out difficulties related to the current regulations concerning land use permits and product registration for commercial sale. Additionally, they emphasized the need to strengthen environmental education.

Composting constitutes a strategic practice for organic waste management, soil enhancement, and the transition toward more sustainable production systems. However, its large-scale implementation necessitates localized, comprehensive, and multi-level public policies.

Keywords: buenos aires province; residual biomass; composting; stakeholders; public policy.

DEVELOPMENT AND VALIDATION OF A COMMUNITY-SCALE WASTE VALORIZATION SYSTEM

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In Montevideo, approximately 1,200 tons of household waste are generated daily, with an estimated 40% consisting of food scraps. Currently, this organic fraction is transported to sanitary landfills, a practice that is environmentally unsustainable due to the generation of greenhouse gases and leachate, which pollute soils and groundwater. Community composting has emerged as a viable decentralized alternative for organic waste management, offering environmental and social benefits while fostering more sustainable cities.

This study presents the design, implementation, and evaluation of a Community Composting Unit (CCU) located in Parque Rivera, Montevideo, which has been in operation since 2022. The CCU uses a modular compartment system to facilitate turning during composting. Organic waste, previously source-separated by nearby housing cooperatives, is collected three times weekly by motorcycle-based haulers contracted by the municipality. Upon arrival, the waste is weighed, visually inspected to remove contaminants, and loaded into the corresponding module. Throughout the process, key variables –including core temperature, compartment material height, and moisture– are monitored and adjusted; water is added during turning when necessary. Finished compost is sieved through a rotary screen to recover reusable wood chips. Two loading regimes (9- and 19-day filling cycles) were tested to assess their impact on process performance.

Since the CCU began operating, the monthly inflow of organic waste progressively increased, stabilizing at approximately 1,500 kg. Source separation quality remained outstanding, with non-organic impurities consistently below 0.51%. Participating households maintained separation practices and periodically received portions of the compost, used in community gardens and urban agriculture, reinforcing engagement. Active involvement of motorcycle haulers not only ensured reliable collection but also enhanced their technical skills, empowering them to make operational decisions and strengthening their connection to the community.

Operationally, the 9-day loading regime achieved and maintained temperatures above 50 °C more consistently and for longer periods than the 19-day cycle, improving sanitization and pathogen reduction. Thermal monitoring showed that, during early stages, temperature was largely independent of ambient conditions due to high microbial activity and heat generation. In later stages, when biological activity slowed, environmental heat losses became significant, with winter batches exhibiting lower average final temperatures than those processed in summer.

Material volume decreased by about 40% by the time it reached central module –where two upstream batches converge– and by roughly 60% by the end of the cycle, reflecting organic matter loss and compaction. To optimize bulk structure and avoid excess chip accumulation, an operational ratio of two-thirds fresh to one-third recycled wood chips (by volume) was defined.

The finished compost complies with Uruguay's DGSA Resolution No. 141/2018 for organic soil amendments, with a C/N ratio of 10 and a germination index exceeding 90%. The CCU yields 0.82 L of fine compost per kilogram of biowaste, with an effective processing capacity of at least 1,800 kg per month.. These results confirm a stable, efficient, and replicable model for decentralized organic waste valorization, whose broader environmental benefits could be quantified through life cycle assessment (LCA).

Keywords: biowaste; community-scale composting; source separation; ecowork.

THE NODO MODEL: A PRODUCER CENTERED FRAMEWORK FOR THE VALORIZATION OF AGRO INDUSTRIAL SURPLUSES AND FOOD SECURITY IN ARGENTINA

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Argentina faces a critical paradox: although it is a leading global food producer, it also experiences annual food losses and waste exceeding 16 million tonnes, of which horticultural products account for a significant share. This inefficiency coexists with high rates of food insecurity, with 38.1% of the population living below the poverty line by the end of 2024. At Nodo, we currently work with over 35 affiliated agricultural producers, corporate and community volunteer groups, and the National Food Banking Network (Red BdA) to rescue surplus agricultural produce, primarily potatoes, carrots, and leafy greens, that are discarded for not meeting commercial aesthetic or size standards. The rescued food is then distributed nationwide through the Red BdA.

The objective of this study is to provide a systemic analysis of the NODO model, a nonprofit organization headquartered in Mar del Plata that tackles food loss at the primary production and post-harvest stages from its inception, functioning as a multisectoral 'living laboratory'.

This study employs a triple impact assessment methodology based on NODO's 2024 operational and consolidated financial data. Social impact was measured in kilograms of rescued food and nutritionally consistent rations served, calculated using the Global Food Banking Network (GFN) standard. Environmental returns were calculated based on avoided greenhouse gas emissions (CO_2e), using factors from the U.S. Environmental Protection Agency's (EPA) Waste Reduction Model (WARM). Economic performance was evaluated by calculating the operating cost per kilogram rescued and per ton of CO_2 eq avoided from being released into the atmosphere.

The 2024 results demonstrate the significant impact and efficiency of the model, which has demonstrated significant growth, expanding its recovery operations from 505 tons in 2022 to 2,664 tons in 2024. The total of 2,664,000 kg of fresh produce in 2024 was converted into approximately 7.8 million nutritious rations. At the same time, this recovery action avoided the emission of approximately 1,465 tons of CO_2 eq. The economic analysis revealed exceptional operational efficiency, with a verified cost of only USD 0.040 per kilogram of food rescued and USD 72.39 per ton of CO_2 eq not released into the atmosphere.

The NODO model exemplifies a high-value valorization pathway for agricultural surpluses. It serves as a validated and replicable framework for circular economy principles and a practical implementation of national public policy (Argentina's Law 27.454). We conclude that this producer-centered, relationship-based (low-tech, high-touch) approach is a powerful and efficient strategy for simultaneously combating food loss and food insecurity.

Keywords: food loss; waste valorizacion; circular economy; producer-centric model; living lab.

ADVANCES IN THE SYSTEMATIZATION OF CIRCULAR BIOECONOMY EXPERIENCES IN THE SOUTH-CENTRAL REGION OF BUENOS AIRES PROVINCE

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There is growing concern about the environmental impacts of agricultural and agro-industrial activities. In this context, new economic approaches promote waste and by-products valorization in order to reduce their impact and make more efficient use of resources. Among these, Circular Bioeconomy is defined as those practices that use residual biomass as a resource and that generate bioproducts -such as food, bioenergy, biomaterials, and bio-inputs- through biological, biochemical, thermal, physical or mechanical processes-, following the principles of circularity (i.e., reduce, reuse, recycle, regenerate, rethink). However, available information on the development status of the circular bioeconomy in Buenos Aires province remains fragmented and incomplete. To identify enabling factors as well as barriers and limitations to the circular bioeconomy within the agri-food system, INTA's Regional Project 030 proposes to survey and systematize circular bioeconomy experiences in the south-central region of Buenos Aires Province. Following a qualitative, exploratory and descriptive approach, a database was created to compile cases that meet the principles of Circular Bioeconomy as previously described, based on information collected through project workshops and key informants. Subsequently, semi-structured interviews were conducted with selected cases, using snowball and convenience sampling techniques, between August 2024 and July 2025. The questionnaires explored the profile of the ventures, main activities, types of inputs used, characteristics and destination of the waste generated, valorization strategy or process, connections with other local stakeholders, and a self-assessment of the experience. Out of 53 identified cases, 29 experiences were surveyed across 14 districts in the south-central region of Buenos Aires Province. Most of the experiences are focused on the production of animal feed (45%) and bio-inputs (41%), with fewer oriented toward bioenergy (10%) and biomaterials (4%). In most cases, a single product is obtained from the valorization process (83%). Based on their role in the value chain, the following types of initiatives were identified: (i) agricultural producers who incorporate technology to valorize their own waste; (ii) companies established with the aim of valorizing third-party organic waste; (iii) businesses dedicated to linking the supply and demand of agro-industrial losses, discards, and co-products; and (iv) food and beverage industries that generate large volumes of waste and outsource its valorization. A variety of waste valorization strategies were identified, with varying levels of innovation and territorial coordination. Key challenges include regulatory frameworks, the conditioning of residual biomass for further use, lack of funding, and the inadequacy of available know-how. These issues highlight the need for further research on valorization possibilities, strengthening technical capacities, and building inter-institutional networks. The systematization of these experiences contributes to informing public policy, fostering knowledge exchange, and supporting the development of more sustainable production models.

