7th International Conference

WASTES

SOLUTIONS
TREATMENTS
OPPORTUNITIES

BOOK OF PROCEEDINGS

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FROM THE EDITOR

Dear colleagues,

It is with great pleasure that we bring to you this Book of Proceedings developed within the context of the 7th International Conference Wastes: Solutions, Treatments and Opportunities.

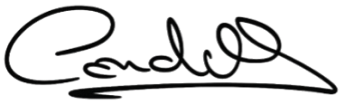
The WASTES Conference, held biennially, serves as a global platform for scientists and industry professionals in the fields of waste management and recycling to share their expertise and experiences. The event fosters thoughtful discussions on achieving a sustainable balance between economic, environmental, and social goals. A core focus is the advancement of innovative techniques, tools, and strategies to transform waste into valuable resources—enhancing environmental performance and deepening our understanding of the industry's environmental impact, while identifying pathways for continuous improvement.

Through this editorial work, we are pleased to extend the reach of the conference by publishing selected scientific contributions derived from the oral presentations and posters. In doing so, we carry the impact of the event beyond its physical boundaries.

This issue features 185 abstracts presented at the 2025 edition. These papers, further refined and developed, represent an important scientific output of the conference. Meanwhile, the full papers submitted were compiled in the book series Springer Proceedings in Earth and Environmental Sciences, which is indexed in Scopus and Web of Science.

The abstracts cover a wide range of themes, including management of waste streams, environmental, economic and social aspects in waste management, marine pollution and bioinvasions, waste-to-energy technologies, life cycle assessment and carbon footprint, biological treatment techniques, sustainable waste valorization technologies, circular economy and industrial symbioses, smart technologies and digital tools in waste management, recycling of wastes and resources recovery, wastes refineries, food waste management and bioeconomy, plastic waste impacts, management strategies and solutions, wastes as critical raw materials resources, the use of wastes as construction materials and as fuels, waste treatment technologies, municipal solid waste (MSW) management, recycling and material recovery, the environmental, economic and social dimensions of waste management, circular economy and waste refinery approaches, life cycle assessment, and topics related to logistics, policies, regulatory frameworks, and market dynamics in waste management.

We hope you find these research contributions insightful and inspiring - and that they motivate you to join us for the 2027 edition of the conference!



Chair of the Organizing Committee

Cândida Vilarinho

TABLE OF CONTENTS

LEVERAGING ON LIFE CYCLE ASSESSMENT TOWARDS SUPPORTING A SUSTAINABLE PORTUGUESE AGRI-FOOD SYSTEM

Sara M. Pinto[1]*, Carolina C. Fraga[1], Rui Gonçalves[2], Emanuel J. Lourenço[1]

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ABSTRACT

The agri-food sector assumes a central importance in the Portuguese economy. Recently, the war situation in Ukraine has had a considerable direct impact on the agri-food sector and industry, driving world food prices to reach a historical record and leading to food rationing in several countries. In addition, there is also an impact on the ingredients imported from war zones applied in food products. In this context, a continued increase in food prices is expected, imposing the urgency of national food self-sufficient but also changing the global food market, empowering an opportunity for the Portuguese brand food industry to stand out globally by offering novel, high-quality, and functional products, obtained through more efficient and advanced processes and, thereby, with more competitive prices.

The emergence of new consumption habits and trends and their dynamic change reinforce the importance of the consumer and establish a new role of challenge and opportunity about health, well-being, food safety, and the social, local, and environmental impact of food products, their manufacturing processes, and supply chains. The agri-food industry faces relevant technological, environmental, and social challenges that require new approaches to research, development, and production and high flexibility to adapt and transform conventional processes and procedures.

The sustainability and circularity of food products and processes are assuming a growing importance in the agri-food sector worldwide, and it is expected to become even more relevant given European regulations changes that foster ecodesign requirements, as well as a widespread call to waste prevention and valorization to meet carbon neutrality targets. Environmental sustainability is a critical area in the agri-food sector strategy, in terms of the raw materials used in the new food products development, manufacture, and packaging solutions, but also regarding production technologies and processes used by the different food industries regarding resource consumption and environmental impacts. Life cycle assessment methodology has been widely used to evaluate different agricultural systems and food processing activities regarding the environment and compare different manufacturing alternatives for the same product. Despite these efforts, several methodological aspects must be improved to guarantee adequate support for decision-making.

This study conducted a Life Cycle Assessment based on the ISO 14040/44 standard to quantify the environmental impacts of implementing improvement actions in the agri-food sector. This research will focus on leveraging the environmental transition, reducing carbon emissions, and the impact of the agri-food industry on the environment by adopting new strategies for reusing and recovering waste and obtaining by-products from the agri-food sector, incorporating advanced technologies to adopt new sustainable packaging solutions capable of reducing waste and introducing new, more resource-efficient production technologies. The results will help identify the most important environmental critical points of the different techniques in an agri-food product. This will help farmers improve their production processes and valorize their by-products, which could be useful in other industries.