Keywords: territorial survey; waste biomass; valorization; circularity principles; bioproducts.

POTENTIAL USE OF RESIDUAL BIOMASS IN THE PERGAMINO DISTRICT: SURVEY, AVAILABILITY ANALYSIS AND OPPORTUNITIES FOR A CIRCULAR BIOECONOMY

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The valorization of biomass waste is a key strategy in the transition toward more sustainable development models, capable of reducing environmental impacts, diversifying the energy matrix, and creating new economic opportunities at the territorial level. In this context, a team from INTA and the Municipality of Pergamino conducted a comprehensive survey aimed at estimating the actual availability of residual biomass in the District, identifying its main sources, current uses, and opportunities for valorization.

A total of 161 interviews were conducted with stakeholders from the agricultural, agro-industrial, food, and urban waste management sectors, combining primary and secondary information. The study identified more than 90,000 tons of residual biomass per year, including: pig slurry (38,786 t/year), poultry manure (34,421 t/year), dairy manure (5,888 t/year), whey (29,394 t/year), animal processing waste (8,683 t/year), seed waste and plant material residues (7,972 t/year), the organic fraction of municipal solid waste (OFMSW) (13,928 t/year estimated), pruning waste (4,088 t/year), sewage sludge (47,450 m³/year), and wood waste (1,132 t/year).

However, the recovery potential of this volume varies. For each case, actual availability was assessed considering factors such as seasonality, dispersion, existing infrastructure, current uses, and logistical or economic barriers. Some waste streams have high effective availability, such as pig slurry from medium and large-scale farms, fresh poultry manure which is mostly co-digested at a local biogas plant (Seeds Energy), or whey which could be used locally instead of being transported to other regions. Other residues, such as manure from pasture-based dairies or meat processing waste from butcheries, are more dispersed and require different strategies for their valorization. The organic fraction of urban waste (OFMSW) and sewage sludge, while supported by some infrastructure, currently show low levels of utilization and high potential for improvement.

The survey also identified noteworthy cases of ongoing valorization: a biogas plant operating with local resources, community composting facilities in rural towns, and industries replacing liquefied petroleum gas (LPG) with biomass. These experiences demonstrate the feasibility of developing context-specific and locally adapted solutions.

The Pergamino District has favorable conditions for consolidating a circular bioeconomy agenda: a significant volume and diversity of biomass, supportive regulations, technical and institutional capacities, and stakeholders with prior experience. To transform this potential into concrete projects, it will be essential to enhance public-private collaboration, strengthen information systems, promote appropriate technologies, design economic incentives, and plan territorial strategies.

This survey serves as a strategic tool for decision-making, local policy formulation, and the promotion of investments aimed at a sustainable transition.

Keywords: biomass; waste; bioeconomy; waste management; territorial development.

AVAILABILITY OF INDUSTRIAL ORGANIC WASTE IN ARGENTINA: A METHODOLOGY FOR MAPPING AND USE IN BIOGAS PRODUCTION

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A constant and reliable supply of feedstock is one of the key challenges for both operational and future biodigesters projects. Argentina has a wide variety of agro-industrial and industrial sectors that generate organic waste streams suitable for biogas production. In this context, identifying substrate generation hotspots across the country is crucial for stakeholders to supply their existing anaerobic reactors or to deploy new facilities effectively. This study aimed to develop a methodology to estimate and map the availability of organic industrial wastes in Argentina. Initially, we identified relevant industrial activities and selected their facilities using georeferenced publicly available data from government records. We then analyzed the production processes in detail for each selected activity to identify relevant waste streams with high biochemical methane potential (BMP). For each activity, we defined key organic residue streams, and estimated their generation based on indicators like employee count, raw material use, or production volume. These values were assigned to each facility and then aggregated at the departmental level — defined as the minimum spatial unit of analysis. Finally, we mapped the estimated annual waste generation using Python-based geoprocessing tools and open-source GIS software, such as QGIS. Our first key result was the annual departmental aggregated estimation of organic waste availability in industrial facilities across Argentina from three sectors: breweries, dairies, and slaughterhouses. This made it possible to identify the provinces and regions with the highest levels of potential biodigesters feedstock availability. For instance, the estimated departmental whey production potential from dairies ranged between 1.500 and 200.000 t/year, with Córdoba and Santa Fe provinces leading the ranking. Brewery waste availability varied from 500 and 38.000 t/year across departments, with Buenos Aires and Santa Fe recording the highest levels of generation. In the case of slaughterhouse residues, departmental estimates ranged between 300 and 43.000 t/year, with notable concentrations in Buenos Aires y Santa Fe. Given the high spatial dispersion of facilities for certain activities and the significant variation in department sizes, future research will focus on implementing coarser-scale spatial analysis units to improve resolution and accuracy. In addition, we plan to develop national BMP maps for the industrial sector by combining the estimated waste availability with methane yield data for each feedstock.

Keywords: organic industrial wastes; geographic information systems (gis); waste mapping; biochemical methane potential (bmp).

SPATIAL DISTRIBUTION OF LICENSED SWINE AND POULTRY FARMS AND BIOGAS PLANTS IN THE CASCAVEL REGION – PARANÁ STATE

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Biogas plants have become an alternative for organic waste management in animal farming. It allows for the reuse of production waste to generate energy and produce biofertilizers. It is also a good waste management practice and able to promote sustainable development. The administrative region of Cascavel in Paraná State, comprising 100 municipalities, stands out significantly in poultry and swine production, according to the IBGE Municipal Livestock Survey (2023). This strong presence of animal farming creates an opportunity to analyze the occurrence of licensed swine and poultry farms and the existence of biogas structures associated with their production chains, aiming to assess the potential for biodigester implementation. Therefore, this work, which is part of the Paraná State Agriculture Federation (FAEP) project, aims to present an exploratory descriptive analysis of the quantity of farms, poultry and swine sheds, biogas structures, and the total herd of the analyzed categories. For this exploratory analysis, data from the National Environmental Licensing Portal - PNLA were used, with the survey and georeferencing of environmental authorizations, environmental licenses, installation and operation licenses, and simplified state licenses from the year 2000 onwards for agricultural activities. Data from sheds, produced by Quartaroli (2024), were also cross-referenced with biogas structure data, mapped from PlanetScope image interpretation, and general animal production data from the Municipal Livestock Survey (PPM), conducted by IBGE (2023), to synthesize poultry and swine production and the presence of biogas structures in the municipalities of the study area. The potential for biogas implementation was also analyzed through the correlation between the total PPM herd and the number of biodigesters and waste lagoons mapped by municipality, resulting in a map of the potential for biogas structure implementation. Regarding the distribution of farms, over 3,800 agricultural-related license registrations were identified in Paraná State, with approximately 2,500 related to the establishment of poultry and swine farms. Considering the occurrence of sheds, biodigesters, and waste lagoons, the study area presented a total of 33,390 animal housing sheds, of which approximately 3,500 has biogas structures, including biodigesters and waste lagoons. By analyzing data on farms, sheds, and biogas structures, thematic maps were created to illustrate the distribution of farms and biodigesters in relation to the municipalities in the Cascavel region. This study also produced a map of the potential for biogas structure implementation, derived from cross-referencing the number of biodigesters per municipality and the total PPM herd, which allowed for the identification of municipalities with the greatest potential for implementing policies that favor the use of biodigesters.

Keywords: poultry farming; biogas; georeferencing; western paraná; swine farming.

PROPOSED METHOD FOR MAPPING BIOGAS PRODUCTION STRUCTURES ON LICENSED SWINE AND POULTRY FARMS IN PARANÁ STATE

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The use of biodigesters for biogas production offers a sustainable option for the swine and poultry production chains. The confinement of these animals generates considerable waste, which is potentially harmful to the environment. Soil contamination and eutrophication of springs, rivers, and lakes result in ecological imbalance and a decrease in water quality, essential resources for agricultural activities. Biodigester technology is an interesting alternative for organic waste management. It enables the generation of thermal and electrical energy (cogeneration) and also promotes the production of biofertilizer, valuable inputs for the agricultural production chain itself, thereby being considered an important tool for promoting sustainable development, addressing climate change, and reducing greenhouse gas (GHG) emissions. Today, there are many structures for biogas production spread out though the country. So, it's relevant to discuss methods for identifying and mapping biodigesters in rural areas to allow for scenario analysis and the creation of public policies for disseminating these technologies. With the use of geoprocessing and remote sensing being viable mapping tools thanks to the ease of visual interpretation in high-resolution images to recognize structures like biodigesters and biodigestion bags. This study presents a method for mapping biogas structures through the visual interpretation of high spatial resolution (3 m) PlanetScope images, covering the visible and infrared spectrums. The QGIS 3.40 software is used with the Planet Explorer plugin to select images with low cloud cover from the first quarter of 2025. Color, texture, and context were defined as visual interpretation criteria for identifying the structures within a 1.5 km² rectangular grid, with only grids containing swine and poultry sheds, as identified by Quartaroli (2024). It is evaluated a total of 13,103 assessed grids with sheds in Paraná state. The visual interpretation criteria are applied since the structures are composed of geomembrane tarpaulins and exhibit low reflectance in the visible range, appearing as dark, smooth-textured surfaces with rectangular and circular shapes. Generally they are located near animal sheds and connected by pipelines. Besides their identification, it was possible to conduct a spatial analysis between the identified biodigesters and animal sheds at the municipal level, which can support public policies that promotes biodigester adoption.

Keywords: poultry farming; biogas; swine farms; mapping; geoprocessing.

TRAINING AS A KEY TOOL FOR THE STANDARDIZATION OF ANAEROBIC DIGESTION EXPERIMENTAL TRIALS

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Anaerobic digestion (AD) technology for waste valorization is increasingly used in our country. This growth must be accompanied by the development of laboratories equipped and specialized in anaerobic tests. In turn, AD tests depend on multiple factors that must be defined within the experimental design. This is why there is a need to unify criteria to standardize the tests so that the results can be compared under the same performance conditions.

The effluent treatability and organic waste valorization laboratory of the Chemistry and Environment Center of the National Institute of Industrial Technology (INTI), which has been working in AD for more than 15 years, carried out a survey of different methodologies and participated with excellent results in two international biogas interlaboratories . With the experience gained, as a first step, appropriate criteria for the main biodigestion tests were defined and unified. Based on this, training was provided to three laboratories of the institution located in different strategic regions of the country.

First of all, the content of the training was elaborated in such a way that theoretical and practical aspects and data treatment were developed. The tests developed were Specific Methanogenic Activity (SMA), Biochemical Methanogenic Potential (BMP), and Semi-continuous Anaerobic Digestion (SCAD). The topics included: definition and concepts, analysis of experimental design factors, such as inoculum types, temperature, mixing level, inoculum/substrate ratio, techniques, materials and methods of the test, data treatment and interpretation of results. For SCAD in particular, we added a description and analysis of control parameters (VLR, FOSTAC, alkalinity, and pH) and operational problems (acidification, overloading, and nutrients).

A 24-hour AD training program was prepared, divided into eight hours of theory, eight hours of SMA and BMP tests, and eight hours of data processing and interpretation. The course was implemented in three INTI Biogas Network laboratories in the Central, Patagonia, and Pampean regions, training a total of ten professionals and technicians.

To continue promoting and strengthening AD technology in Argentina, it is important to continue training regional INTI laboratories as well as experimental stations of the National Institute of Agricultural Technology (INTA). Next, a survey will be carried out of private AD laboratories to facilitate knowledge transfer and unify criteria for test performance and result presentation. Once the target laboratories have been reached, interlaboratory tests will be carried out using selected substrates. These tests will build on the experience gained from previous biogas interlaboratory studies and the experience and capacity of the SAC (Argentine Calibration and Measurement Service) group of INTI.

Keywords: anaerobic digestion (ad); standardization; training; laboratories; methodology.

CIRCULAR BIOCARBON: TURNING MUNICIPAL WASTE INTO HIGH-VALUE PRODUCTS – THE ZARAGOZA BIOREFINERY CASE STUDY

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While there have been huge advances in waste recycling over recent decades, municipal solid waste (MSW) continues to represent a largely untapped resource. A substantial amount of the OFMSW is typically lost to incineration or landfilling, even though it retains considerable value and presents a key opportunity to further the circular economy. The CIRCULAR BIOCARBON flagship project, funded by the Bio-based Industries Joint Undertaking (BBI-JU) under the H2020 research and innovation programme, addresses this issue by designing and deploying a first-of-its-kind biorefinery to valorise the organic content of urban waste streams through a cascade of integrated and innovative technologies.

Two demonstration sites, located in Zaragoza (Spain) and Sesto San Giovanni (Italy), will operate simultaneously for three years to validate the replicability of the system in diverse regional contexts. The Zaragoza facility, inaugurated in October 2024, already shows promising early-stage results, and the poster presented in the conference, will be presenting an overall overview of this relevant biorefinery.

At the Zaragoza site, the anaerobic digestion unit is currently operating at a capacity of 2,400 m^3 under mesophilic conditions, enabling the efficient co-digestion of the organic fraction of municipal solid waste (OFMSW) and sewage sludge. This process generates biogas with a methane content of approximately 55%. The biogas is subsequently upgraded on-site through a purification system that separates it into ultrapure methane and carbon dioxide streams, each achieving a purity level above 98%.

The solid digestate is subjected to composting, producing a mature, carbon- and phosphorus-rich organic matrix with high agronomic value. In parallel, the liquid fraction from the digester undergoes aerobic treatment, resulting in a clarified permeate. This nutrient-rich liquid is then used as a cultivation medium in the facility's algae reactor, which is also fed with the recovered CO_2 stream from the biogas upgrading process. The integrated system is currently supporting robust algal growth, with concentrations exceeding 0.7 g/L.

The project not only advances technological integration but also aims to unlock new business models and industrial symbioses within the circular bioeconomy. The Zaragoza biorefinery is already contributing to five new cross-sector interconnections and enabling the creation of three novel bio-based value chains. This includes the development of six new building blocks, three innovative bio-based materials, and five consumer-ready products. The strategic location of Zaragoza, in proximity to relevant industrial clusters and stakeholders, further enhances the project's potential to generate real market impact and scale up operations.

CIRCULAR BIOCARBON demonstrates how urban waste streams can be transformed into valuable products through a localized, circular, and industrially viable approach. By operating in multiple locations and engaging diverse ecosystems, the project provides a replicable model for other European cities aiming to transition toward a sustainable, bio-based economy. Furthermore, the initiative actively engages with policymakers, industry actors, rural regions and citizens, reinforcing its systemic influence across the bioeconomy value chain.

Keywords: biorefinery; flagship project; waste valorisation.

I3-4-BIOFERTILIZERS: INTERREGIONAL INNOVATION INVESTMENTS FOR BIOFERTILIZERS AND CIRCULAR BIOECONOMY SOLUTIONS FOR A SUSTAINABLE AGRICULTURE

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I3-4-BIOFERTILIZERS is a transformative EU-funded project (2024–2027) that promotes interregional cooperation to scale up, demonstrate, and commercialize innovative biofertilizer solutions across Europe. With a total budget of €9.1 million—€6.9 million co-funded by the EU—the project brings together 18 partners from 12 European regions, including SMEs, research centers, innovation agencies, clusters, and public authorities.