Keywords

Life Cycle Assessment; Agri-food; Carbon Footprint; Improvement Actions

KERATIN-BASED ADSORBENT FOR SUSTAINABLE RECOVERY OF PLATINUM GROUP METALS

Amir Nobahar [1], Flavia N. Braga[1, 2, 3], Helena Passos[2, 3*], Filipe H. B. Sosa[1], Nicolas Schaeffer[1], João A.P. Coutinho[1]

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ABSTRACT

Spent autocatalytic converters (SACCs) serve as a major secondary source of platinum group metals (PGMs), including Pd, Pt, and Rh, all of which are essential for various industrial applications (1). Recovering these metals is crucial to mitigate resource scarcity and reduce environmental impact. However, conventional methods typically involve hazardous reagents and high costs (2). As an eco-friendly alternative, keratin-based biowastes, such as chicken feathers, are abundant, cost-effective, and equipped with functional groups that enable efficient and selective metal adsorption (3,4).

In this study, keratin-rich chicken feathers were evaluated for their capacity to selectively adsorb Pd from both synthetic multimetallic solutions containing Pd, Pt, Rh, Fe, Zn and Ce and real HCl-based SACCs leachates. Batch adsorption experiments assessed the influence of HCl concentration, contact time, temperature, and initial metal concentrations on metal uptake by chicken feathers. Under optimized conditions, chicken feathers demonstrated nearly complete adsorption of Pd, along with minimal adsorption of Pt, while effectively minimizing the uptake of other metals.

Desorption tests using 0.2 M thiourea in 0.5 M HCl nearly fully recovered Pd. When applied to real leachates, this approach yielded substantial Pd recovery and limited co-adsorption of other metals. Investigations into the adsorption mechanism identified chemisorption of Pd-chloride complexes onto the amino groups of keratin as the primary adsorption pathway.

These results demonstrate the viability of keratin-based biowastes as a cost-effective, sustainable solution for PGM recovery. By reducing reliance on environmentally harmful reagents and addressing the growing need for critical metals, this approach offers both economic and ecological benefits. Future research will focus on scaling up the process and exploring its adaptability to other industrial waste streams.

Keywords

Keratin-based Adsorbent; Metal Adsorption; Platinum Group Metals; Spent Autocatalytic Converters; Waste Management

VALORIZATION OF WASTE TANTALUM CAPACITORS THROUGH THE RECOVERY OF CRITICAL AND VALUABLE METALS

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ABSTRACT

The rapid technological advancements and the shortened lifespan of electronic devices has led to a growing e-waste crisis. This has significantly increased the volume of waste tantalum capacitors (WTCs), components that are widely used, from smartphones to aerospace systems, due to their high capacitance density and reliability. Tantalum (Ta), a key component of WTCs, is a rare and valuable material identified by the European Union as critical [1]. Although Ta capacitors represent approximately 34% of global Ta usage [2], less than 1% of this metal is currently recovered from end-of-life products [3]. Solving this gap is essential for the sustainable and efficient recovery of Ta and other valuable metals from WTCs. Recovering metals from WTCs presents considerable challenges due to their complex composition and the difficulties associated with extracting and refining Ta. This study proposes an innovative hydrometallurgical process to overcome these obstacles by keeping Ta in the solid phase instead of dissolving it in the liquid phase. This approach not only enables the efficient recovery of Ta but also facilitates the extraction of manganese (Mn), nickel (Ni), copper (Cu), zinc (Zn), and silver (Ag). The process begins with pretreatment steps involving the manual dismantling of WTCs and milling them into a fine powder. This is followed by a leaching stage, where the powder is treated with a sulfuric acid solution optimized using response surface methodology. During leaching, Mn, Ni, Cu, and Zn are dissolved, while Ta and Ag remain in the solid residue. The dissolved metals are then processed, starting with the precipitation of Mn, followed by sequential liquid-liquid extractions using a dodecane and Cyanex® 272 organic solvent system at different pHs. This process achieves high recovery efficiencies, attaining purities of 93% for Zn, and 98% for both Cu and Ni, with total recovery rates exceeding 97% for all three metals. In the final step, Ta and Ag are separated from the residual solid fraction using diluted nitric acid solutions, producing Ag and Ta with purities of 96% and 98%, respectively.

Keywords

Circular economy, Critical metals, Hydrometallurgy, Recycling, Waste valorization.