As Europe moves toward more sustainable and resilient agricultural practices, biofertilizers and biostimulants offer a promising alternative to chemical fertilizers. They enhance soil fertility, improve crop productivity, and support climate-resilient farming, all while reducing environmental harm. I3-4-BIOFERTILIZERS aims to position these solutions as key drivers of the circular bioeconomy and sustainable food systems.

The project identifies high-potential business cases through in-depth needs assessments and provides both technical and financial support to SMEs along the biofertilizer value chain. A dedicated fund of €1.8 million will support third-party projects, complemented by advisory services to accelerate market uptake.

A cornerstone of the initiative is its emphasis on interregional collaboration, fostering knowledge exchange, shared innovation strategies, and the creation of regional innovation valleys.

At this conference, we will showcase successful strategies and early-stage cases that demonstrate how I3-4-BIOFERTILIZERS is contributing to the future of sustainable agriculture.

Keywords: bioeconomy; biofertilisers.

TECHNO-ECONOMIC ASSESSMENT OF SMALL-SCALE ANAEROBIC DIGESTION IN SWINE FARMING

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Swine waste management has gained significance due to the increasing demand for renewable energy and growing environmental concerns. Anaerobic digestion stands out as a viable alternative, enabling energy recovery from organic residues while supporting climate goals. In Brazil, electricity generation from biogas is the most common application, and assessing its feasibility at smaller scales is important to support broader adoption on farms. This study presents a preliminary techno-economic feasibility assessment of two distributed generation projects based on real-world configurations: one involving monodigestion of swine manure from a finishing unit, and another combining manure and swine carcasses from a piglet production unit. Both systems are designed for 75 kW biogas generators, aiming to identify the lowest viable scale for cost-effective implementation. As a criterion for economic feasibility, the Internal Rate of Return (IRR) must exceed the Minimum Attractive Rate of Return (MARR), a benchmark typically based on Brazil's interbank deposit rate (CDI), which serves as a proxy for baseline investment attractiveness. The first case analyzed the monodigestion of manure from a finishing unit. The minimum economically viable scale, assuming 12 hours/day of operation, was 4,000 animals. Performance indicators were: Simple Payback (SP) of 8.46 years, IRR of 10.27%, Return on Investment (ROI) of 174%, and Levelized Cost of Energy (LCOE) of BRL 0.52/kWh. A ±40% sensitivity analysis on capital expenditure (CAPEX) showed significant variation: with 40% CAPEX reduction, SP was 5.62 years, IRR 19.3%, ROI 419%, and LCOE BRL 0.44/kWh; with a 40% increase, SP reached 12.34 years, IRR dropped to 4.91%, ROI to 68%, and LCOE rose to BRL 0.59/kWh. The second case evaluated the codigestion of manure and swine carcasses from a piglet production unit that operated 11 hours/day. The minimum viable scale was 1,460 animals; a significant reduction compared to the first case. This lower threshold results from the higher organic load and energy potential introduced by carcasses, as well as the specific characteristics of the manure and differing excretion volumes across production stages. Indicators were a SP of 7.87 years, an IRR of 11.44%, an ROI of 211%, and an LCOE of BRL 0.50/kWh. With a 40% CAPEX reduction, results improved to a SP of 5.18 years, an IRR of 20.86%, a ROI of 480%, and an LCOE of BRL 0.43/kWh. A 40% increase resulted in a SP of 12.92 years, an IRR of 6.11%, a ROI of 95%, and an LCOE of BRL 0.58/kWh. Compared to monodigestion, codigestion reduced the minimum viable scale by 63%, highlighting its superior efficiency in smaller-scale systems. The results demonstrate that both configurations can be economically feasible at defined thresholds, with codigestion offering greater flexibility in minimum scale. These findings underscore the need for tailored system design, cost optimization strategies, and a detailed understanding of residue profiles to unlock the potential of anaerobic digestion in smallholder swine farming.

Keywords: anaerobic digestion; codigestion; distributed generation; swine production; economic feasibility.

BETA TECH CENTER: CONTRIBUTING TO SUSTAINABLE RURAL DEVELOPMENT

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he BETA Technological Center at UVic-UCC is committed to advancing sustainable rural and environmental development through applied research, innovation, and knowledge transfer. With expertise in water and soil management, waste and resource recovery, and sustainable agri-food systems, BETA collaborates closely with both public and private stakeholders to tackle key environmental challenges.

A major research line within the Environmental Technologies and Circular Bioeconomy Team is the development of innovative technologies and value chains for biostimulant production. Located in a rural region of central Catalonia, BETA actively supports the circular bioeconomy by engaging with the agri-food sector, the region's most prominent industry. Through this collaboration, the center transforms agri-food by-products into high-value biostimulants, such as exopolysaccharides, plant growth-promoting rhizobacteria (PGPR), and protein hydrolysates.

These efforts have been the focus of several applied research projects, including Agri-Prosume, BioreFISH, SEMPRE-BIO, and ALGA-GESTIÓN, which aim to demonstrate sustainable and scalable solutions for agricultural innovation. Furthermore, BETA coordinates the European project I3-4-BIOFERTILIZERS, which supports investment in SMEs developing biofertilizers, biostimulants, and sustainable agriculture technologies. The project fosters regional economic development and interregional cooperation, aiming to open new markets and strengthen the role of bio-based solutions in sustainable farming.

Through its research and collaborative initiatives, BETA Tech Center is helping to drive the transition toward more resilient and sustainable agricultural systems at both regional and European levels. In this presentation, we will showcase successful case studies from these projects, highlighting their impact and replicability in the context of sustainable agriculture.

Keywords: rural development; resource recovery; sustainability; sustainable food production systems; bioeconomy.

ABON.AR: A WEB APPLICATION FOR THE AGRONOMIC USE OF LIVESTOCK SLURRY AND MANURES

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The intensification of livestock production systems in Argentina has led to an increased concentration of slurry and manure, which poses a significant environmental risk if not properly managed. At the same time, the low replenishment of nutrients in agricultural soils of the Pampas region has contributed to the degradation of their chemical and physical fertility. In this context, livestock slurry and manure emerge as a sustainable alternative to replace or complement chemical fertilizers, providing essential macro- and micronutrients for crop development through their agronomic use.

This paper presents the development of Abon.AR, a responsive web application designed to facilitate the management of livestock slurry and manure. Its main objective is to provide farmers, and agricultural professionals and technicians with an accessible, user-friendly, and responsive app (laptops, tablets, smartphones) that enables data logging, analysis, and decision-making based on historical field and crop data.

The application allows detailed logging of field data, including applied slurry or manure doses, soil analysis results, slurry composition, crop types, and obtained yields. The dose calculation is based on a nitrogen balance model, taking into account crop nitrogen requirements, slurry composition, chemical fertilizer contributions, and soil analyses results.

Abon.AR enables systematic monitoring of slurry management in the field by consolidating scattered and heterogeneous information into a centralized platform. The app automatically standardizes measurement units from laboratory data analyses, facilitating its interpretation and comparison. The visualization of yield trends and soil parameters over time allows for the assessment of field evolution across different growing seasons, providing valuable insights for agronomic decision-making. In addition, the tool includes a feature to assist in calibrating manure spreaders (liquid and solid), based on the recommended application dose, thus supporting effective fieldwork.

The application serves as a technological tool that enhances the efficient and sustainable management of livestock slurry and manure. By enabling data logging, technical dose calculations, and the analysis of productive and soil-related trends, the platform supports evidence-based decision-making rather than relying on generic data. Its accessible and user-friendly design encourages adoption by farmers and professionals, while its modular structure facilitates future adaptations to meet emerging regulatory or production demands. Ultimately, Abon.AR offers a practical solution for the agronomic utilization of slurry, with a positive impact on the productivity and sustainability of agricultural systems.

Keywords: app; manure; management; data logging.

CAPABILITIES AND ALTERNATIVES FOR INTEGRATED LIVESTOCK WASTE MANAGEMENT IN BUENOS AIRES METROPOLITAN AREA (AMBA)

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The generation of solid organic residues from farms, mainly poultry farms, but also porcine and cattle farms located near cities, leads to management problems and conflicts. Large volumes are often transported without treatment to intensive and extensive crops, in violation of regulations. However, these materials are rich in nutrients and can be used as a resource for agronomic recovery, if there are capacities and alternatives that allow for their integrated management.

This study proposes a methodology to identify the actors involved in the issue, in addition to producers, and the capacities that should be strengthened through investment, research, and public policy.

The use of livestock waste by producers was investigated through interviews. In addition, intermediary companies that clean barns and extract bedding or manure for transport and sale to horticultural producers were mapped and identified; also companies that add value to this residue and produce a stabilized product that complies with regulations.

Different regional actors were evaluated, such as municipalities, universities, INTA, and SENASA, which showed varying degrees of development in research and action strategies applied to the advancement of integral management of this waste.

Composting is considered an appropriate and low-cost technology for treating this waste. However, very few poultry or horticultural producers have made progress in implementing this technique because the large volumes involved require machinery for turning the compost and labor for periodic temperature and humidity checks.

In this sense, there is a lack of coordination between technologies, public policies, and the realities of the productive sector, with a focus on designing and validating productive technologies, but without addressing the problem through dialogue between stakeholders. In the context of sustainable and safe food production, it is important to make efforts en pursuit of integral management of RSOs, propose alternative processes for the co-construction of territorial capacities to convert this waste into high value-added products, promoting the improvement of the quality of life of producers, the creation of businesses and jobs, and care for the environment, from a multidimensional and circular economy approach.

Keywords: interviews; actors; territory; development; co-construction.

SHAPING THE FUTURE OF SOIL HEALTH: THE SPANISH LIVING LAB'S ROLE IN SUSTAINABLE AGRICULTURE

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Soil health, defined by optimal chemical, physical and biological conditions of soils, is crucial for food and biomass production. Nowadays, around 50% of arable lands in Europe are considered as unhealthy due to moderate and severe erosion, leading to annual agricultural losses of €1.25 billion. Additionally, 24% of food produced in the European Union (EU) is wasted, primarily during processing stages. To combat these issues, food processing residues can be converted into recycled fertilizers or soil improvers, enhancing soil health through circular bioeconomy practices and improving the sustainability of the food production system. A promising solution lies in the implementation of living labs (LL), which foster co-creation and innovation. These collaborative environments offer opportunities to develop and test solutions for soil health to address soil health challenges effectively.

In this context, DeliSoil project (GA: 101112855) aims to establish 5 LLs around Europe, including in Finland, Denmark, Germany, Italy and Spain, to develop advanced solutions for the valorization of food industry residues and create safe and sustainable soil enhancers and fertilizing products. Each LL will assess the feasibility of the technologies used to transform the residues, as well as quality, safety and agronomic potential of the end products, while considering sustainability end environmental impacts and potential technical, legal, social and economic barriers. The progress made in the Spanish LL will be highlighted as an example of how local advances are contributing to the overall project goals.

The Spanish LL (Catalonia, Spain) focuses on processing mix-food residues using five innovative technologies: anaerobic digestion, solid-state fermentation, composting, pyrolysis and non-thermal atmospheric plasma. Key aspects monitored include feedstock characterization, operational parameters, and product quality. Additionally, the safety of the products is being analyzed, particularly regarding heavy metals and biological hazards. The products derived from these technologies are being tested in pot and field trials to evaluate their effectiveness on plant growth and soil quality. Stability of the products will also be evaluated using soil respirometry. These trials will provide essential data on how each product contributes to soil improvement, supporting the LL's goal of developing safe, sustainable and effective soil enhancement solutions.

The LL has adopted a multi-stakeholder approach based on the quadruple helix model, integrating actors from industry, policy, society, and academia. This includes food processing industries, waste management companies, agricultural training schools, policymakers, universities, and research centers. A regional working group has also been created to align project objectives with local needs and co-develop tailored solutions for soil health. The aim is to create a collaborative platform for sharing insights from technology monitoring and product testing activities. To achieve this, dissemination activities such as training sessions, workshops, and webinars will support collaboration, enabling the group to refine strategies and co-create impactful solutions by leveraging their expertise. This approach will allow stakeholders to co-develop practical solutions and refine strategies to improve soil health, encouraging active participation and fostering a deeper understanding of the project's goals. Additionally, the LL will support the co-creation of sustainable practices for long-term agricultural resilience.

Keywords: soil health; living labs; food industry by-products; collaborative innovation; sustainable agriculture.

AGRICULTURAL AND AGRO-INDUSTRIAL WASTE AS ENERGY VECTORS: AN ANALYSIS OF BIOGAS AND BIOMETHANE IN VIEW OF BILL 2.159/2021-BRAZIL

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Brazilian agriculture and agribusiness, despite their economic importance, are responsible for a large volume of organic waste, which, if poorly managed, causes serious environmental impacts, such as greenhouse gas emissions and soil and water contamination. On the other hand, this waste has high energy potential, since when transformed into biogas and biomethane, it contributes to the circular economy of the productive chain, the energy transition, and the reduction of emissions, especially in intensive sectors.

Brazil offers advantages for the energy use of waste, both due to the scale of its agro-industrial matrix and its favorable climate conditions. According to the National Energy Research Company (EPE, 2023), the methane potential of biogas in Brazil, considering livestock and agricultural waste, was 76.3 GNm³/year in 2021 and is projected to reach 95.5 GNm³/year by 2031. When converted to electricity, this value would be equivalent to 44% and 55%, respectively, of total energy consumption in Brazil in 2024 (EPE, 2025). Alternatively, if this theoretical potential were converted to biomethane, it would represent 79 billion m³/year and 99 billion m³/year, respectively, a volume that could replace the equivalent of 82 and 103 billion liters of diesel per year, representing 1.2 and 1.5 times of all diesel B sold in the country in 2024 (ANP, 2025). However, the development of the biomethane chain faces obstacles, including environmental licensing, whose complexity and variation between states hinder the feasibility of projects. Bill 2.159/2021, which regulates environmental licensing, seeks to standardize and simplify procedures, proposing mechanisms such as Licensing by Adhesion and Commitment (LAC) for low-impact projects. This measure could benefit decentralized biogas and biomethane initiatives by reducing bureaucracy. This study aims to analyze the potential impacts of the approval of Bill 2.159/2021 on the energy use of agricultural and agro-industrial waste.

Although the bill proposes advances in predictability and speed, its effectiveness will depend on future regulation and alignment with other public policies and sectoral climate mitigation plans. It will also be essential to define objective technical criteria for classifying environmental risks.

On the other hand, the bill raises significant concerns. Exempting licensing requirements for certain agricultural activities, combined with the weakening of environmental impact assessments and the lack of definition of classification criteria, could lead to environmental setbacks, legal uncertainty, and reduced transparency. Highly polluting and non-renewable sectors could benefit unduly from this relaxation, exacerbating deforestation and threatening indigenous and traditional communities. Thus, while it may provide some specific stimulus for sectors such as biogas and biomethane, the benefits would be disproportionate when compared to the potential negative impacts on other areas. The risk of environmental setbacks, the weakening of regulatory mechanisms, and the potential for the worsening of unsustainable practices in intensive sectors would far outweigh the specific gains for the biomethane chain, compromising the coherence of public policies aimed at energy transition and sustainability.

Keywords: environmental regulation; biomethane; biogas; energy transition.