MACHINE LEARNING-DRIVEN FRAMEWORK FOR LITHIUM-ION BATTERY RECYCLING

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ABSTRACT

The increasing popularity of lithium-ion batteries (LIBs) as both portable and large-scale energy storage devices necessitates sustainable solutions for managing their eventual disposal. LIBs contain critical raw materials, such as lithium, cobalt, and graphite, whose supplies are considered strategically, socially, and economically important by the European Union. Therefore, waste LIBs represent a significant urban ore, a recovery opportunity for ensuring a more sustainable and circular economy of such materials. Efficient recovery and separation are of paramount importance. However, identifying optimal leaching conditions can be complex due to the diversity of battery chemistries, leaching agents, and the need to balance economic and environmental considerations. While some attempts have been made to apply machine learning techniques to tackle this interesting optimization problem, these efforts have often overlooked the practical aspects of implementation and real-world applications. In this work, a methodical data-driven approach to modelling the leaching of key metals from LIB cathodes is presented. The existing literature is leveraged to construct a leaching model using machine learning algorithms, allowing for efficient and agile screening of leaching conditions. Our model considers key performance indicators such as yield, selectivity towards a particular metal, heating requirements, solvent costs, CO2 emissions and other environmental impact indicators to provide a preliminary economic and environmental assessment of different leaching strategies. This approach enables researchers to identify promising conditions that maximize metal recovery while minimizing environmental harm. To showcase the practical application of this methodology, a user-friendly graphical interface was developed to leverage machine learning packages currently available for Python for this purpose. This makes these powerful tools accessible to a wider audience, including researchers and industry professionals who may not have a strong computational background. The data-driven methodology presented here represents a significant advance in integrating computational tools into the development of novel, greener metal recycling processes. By providing a more comprehensive approach to evaluating leaching conditions, these tools help advise the development of more sustainable and economically viable LIB recycling practices. Furthermore, this approach can be extended to address other waste recycling challenges, offering a versatile framework for optimizing resource recovery across various industries.

Keywords

Wastewater surveillance, SARS-CoV-2, SARS-CoV-2 variants, Early detection

USE OF FERRUGINOUS SLUDGE FROM WATER TREATMENT PROCESSES FOR ADSORPTION OF AQUEOUS AND GASEOUS POLLUTANTS

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ABSTRACT

Environmental pollution by metals is one of the major global challenges, as these pollutants negatively affect human health and the stability of ecosystems. Metals, especially heavy metals and some metalloids (arsenic), are toxic and bioaccumulate, compounding their harm. Various methods are being developed to remove heavy metals from water in response to these challenges. One promising solution is to use ferruginous sludge from groundwater treatment processes (GWTRs) as sorbents. GWTRs, a by-product of these processes, have properties that make them an attractive and economical solution for environmental protection. The research conducted was aimed at a comprehensive analysis of the phase and chemical composition of GWTRs, their physicochemical properties, and adsorption capacities towards selected metals: Pb(II), Cd(II), Cu(II), Zn(II), Cr(III), Cr(VI), As(V). Precipitates characterization included advanced analytical techniques such as X-ray diffraction (XRD), X-ray fluorescence (XRF), infrared spectroscopy (FTIR), BET analysis, and SEM-EDS microscopy. The results showed that the GWTRs have an amorphous structure, with ferrihydrite dominating and minor admixtures of quartz and calcite. The content of iron oxides (Fe2O3) was 32-55%, which significantly affects their adsorption properties. The sediments were characterized by a mesoporous structure with a specific surface area from 49 to 246 m²/g and an isoelectric point (pHIEP) in the range of 4.0-4.5.

In adsorption experiments, GWTRs achieved metal removal efficiencies of tens to 230 g of metal per kg of sorbent, comparable to commercially available sorbents such as zeolites and bentonites. Optimal adsorption conditions are pH 5-8, 4-5 hours reaction time, and temperature of 25°C. Adsorption isotherm models were used to describe the adsorption equilibrium, with the Langmuir model best representing the data, indicating homogeneity of the sorbent surface. Kinetic studies showed that the adsorption mechanism is based on chemisorption, and the process is endothermic and spontaneous, confirmed by thermodynamic data.The study showed that the mechanism of metal adsorption includes inner-sphere adsorption, coprecipitation of iron compounds, and incorporation of metals into the structure of ferrihydrite. In addition, the formation of distinct mineral phases, such as carbonates or metal hydroxides, was observed.

The obtained results have multifaceted practical significance. GWTRs can be used to treat metal- contaminated waters, allowing efficient removal of pollutants and reducing the amount of sludge waste disposed of in landfills. In addition, the potential of these sludges to remove other contaminants, such as gaseous compounds (e.g., H2S), opens up new possibilities for their use in a circular economy.The study's results indicate that GWTRs can be an effective and economical adsorbent, comparable to more expensive commercial alternatives. The developed method of using GWTRs is not only part of environmentally friendly solutions but also promotes cost reductions in waste disposal and water treatment.