ORGANIC WASTE AND THE CIRCULAR TRANSITION IN ARGENTINA: PROGRESS, CHALLENGES AND THE 2030 ROADMAP

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This paper presents an analysis of the current state of organic waste valorization in Argentina, identifying the main structural challenges and highlighting progress made under the National Program for Organic Waste Valorization (PROVO), in coordination with the Climate and Clean Air Coalition (CCAC). The aim is to demonstrate how a coordinated national strategy, based on a multisectoral roadmap, can contribute to more climate-responsible, efficient waste management aligned with circular economy principles.

The information presented is based on technical surveys carried out between 2022 and 2024 as part of the CCAC AR-21-001 project. These included municipal site visits, interviews with key stakeholders, regulatory analysis, and the monitoring of pilot initiatives. Additionally, national estimates were processed regarding organic waste generation from multiple sources: source-separated municipal waste (FORSU), agricultural and livestock residues, sludge, food industry by-products, and losses in primary production.

Argentina generates approximately 270 million tons of organic waste annually. Less than 5% is currently valorized, and over 5,000 final disposal sites, many of them open dumps, remain active, significantly contributing to methane emissions, estimated at 23.3 $MtCO_2e$ in 2022. In response, a national roadmap was developed through the creation of PROVO (Resolution 27/2023), structured around six strategic pillars.

At the household level, actions such as composting and biodigestion are encouraged, tailored to local contexts and supported by technical assistance and community training campaigns to ensure the safe use of subproducts. However, it is recognized that less than 20% of waste is generated in cities, while more than 80% originates from productive activities. Therefore, priority is given to interventions in rural and industrial sectors.

In this regard, the roadmap proposes the development of territorial supply-demand models to guide the location of valorization plants, considering factors such as waste availability, logistical emissions, required investments, and market opportunities for subproducts. Economic instruments are also promoted, including incentives for recovery and recycling, and penalties for final disposal.

A third strategic line aims to match waste availability with the demand for subproducts (such as energy, compost, and digestate), through regional studies on residual biomass. A fourth strategy emphasizes public-private partnerships with clearly defined roles and joint action plans, shifting from punitive oversight to supportive and collaborative governance. Finally, the roadmap underscores the importance of strengthening municipal capacities and implementing public policies with a territorial approach, clear regulatory frameworks, strategic planning, financing mechanisms, and continuous monitoring and improvement.

PROVO's roadmap lays the foundation for transforming organic waste management in Argentina. Through multilevel actions, intersectoral collaboration, and territorial focus, it seeks to establish a viable and sustainable valorization model adapted to local realities, contributing to both productive development and climate change mitigation.

Keywords: organic waste valorization; circular economy; climate mitigation; public-private partnerships; territorial planning.

WASTE VALORIZATION AND SUSTAINABILITY IN THE STATE OF RIO DE JANEIRO: THE PROJECT FOR THE INSTALLATION OF A BIOMETHANE PLANT AT THE GERICINÓ PRISON COMPLEX

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In light of the intensification of environmental, economic, and social crises, and the environmental commitments assumed globally—especially in relation to the goals for achieving the Sustainable Development Goals (SDGs)—a paradigm shift in traditional models of production and consumption is essential.

It is in response to this demand that the circular economy emerges as a strategic approach to transforming linear models based on extraction, production, use, and disposal, by promoting the regeneration of natural systems and the efficient use of resources throughout their life cycle. In the Brazilian context, the circular economy is directly related to the challenges of managing urban solid waste and the structuring of integrated and effective public policies.

Thus, public administration initiatives are gaining ground not only as strategic agents in promoting policies but also as true protagonists.

In this scenario, the State of Rio de Janeiro, through the Regulatory Agency for Energy and Sanitation of the State of Rio de Janeiro – AGENERSA, stands out in leading an innovative reference project focused on environmental sustainability, smart solid waste management, and social inclusion. This involves the installation of a biomethane production plant attached to the Gericinó Prison Complex, one of the largest in Latin America, employing prison labor.

The project is based on the valorization of organic solid waste as a renewable energy resource, through the eco-efficient allocation of food scraps—the main raw material—sourced from state agencies, including the Complex itself; promoting circular economy principles at all stages of the process, with a focus on reducing greenhouse gas emissions.

The process aims at purifying the biogas generated through anaerobic digestion, converting it into biomethane of a quality that meets certification standards, so that it can be injected into the natural gas distribution network.

Injecting biomethane into the natural gas grid represents a strategic advance for diversifying the energy matrix and increasing the share of renewable sources in urban supply. In addition to promoting energy security, it reduces dependence on fossil fuels and contributes to the decarbonization of the energy sector. As a result, biomethane ceases to be an isolated resource and becomes a structured part of the state's energy infrastructure.

The project also involves prison labor in the plant's operational activities, contributing to resocialization by offering opportunities for social reintegration, aligned with public policies of inclusion and the reduction of criminal recidivism.

The aim of this paper is therefore to present an initiative that represents a milestone in the integration of public policies on the environment, energy, and social justice. By combining clean technologies, waste management, and resocialization, the project establishes a replicable model of urban sustainability with positive and lasting environmental, economic, and human impacts.

Keywords: waste valorizarion - circular economy - biomethane - public administration - inovation.

MANURE VALORIZATION FROM INTENSIVE LIVESTOCK OPERATIONS IN BUENOS AIRES PROVINCE, ARGENTINA

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Wet biomass from stabled animals includes animal manure and effluents resulting from livestock activities such as: feedlots, dairy farms, pig farms and poultry farms. Animal manure, without proper management, causes: soil, surface and groundwater contamination, odors, proliferation of rodents, insects and other vectors as well as atmospheric emissions of greenhouse gasses (GHG) specifically methane, nitrous oxide and carbon dioxide. Spatial analysis of the quantity of manure, slurry, and guano from confined animals, by type of production, allows us to visualize their distribution and the potential for their use as distributed renewable generation (DRG), biogas or electricity, as well as organic amendment. Documents from various public and private institutions were consulted. Primary data collection was carried out through semi-structured interviews and field visits in search of "witness cases". The QGIS program was used in order to integrate the analysis of the biomass volume from confined animals. The province of Buenos Aires presents a great potential with about 12.105.345 tons of wet biomass per year, coming from establishments with more than 100 animals, with the price of the tariff being the determining factor for the generation of distributed electricity. On the other hand, for the production of agricultural bio-inputs there is a potential of 1.609.621 tons per year from establishments with less than 100 animals, with the possibility of their commercialization under Resolution N°. 1.004/2023 of SENASA. Strategic management requires state policies and measures based on a Decision Support System (DSS) that incorporates the different options for its use with key information anchored to the territory.

Keywords: keywords: wet biomass valuation; concentrated animal operations; decision support system; distributed renewable energy; bio-inputs.

WASTE MANAGEMENT FROM STREET MARKETS AND SUPPLY COMPANIES: ALTERNATIVES FOR TREATMENT WITH ENERGY RECOVERY

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Economic growth combined with sustainable development is one of the greatest challenges facing nations worldwide, this century. The United Nations, in its 2030 Agenda, established 17 Sustainable Development Goals (SDGs), with 169 integrated and indivisible targets. Highlights include: diversifying the energy matrix, including clean and renewable sources, and reducing waste generation, focusing on its reduction and the use of environmentally friendly technologies for its treatment. Brazil is an emerging economy that, in 2019, was among the 10 largest in the world. Santo André is a Brazilian municipality recognized as an example of public policies that encourage sustainable waste management practices, ranking as the second-best solid waste manager in the state of São Paulo in 2023. Even so, there is still a long way to go toward more efficient and sustainable management of municipal solid waste, considering the scenario of a circular economy. The municipality, which generates approximately 640 tons of solid waste daily, has selective collection rates of around 5%, meaning that over 200.000 tons of waste are disposed of annually in the municipal landfill, which is expected to have a maximum useful life of 5 years. Among this waste, approximately 6.5 tons of organic waste per day originates from street markets and the Regional Supply Company, which could be used for other treatment methods, such as composting or anaerobic digestion. Therefore, this study aimed to analyze the characterization of the organic waste and estimate its potential for energy recovery through different routes: direct combustion in boilers, anaerobic digestion in landfills, and anaerobic digestion in controlled environments. Given its high humidity levels (between 70 and 80 %) and volatile solids up to 80 %, anaerobic digestion was the most appropriate technology. If performed in controlled environments, it can generate 140.000 Nm3 of biomethane annually, which can be used locally for heating, electricity generation, and biofertilizer production. Although this value may be considered low, if compared to the total volume of MSW generated in the municipality, it represents a decentralized solution that the municipality can consider as it moves toward more sustainable solid waste management.

Keywords: anaerobic digestion; organic fraction; biomethane; landfill gas; waste to energy.

FROM WASTE TO RESOURCE: THE POTENTIAL OF POULTRY LITTER FOR LOCAL DEVELOPMENT. A POLICY BRIEF PROPOSAL

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In the district of General Pueyrredon, located in Buenos Aires Province, Argentina, intensive broiler chicken production generates approximately 6,000 tons of poultry litter annually. This organic waste, comprising a mixture of excreta and bedding material, is commonly applied as fertilizer in the peri-urban horticultural belt surrounding Mar del Plata, which contributes approximately 87% of the district’s agricultural value. However, the widespread use of raw poultry litter occurs largely without prior treatment or soil nutrient assessment relative to crop requirements.

This practice presents significant environmental and public health concerns, including the potential dissemination of antibiotics, antibiotic-resistant bacteria, and pathogenic microorganisms, as well as risks associated with nutrient overloading and leaching. Although Argentine regulations mandate the treatment of poultry litter (e.g., via composting) prior to off-farm transport, compliance remains limited. Key barriers include insufficient incentives, inadequate infrastructure, limited regulatory enforcement, and a general lack of technical expertise among producers. In response to these challenges, this study aimed to develop a policy brief to promote on-farm composting of poultry litter to convert this waste into a stable, sanitized, and value-added soil amendment. A multidisciplinary team was assembled to assess the extent of the issue, map the relevant stakeholders, and identify local decision-makers critical to the successful implementation of such a policy. The development of the brief was informed by scientific evidence demonstrating that composting significantly reduces pathogen loads, antibiotic residues, and antibiotic resistance genes, while also stabilizing organic matter. Furthermore, field studies indicate that the application of composted poultry litter enhances crop yields more effectively than untreated material. The resulting policy brief includes an executive summary tailored for policymakers and the general public, supported by an infographic to facilitate knowledge understanding and stakeholder engagement. This proposal serves as a strategic tool to align local farming operations with national regulations, empower producers with accessible solutions, and foster a circular economy in the horticultural sector.

Keywords: general pueyrredon; animal husbandry waste; composting; stakeholders; public policy.

PROGRESS, IN THE ENVIRONMENTAL ASSESSMENT OF THE PUESTO DEL MARQUES MUNICIPAL COMMISSION SLAUGHTERHOUSE IN THE COCHINOCA DEPARTMENT OF THE JUJUY PROVINCE, ARGENTINA

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The slaughterhouse of the Municipal Commission of Puesto del Marques is located on the periphery of the urban area, next to National Route 9, in the department of Cochinoca, province of Jujuy, Argentina. It does not have an Environmental Management Plan; however, it plays an important social and economic role in the region, responding to extensive Andean subsistence livestock activity while facilitating the supply of food resources to the area. It was considered opportune to investigate, through the project financed by SECTER-UNJu Res N°2615/25, entitled "Environmental diagnosis of the slaughterhouse of the Municipal Commission Puesto del Marques, department of Cochinoca, province of Jujuy. Application of nanotechnologies and biotechnologies for the proper management of liquid discharge at a prototype level," to initially evaluate the current status of the slaughterhouse through interviews, surveys, participant observation, and photographic records. Furthermore, nanotechnologies (nanoclay-based filters) and biotechnologies (through phytoremediation species) will be investigated at a prototype scale to reduce the organic load of the untreated liquid discharge. Physical, chemical, and biological variables of the liquid effluent will be monitored. Initial results of the environmental diagnosis, obtained through participant observation and photographic records, indicate that the building conditions—both in terms of size and sector distribution—are deficient according to SENASA regulations for rural slaughterhouses. The processing areas are poorly defined (stunning, slaughter, and cutting); ante-mortem, during-slaughter, and post-mortem procedures are carried out in a single room. The absence of a continuous and orderly flow in the slaughter process compromises both food safety and animal welfare. The validation of the surveys and interviews shows that they slaughter a higher proportion of cattle and, to a lesser extent, domestic camelids. At the same time, a new actor has emerged: the "middleman," who buys and sells livestock, a livelihood made feasible by the presence of the slaughterhouse. Furthermore, it lacks animal health and welfare professionals or technicians to comply with regulations aimed at reducing the risk of zoonotic-parasitic diseases and promoting animal welfare. The liquid waste from the slaughter process is immediately washed and channeled outside, where it flows into a single pond containing parts of both green and red viscera resulting from the washing process. Meanwhile, the green viscera from the rumen are transferred to an outdoor platform where they are burned once dry, along with the hides. The slaughterhouse provides livestock owners and non-owners with a cleaner, less labor-intensive slaughter process and a more direct contribution to their family economy. Once the environmental diagnosis is complete, a management proposal for the effluents of the Puesto del Marques Municipal Commission Slaughterhouse will be developed.

Keywords: environmental assessment, slaughterhouse, slaughter, waste.

ADVANCES AND CHALLENGES IN ENVIRONMENTAL REGULATIONS OF DAIRY SLURRIES IN SOUTH AMERICA: A COMPARATIVE REVIEW (2017–2025)

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Dairy production plays a vital role in the rural economies of South American countries such as Uruguay, Argentina, Brazil, and Chile. However, the intensification of dairy systems has led to increasing volumes of cattle slurries that pose environmental risks if they are mismanaged. These slurries could contribute to water pollution, and soil and air degradation. Despite these concerns, specific regulatory frameworks have historically been weak or outdated. Since 2017, some countries have modernized their legislation with greater focus on sustainability. This study compares slurry management regulations in Uruguay, Argentina, Brazil, and Chile from 2017 to 2025, identifying key strengths and weaknesses.

Preliminary findings show marked differences across countries. Uruguay introduced a national environmental risk matrix, voluntary certifications, and mandatory sustainability plans in sensitive zones. A decree on water pollution is under revision, updating parameters such as phosphorus in soil and water. The matrix also now includes milking parlor and slurry application practices.

In Argentina, provincial governments have incorporate regulations. The provinces of Buenos Aires enacted legislation for controlled slurry reuse in agriculture, with technical standards protecting water and soil. Córdoba established reuse criteria in 2017, the environmental parameters of which are currently under review. Recent laws created an environmental tribunal and offender registry with proportional sanctions. These measures are supported by broader environmental legislation on emissions and remediation.

Brazil is debating reform of its environmental licensing law. If passed, small- and medium-scale livestock farms—most dairy operations—would be exempt. Only large confinement farms would require licenses. Other frameworks, like the Forest Code, remain in effect.

Chile has no slurry-specific law, but general environmental regulations apply to dairy and livestock operations. Notably, public–private efforts have promoted sustainability initiatives such as the national dairy standard and milk company incentives related to better manure management. These encourage adoption of Best Management Practices despite the absence of slurry specific regulations.

Uruguay and Argentina show the most significant regulatory advances, particularly in reuse and sustainability. Yet, regional challenges persist: limited enforcement capacity, outdated norms, and lack of coordination. Chile’s voluntary model illustrates how public–private cooperation can improve practices in advance to normative. South America still lacks a unified framework. Strengthening enforcement, modernizing regulations, incentives and fostering regional cooperation are essential for sustainable slurry management.

Keywords: dairy slurry; environmental regulations; wastewater management; south américa; policy analysis.