Keywords

circular economy; metals removal; chemisorption; iron compounds; ferrihydrite

INTEGRATING PLASTIC FILM RECYCLING IN PRODUCT MANUFACTURING: A DESIGN STUDY ON THE REUSE OF LOW-DENSITY POLYETHYLENE

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ABSTRACT

The recognition of environmental degradation and its consequences in terms of pollution and damage to ecosystems has encouraged several companies and consumers to find new ways to recycle and reuse plastic, especially single-use plastic, in order to combat waste, pollution and promote a circular economy.
There are several types of plastics, with different physical and chemical characteristics that make them suitable for various applications. In fact, due to its presence in food packaging and the several advantages it offers in the industrial and medical sectors, polyethylene is currently the most widely produced plastic on a large scale. Therefore, to promote sustainability, there are several benefits to recycling polyethylene. Its recycling is more energy-efficient than incineration, it is cheaper to produce from recycled materials than from new raw materials, and, in addition to being beneficial for the environment, recycling also generates a source of income that helps combat the costs associated with incineration or landfill disposal.
Plastic films made of Low-Density Polyethylene (LDPE) are used and discarded daily during product packaging in the industrial sector. Unfortunately, a large amount of this plastic is wasted and does not get recycled, thus ending up in landfills or being incinerated.
Nautilus is a Portuguese company that uses plastic films in its daily operations for the transportation and accommodation of its furniture and other products. Thus, this work seeks to collaborate with Nautilus and help the company work out their environmental concerns in the way it values and reuses its production waste. The aim is to study the viability of reusing plastic films at the end of their life to create new objects and products that could become part of the company's product catalog.
The final goal of this work is to present a proof of concept by designing a new product made from 100% recycled plastic film that showcases the potential of this material and integrates recycling strategies in the business context.
Experiments were conducted to test the behavior of polyethylene when pressed and submitted to different pressure and thermal cycles. Additionally, tensile tests and macro and microscopic analysis will be performed to evaluate the material properties.
Finally, a product will be designed to demonstrate the viability to give a second life to this material, add value to the company, and decrease their environmental footprint.

Keywords

Design from waste, Sustainable Design, Circular Economy, Plastic film waste,
Polyethylene, Recycling.

EVALUATION OF THE ENVIRONMETAL IMPACTS OF DAIRY MANURE MANAGEMENT THROUGH LIFE CYCLE ASSESSMENT

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ABSTRACT

The effective management of cattle waste is crucial in today's dairy industry because of its substantial environmental effects. The process encompasses several stages, including collection, storage, processing, and fertilizer application, each with distinct environmental implications. Key concerns include the release of greenhouse gases, such as methane and nitrous oxide, nutrient runoff, and ammonia volatilization, which contribute to global warming, eutrophication, and acidification. Furthermore, inadequate waste management can result in soil and water pollution, threatening ecosystems and public health.

This study employed life cycle assessment (LCA), a comprehensive and standardized approach, to evaluate the environmental impact of dairy manure management systems. It focused on identifying critical environmental issues related to the storage and directly application of cattle manure on a typical farm in central Portugal, with the aim of recommending practices to minimize negative environmental impacts. The reference flow was one ton of dairy manure (wet mass) loaded from the storage unit at the farm, transported to farmlands, and spread as organic fertilizers with a manure spreader. Manure was assumed to be applied to cultivated grasslands. The ReCiPe 2016 method was used for the impact assessment, covering 18 midpoint categories and three endpoint damage categories: human health, ecosystems, and resources.

The results showed that human health was the most significantly normalized damage category, followed by ecosystems and resources. Manure storage has emerged as the primary contributor to environmental impacts, accounting for approximately 85% of human health damage and 86% of ecosystem damage when the avoidance of chemical fertilizers was not considered. The remaining 15% and 14% of the impacts were attributed to soil application. Avoiding the use of chemical inorganic fertilizers reduced human health damage by 13%, ecosystem damage by 16%, and significantly decreased resources related impacts. This study provides valuable insights for policymakers and dairy farmers aiming to enhance the sustainability of dairy cattle waste management practices in central Portugal. It offers practical recommendations to help minimize the environmental footprint of the region's dairy industry.

Future work will evaluate the environmental performance of various manure management strategies, such as anaerobic digestion and composting, under different operational scenarios, comparing them to direct land application. The study will also explore policy implications emphasizing the need for incentives to adopt sustainable manure management systems, improve emission monitoring and regulation, and enhance farmer education on best practices.

Keywords

Dairy waste management, Environmental impacts, Life cycle assessment, Manure application

FABRICATION OF MORE SUSTAINABLE HYBRID ALKALINE CEMENTS USING BIOMASS ASHES

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ABSTRACT

In recent years, the use of biomass for heat and power generation has increased substantially in Europe, making it the fastest growing renewable energy. Spain is the third largest European country in terms of absolute forest biomass resources (behind only Sweden and Finland). The combustion of biomass waste generates mainly two types ashes; fly ash, fine particles carried by gas streams out of the combustion chamber and collected in filters, and boiler or bottom ash, consisting of fully or partially burnt material, which is the coarsest fraction and usually contains different types of mineral impurities. The construction industry can accommodate these by-products, usually by replacing part of the Portland cement with a small fraction of ash (up to 5-15%), as above these values the strengths are greatly affected.

The present work explores the possibility of using various types of fly ash and bottom ashes of different origin, chemical and mineralogical composition, to produce hybrid cements (70 % biomass ash-30 % of Portland cement). Blended cements (prepared with 70 % of Portland cement-30 % biomass ash) were also prepared. For this purpose, pastes of these cements were made and cured for 28 days. Mechanical tests were determined after 2 and 28 days. The reaction products were characterized from the mineralogical and microstructural point of view. The kinetic of hydration was explored using isothermal calorimetry. The results obtained show the key role played by the chemical and mineralogical composition of the biomass ash in the mechanical development of the different cements developed. The reaction products generated in the hybrid cements are going to be very similar to those produced in the blended systems.

Keywords

Biomass ash; sustainability; valorization; Hybrid alkaline cements; blended cements.

DEVELOPMENT OF SUSTAINABLE RICE HUSK BIOCOMPOSITES: A LIFE CYCLE ASSESSMENT APPROACH

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ABSTRACT

Rice is the most widely consumed cereal globally, serving as a staple food for nearly half the world's population. Its production is expected to reach 3 billion tonnes by 2050, driven by technological advancements. In Portugal, rice cultivation holds a significant social and economic role, with an annual production of approximately 160.000 tonnes, leading Europe in per capita consumption. Rice Husk (RH), a by-product comprising about 20% of the total rice paddy, has historically been 27oznan2727icz2727, often serving as animal bedding or being burned in open fields—environmentally unsustainable practices. However, its organic composition, increasing availability, and notable mechanical properties have sparked interest in its use for circular economy applications. Considering the properties of natural fibers such as RH, along with the global dependence on plastic and its status as a major source of pollution, there is a growing demand for sustainable biocomposites. Natural fibers are widely adopted due to their accessibility, renewability, nontoxicity, cost-effectiveness, biodegradability, and adequate mechanical performance. However, challenges remain regarding bioplastics' recyclability and their integration into existing waste management systems, which requires further study. This gap could be addressed using a Life Cycle Assessment (LCA) approach, providing a robust methodology to evaluate the environmental impacts of alternative materials and processes. This project, part of the Be.Neutral Agenda – Mobility Agenda for Carbon Neutrality in Cities, aims to position Portugal as an exporter of zero-carbon mobility products. It focuses on developing biocomposites using RH for automotive interior applications. Using the LCA methodology based on ISO 14040:44 standards, this preliminary study assessed the environmental performance of three RH- based formulations (D1, D2, and D3) compounded with polypropylene (PP) during the injection moulding process, compared to a baseline ready-to-use compounded formulation (D0), with 90 % PP and 10% talc filler. The three RH-based formulations developed in this project are compounded with 80% PP and 20% of the following Masterbatch compositions: I) D1 – 41% low-density polyethylene (LDPE) with 50% RH incorporation and 9% additives; II) D2 – 41% PP with 50% RH incorporation and 9% additives; and III) D3 – 31% LDPE with 60% RH incorporation and 9% additives. The functional unit was the production of one kilogram of a compound, with a system boundary encompassing raw material production, the injection phase with PP compounding, and end-of-life options (landfill and mechanical recycling). The LCA was conducted using SimaPro software (v.9.6.0.1), applying the ReCiPe 2016 Midpoint (H) (v.1.09) method. Input data was sourced from the Ecoinvent database (v3.10), with mass allocation per cutting unit ("Cut-off, U"). This study evaluates the four formulations using a decision-making matrix based on mechanical characterisation (classification from 8 to 1, where 8 is full compliance) and environmental performance (rated from 6 to 1, where 6 is the best). A multiplication factor (1.333) was applied to the environmental performance scale to ensure both criteria contribute equally to the evaluation. As the aim of themechanical performance assessment is to achieve the baseline value, all three analysed formulations were compared against the baseline formulation D0. Results revealed that formulation D2 exhibits the best performance when considering only the mechanical characterisation, ranking 4.5, while formulation D1 ranks the lowest with a score of 4.0. From an environmental perspective, among all formulations, D0 with landfill as the end-of-life option exhibited the highest environmental impact, while D3 with mechanical recycling presented the lowest total environmental impact. However, when combining mechanical characterisation with the LCA analysis, formulation D3, with the recycling end-of-life option demonstrated the best overall performance, achieving a score of 12.3. Whereas, formulation D1, with landfill as the end-of-life option, ranks the lowest, with a total score of 5.3. It can be concluded that formulation D2 demonstrates the best performance in terms of mechanical properties, while D3—with a recycling end-of-life option—proved to be the best environmentally. When comparing the three formulations, higher rice husk content was associated with lower environmental impacts. Combining both mechanical and environmental characterisation, formulation D3 emerged as the optimal choice, with a recycling end-of-life option. Two limitations were identified in this study. The first concerns the decision-making matrix, which may require adjustments to achieve a more balanced analysis of the components. The second relates to the need for legislation and regulatory frameworks to address the impact of bioplastic waste on waste management systems. Further studies are required to assess the influence of these incorporation rates on mechanical recycling processes.