INDUSTRIAL WASTE TRANSFORMATION INTO BY-PRODUCTS: REGULATORY BARRIERS AND A SUCCESSFUL CASE FOR CIRCULAR ECONOMY IMPLEMENTATION IN ARGENTINA

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One of the main barriers to the adoption of circular economy models by agro-industrial companies in Argentina is the complexity of the legal framework and the bureaucratic burden involved in registering waste as by-products. This situation creates uncertainty, hidden costs, and often leads to the underutilization of materials with significant valorization potential.

In this study, we present a real-world case involving the successful registration of potato waste as an approved by-product for use in animal feed, in compliance with SENASA (National Service of Agri-Food Health and Quality) regulations.

The case centers on a major agro-industrial food company located in the General Savio Industrial Park of Mar del Plata, which generates approximately 15 tons per day of mixed organic waste—including potato peels, dough trimmings, food scraps, and corn kernels.

As the company lacked the infrastructure to treat or manage this waste internally, it faced high costs related to transportation and final disposal. One potential solution was to repurpose the material as a raw ingredient for animal feed. However, in order to do so, the material must be officially registered with SENASA as a by-product suitable for animal nutrition.

After several unsuccessful internal attempts to complete the registration process, the company was unable to obtain approval from the regulatory authority, mainly due to a lack of understanding of the applicable regulations and associated technical requirements.

For this reason, the objective of this work is to inform producers about the legal and technical requirements that must be implemented in their industries in order to enable the transformation of their waste into inputs for secondary production chains, such as animal feed.

The applied methodology was structured according to SENASA Resolution 1415/2024, which approves the Technical Standard for Animal Feed in the Argentine Republic. The process included: (1) appointment of external Technical Direction; (2) evaluation of the agro-industrial residue according to safety, identity, and traceability criteria required in Chapter II of the regulation; (3) development of technical datasheets and sampling protocols; (4) performance of physicochemical, microbiological, and contaminant testing in accredited laboratories; (5) classification of the type of generating facility and final use of the by-product according to its functional category (energy, protein, fiber, etc.); and (6) preparation and submission of the formal application dossier to Senasa.

The development also included pilot-scale feeding trials and internal cross-audits to ensure compliance with the Good Manufacturing Practices (GMP) established in the regulation.

This case demonstrates how an agro-industrial company can transform waste into a resource, closing material loops, reducing waste, and generating shared value, in alignment with circular economy principles.

Key success factors include specialized regulatory knowledge, intersectoral collaboration with regulatory bodies, and solid environmental and engineering management. In conclusion, it is intended that producers be motivated to register their by-products by viewing the experience presented in this work as a feasible and replicable example that can be successfully implemented.

Keywords: circular economy; by-product; senasa; animal feed; agro-industrial waste; regulatory barriers.

CIRCULAR ECONOMY AND BUSINESS MODELS: CASE STUDIES IN THE FISHING INDUSTRY

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As a result of the profound changes in purchasing patterns driven by younger generations who are more conscious and responsible for what is produced and consumed, together with the health crises that brought food safety to the center of the debate, the demands on production models have evolved towards more sustainable and circular schemes. In this context, the fishing industry finds in the circular economy (CE) paradigm a strategic vehicle for the generation of value, with a remarkable potential in the reuse of waste, diversification of by-products and generation of renewable energy from organic waste.

This new paradigm requires a rethinking of business strategies, promoting the transformation of production practices towards more efficient and sustainable models. These changes, aligned with the need to comply with international certification standards, are being developed in conjunction with the incorporation of emerging technologies in both organizational management and operating processes. This transition process distances itself from traditional linear models, moving towards increasing degrees of circularity, with positive impacts on the economic, social and environmental dimensions.

In view of the scarcity of scientific studies that address the processes of organizational transformation towards circular models in the fishing sector of Mar del Plata, the study of two paradigmatic cases is proposed. The selection is based on the uniqueness of their sustainability-oriented practices, the adoption of technological platforms and the redesign of the value proposition under CE principles. The objective of the work is to understand the transition from the linear model of fishery product processing to sustainable production schemes, allowing the identification of the differential capacities that configure circular competitive advantages.

The methodological approach is qualitative and exploratory, based on semi-structured interviews with key actors and content analysis of secondary sources from official websites and business portals. The analysis framework is structured on the basis of the taxonomy of circular business models proposed by Urbinati, Chiaroni and Chiesa (2017), who identify two main dimensions of circularity (the value proposition and customer relationships and the value network, the relationship with suppliers and internal activities) and four modes of adoption together with the approach of Kalmykova, Sadagopan and Rosado (2018), who highlight the absence of parts of the value chain, such as manufacturing and distribution, under the CE paradigm.

The analysis shows incipient to intermediate levels of circularity, evidencing transition processes characterized by the adoption of enabling technologies. The identified practices establish changes both for the value network -through the valorization of waste and organic by-products- and in the value proposition, through new digital marketing channels. The research contributes to know the practices developed in the new business models of the fishing industry of Mar del Plata, under the circular economy paradigm, mainly focused on the reuse or reduction of raw materials for their subsequent reincorporation into the production cycle with a medium-low degree of circularity.

Keywords: sustainability; degree of circularity; enabling technologies; value chain; organizational practices.

HIGH-PERFORMANCE COMPOSTING AND CIRCULAR LOGISTICS IN AN AGRO-INDUSTRIAL CLUSTER: THE AHB APPROACH

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Asociación de Horticultores de Bernal (AHB) operates the integrated solution for agroindustrial organics that combine high-performance composting and a centralized service model at Agropark Querétaro. Including a mitigation pathway eligible for carbon credits, and preventive management of agricultural plastics. This submission summarizes the operational day to day, monitoring framework, and quality controls that enable traceable, climatebeneficial material flows inside a greenhouse-dominated cluster. Agropark Querétaro is a high-tech greenhouse cluster located in central México, with its over 300 hectares and 13 different operations coexisting in it; AHB operates a hub-and-spoke twine—that contaminates feedstocks and risks microplastic inputs to soils. AHB applies contractual purity specifications and do-not-accept lists, origin inspection with penalties, preprocessing (screening), and parallel collection and baling routes for clean plastics destined for recycling. Producer training and procurement guidance reduce contamination at source; bioplastics are critically assessed to avoid materials lacking appropriate standards or composting conditions. These new technologies are promising, but they remain difficult to integrate into the value chain because of high prices and resistance from established industry beliefs about what constitutes true sustainability. The integrated approach—robust composting operations, centralized logistics, MRV-grounded climate accounting, and plastics risk management—offers a scalable pathway for agro-logistics scheme: generators request the collection and removal of their waste materials. These materials are inspected at the point of origin to further reduce contamination and traced by load ID using an in-house developed app, with checkpoints and verification as photos and GPS task to ensure traceability. Weekly cycles target windrow formation, fusion near week six, and harvest around week nine, matching throughput to labor and equipment (turner, backhoe, tractor). This concentrates organics previously landfilled or burned, reduces hauling and disposal costs, and supplies consistent compost for on-site soil-health programs. For climate accounting, AHB structures a project aligned with recognized methodologies to quantify three benefit streams: (i) methane avoidance by diverting organics from anaerobic decomposition in landfills; (ii) partial displacement of mineral fertilizers via compost-borne nutrients (not included right now); and (iii) accrual of soil organic carbon from systematic compost application (in process). The MRV system defines boundaries and baselines, sampling frames, and uncertainty handling; integrates mass-balance records, energy use, compost analytics, and field protocols (application rates, composite soil sampling); and addresses permanence, leakage, and double-counting safeguards. A recurrent challenge is plastic co-generation—greenhouse and mulch films, drip tape, and industrial clusters to convert operational liabilities into agronomic and climate assets. Priority next steps include capacity expansion, third-party registration of the carbon project, refinement of soil monitoring, and partnerships that internalize circularity across the regional supply chain while maintaining stringent product quality.

Keywords: composting; agropark querétaro; carbon credits; agricultural plastics; mrv.

Organizers

Co-organizers

Collaborators

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