Keywords

Life Cycle Assessment; Sustainability; Environmental impacts; Mechanical recycling; Biocomposites.

APPLYING GREEN PROPOLIS AS A CO-PRODUCT OF HONEY PRODUCTION TO DEVELOP AN AQUEOUS AEROSOL WITH ANTIMICROBIAL ACTIVITY

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ABSTRACT

Developing new ways to fight and/or control the dissemination of bacterial infections has become increasingly urgent. One of the approaches to accomplish it is by targeting skin disinfection, as many microorganisms spread to the body through this organ and can infect wounds and the skin itself. Aerosols are regarded as practical, safe and easy to apply, making them a suitable vehicle for developing antimicrobial solutions from natural origin. Propolis is a natural product honeybees produce for the construction and protection of beehives. It presents numerous health benefits as its composition includes several active molecules of interest, such as phenolic compounds, which possess already-reported antimicrobial activity. Green propolis originated in Brazil (a "by-product originated during the production of honey) is known for the phenolic compounds it can accumulates (Contieri et al., 2023). However, these compounds need to be separated from the other constituents of propolis, and conventional extraction methods and solvents may not present the best yields and sustainable requirements. Moreover, the most used solvents, such as ethanol, can be harmful to skin. This points to an urgent need to develop safer solutions for both the environment and humans without compromising the antimicrobial effects of the final product. In this work, a propolis-based extract was developed using an ultrasound-assisted extraction combined with a eutectic solvent (ES) application. Ess represent a good alternative to other extraction solvents, since they can be prepared in a natural and sustainable way with relative ease. These are characterized by their low melting temperatures (Abbot et al., 2004), which makes them very appealing, as it allows for the creation of novel liquids/solvents in simpler and environmentally friendly ways.

They are prepared by combining hydrogen bond acceptors (HBA) with one or more hydrogen bond donors (HBD), a process which is usually done through inexpensive and straightforward methods and generates versatile solvents that, depending on the HBA/HBD combination, can be thermally stable, with low vapor pressures, low-toxicity, high purity and biodegradable. Depending on the HBA/HBD combinations, these solvents can also be task-specific, making their use possible for various food, medicine, and cosmetics applications. This methodology yielded an extract richer in phenolic compounds which successfully inactivated methicillin-resistant *Staphylococcus aureus* (MRSA) and *Pseudomonas aeruginosa*, two important bacteria involved in skin infections. This extract was used to create an aerosol prototype for possible skin application, which maintained antibacterial activity, after its packaging in a spray for at least 8 months.

Keywords

Green Propolis, Eutectic solvents, Phenolic compounds, Antimicrobial Aerosol.

EXTRACTION OF BETACYANINS FROM FOOD WASTE USING EUTECTIC SOLVENTS AND PIGMENTS STABILIZATION

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ABSTRACT

Waste materials, including industrial effluents, can be a source of valuable pigments that can be commercially repurposed through efficient extraction and purification processes. Eutectic solvents (ES) are normally considered as effective solvents for pigment extraction and purification. This approach intends to reduce waste, minimize the environmental impact of pigment production, promote resource circularity, and contribute to a more sustainable future. In this work, a process of extraction of betacyanins from red beetroot waste was developed. The process was optimized regarding the ES molar ratio, the solid-liquid ratio (SLR), water content, pH, and extraction time. After optimization, the extraction yielded around 18 mgbetacyanin.gbiomass-1. Moreover, the stability of the pigment was studied by adsorption mechanisms and its degradation kinetics at different temperatures and light exposure conditions investigated, considering the main objective of introduce it as a natural ingredient in a lipstick.

Keywords

Betacyanin, eutectic solvents, extraction, process optimization, pigments' stability.

RECOVERY AND SEPARATION OF VALUABLE METALS OF SPENT LITHIUM-ION BATTERIES

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ABSTRACT

Lithium-ion batteries (LIBs) are one of the most important electrochemical energy storage devices [1]. Given the content of LIBs in metals and their increasing production rate, it is vital to develop efficient, ecological, and economical worthwhile recycling processes [1,2]. This need becomes even more pressing when considering that the metal concentrations in LIBs often exceed those found in natural mineral reserves [3]. Nevertheless, at the end of their lifecycle, only a limited number of LIBs undergo recycling treatments [4].

Among the various recycling techniques, hydrometallurgy—which includes leaching, separation, and refining—is a viable metallurgical option. When compared to pyrometallurgy, hydrometallurgy offers better recovery rates, higher purity, and lower greenhouse gas emissions, thus holding greater ecological potential [1].

In this work, a new hydrometallurgical process for the treatment of waste lithium-ion batteries (based on lithium nickel manganese cobalt oxide cathodes) is presented. The developed process integrates various approaches, ranging from inorganic leaching using an alternative mineral acid to more complex separation methods as solvent extraction and precipitation processes.

The quantification of the metals involved in the different processes was performed using techniques such as ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry) and XRF (X-Ray Fluorescence). Overall, the results demonstrated that the developed integrated process can produce LiCl solutions with ppm levels of other cationic impurities.

Keywords

Lithium, Transition Metals, Battery Recycling, Circular economy

MICROPLASTICS CONTAMINATION OF MUSSELS AND WATER FROM THE PORT OF SINES, PORTUGAL

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ABSTRACT

Seaports are particularly susceptible to microplastic (MP) pollution through a series of human activities occurring in these areas. Thus, monitoring the biological communities and water is important to assess the impacts of MP pollution. In this work, we quantify extent of MP pollution in the Port of Sines, the main port in the Iberian-Atlantic coast, capable of receiving any type of vessel, which makes this port a potential source and sink of contaminants, including MP. Adjacent to this port, there are moderate to very exposed marine areas with regional and national importance for fisheries, tourism, and conservation. The present study reports the quantity, shape, colour and polymer type of MP in whole soft tissues of mussels (Mytilus spp.), and seawater samples collected in 2022 and 2023. Here, a baseline evaluation of MP concentration at the seawater surface and column was conducted in triplicate with a manta and bongo nets (150 µm mesh), respectively for horizontal and vertical tows, in a total of six sampling sites outside and inside the port. Mussels and water were collected in the same sampling sites. Samples were digested with 10% hydrogen peroxide and filtered through 0.10 µm nylon membranes. Microparticles were classified according to their type into two categories: fibres and fragments. Preliminary results show that all mussels analysed (n=60) presented microparticles. Of 311 microparticles observed, 71% were fibres and 29% were fragments. Both categories showed variations in length, size and colour. Chemical analysis by FTIR spectroscopy is in progress. This work will contribute with baseline data regarding MP pollution and accumulation in biota and water of the Port of Sines and adjacent coastal areas, providing a solid background for future research to assess effects of MP in the marine environment and their potential hazards, helping policymakers to make knowledge-based decisions on plastic litter management.

Keywords

Microplastics; Water pollution; Coastal areas; Environmental monitoring

TRANSFORMING INDUSTRIAL WASTE INTO SUSTAINABLE BUILDING SOLUTIONS. A COMPARATIVE LIFE CYCLE ASSESSMENT

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ABSTRACT

The study evaluates the environmental performance of construction materials incorporating Electric Arc Furnace Slag (EAFS) as a substitute for conventional aggregates, utilizing Life Cycle Assessment (LCA) in accordance with UNE-EN ISO 14040 and 14044 standards. The analysis encompasses the entire product lifecycle, from raw material extraction to end-of-life disposal, following a cradle-to-grave approach. Using SimaPro v.9.5 software and the Ecoinvent v.3.6 database, impacts are assessed across key categories, including global warming potential, acidification, and resource depletion. The main data sources used for the inventory development were the dosages, physical and mechanical properties and leaching data obtained experimentally. The focus is on three material types: concrete, asphalt concrete, and porous asphalt, each evaluated in control (traditional aggregates) and experimental (EAFS aggregates) scenarios. Findings indicate that substituting conventional aggregates with EAFS leads to reductions in environmental impacts, notably in global warming potential and resource depletion, attributed to decreased cement usage and the recycling of industrial by-products. The main difference between the products is found in the ecotoxicity impacts, due to concrete tends to leach more compounds, whereas asphalt, which uses bitumen as a binder, is less prone to leaching because is water-insoluble and acts as a barrier. Additionally, cement production is energy-intensive and consumes substantial raw materials, leading to significant emissions.

Overall, integrating EAFS into construction materials supports circular economy objectives by reducing the consumption of virgin resources and minimizing waste. This study provides a framework for enhancing the sustainability of construction practices through innovative material reuse.

Keywords

Life Cycle Assessment (LCA); Construction Materials; Electric Arc Furnace Slag (EAFS); Environmental Impact; Leaching.

CHARACTERIZATION AND VALORIZATION OPPORTUNITIES FOR WATER DECARBONIZATION SLUDGE

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ABSTRACT

Valorization of waste materials is a key element of the circular economy, which facilitates the efficient utilization of materials, resulting in cost reductions and conservation of raw materials. Moreover, diminishing natural resources force the implementation of novel strategies mostly connected to reuse, recycling, or recovery concepts. The water sector is a significant source of various by-products, some of which are produced as sludges. Sludges are highly hydrated mixtures of diverse materials characterized by widely varying properties, e.g., sewage sludge, alum sludge, or ferric sludge. From this group of byproducts, a particularly interesting sludge material is lime sludge, which exhibits high Ca content, considerably high purity, and interesting physicochemical properties. In this study, we aim to characterize lime sludge origination from a water decarbonization plant, which is an element of the technological process in a coal-fired power plant. The decarbonization process is conducted by the uptake of water from a local river, adjusting water temperature, and addition of Ca(OH)2 to regulate water pH and Fe2(SO3)4 as a coagulant. During this process, a sludge forms, which is separated by filtration and stored in open ponds. Samples of lime sludge were collected and transported to the laboratory, dried at 60°C for 24 h, and crushed in agate mortar. Dry samples of lime sludge were characterized regarding their chemical and phase composition, morphology, and textural properties.

The lime sludge primarily consists of CaO (49.1%), Fe2O3 (5.5%), SiO2 (4.9%), and about 1% of Al2O3 and MgO. Additionally, it exhibits a Loss on Ignition (LOI) value of 37.2%. The x-ray diffraction (XRD) analysis reveals the presence of Calcite (CaCO3) and Quartz (SiO2) as the main phases present in the material matrix. Moreover, Mossbaouer spectroscopy (MS) indicates the presence of ferrihydrite. Transmission electron microscopy (TEM) images show the calcite as sharp edge particles with diameters of several micrometers. Ferrihydrite is depicted by TEM in the form of nanometric particles that assemble micrometric aggregates or enclose calcite particles. Dried lime sludge exhibits a specific surface area of 23.5 m2/g and a total porosity of 0.05 cm3/g. Chemical composition, high specific surface area, and relatively high purity of the material allow for easy valorization and multiple applications. The presence of reactive calcium (Ca) and iron (Fe) species enhances the material's potential for immobilizing various pollutants, including heavy metals such as As, Pb, Cu, Ni, Ce, V, Zn, Co. Additionally, it can target nutrients like PO43-, NO3-, NO2- or NH4+. Lime sludge shows promise as an adsorbent for these pollutants, either as a filtration medium or as an element of constructed wetlands. Moreover, the potential application could be extended as soil pH and structure adjustment or as raw material for cement, brick, and ceramics production.

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Keywords

waste materials; circular economy; reuse; sustainable management

PH DEPENDENT LEACHING CHARACTERIZATION OF TRACE ELEMENTS FROM 100% WASTE- BASED SUSTAINABLE MATERIALS.

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ABSTRACT

Alkali-activated materials (AAMs) are a cost-effective and environmentally friendly alternative to valorise industrial wastes and by-products as construction materials. However, to ensure the absence of risks to the environment during their life cycle, it is necessary to assess the emission of hazardous substances from waste-based AAMs. In the demolition phase, AAM in granular form could be exposed to varying pH conditions in the environment, leading to drastic changes in the leaching of substances.

The aim of this research is to evaluate the influence of pH on the trace elements release from three AAMs. The AAMs consist of a mixture of Blast Furnace Slag (BFS) and Sewage Sludge Ash (SSA) as alumina-silicate precursors and KOH and K2SiO3 (M0 sample) as conventional activator blend, and Almond shell Biomass Ash (ABA) and Rice Husk Ash (RHA) (M1 and M2 samples) as waste-derived activators. For this purpose, the Compliance leaching test (EN 12457-4) and the pH dependent leaching test (EN 14429), in a range of pH values between 2 and 12, proposed in the context of the end-of-waste criteria of the EU Waste Framework Directive were performed.

The evaluation of the raw materials and AAM by Compliance leaching test shows that alkaline activation reduces the mobility of the pollutants, considering them as environmentally acceptable materials according to EU Inert landfill criteria. However, the dependence of pH on the release of As, Cr, Mo, Sb, Se and V has been studied, due to they are critical in the wastes. From the results obtained, no difference was observed between the alkaline activators used, commercial reagents versus wastes on the pH-dependent leaching of As, Cr, Mo, Sb, Se and V. The leaching data will be used to develop a geochemical speciation model that will allow an in-depth assessment of the leaching to predict the long-term impact.

Keywords

Alkali-activated materials (AAMs); Leaching Construction Materials; Electric Arc Furnace Slag (EAFS); Environmental Impact;.

VALORISATION OF MUNICIPAL SOLID WASTE INCINERATION (MSWI) FLY ASH IN CEMENT

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ABSTRACT

The use of waste as supplementary cementitious materials (SCMs) in cement manufacturing is well known and regulated by law. The main SCMs used are fly ash from coal-fired power plants, blast furnace slag and silica fume. However, the availability of some of these wastes such as fly ash in some countries is limited due to the gradual elimination of coal-fired power plants. Nevertheless, there are other wastes such as ash from municipal waste incineration which are stockpiled in landfills that could be used in the construction industry. The use of fly ash from Municipal solid waste incineration (MSWI) ash in construction could provide local solutions to for the valorisation of these wastes. However, these ashes normally present undesirable components (high concentration of heavy metals, dioxins and soluble chlorine salts), so their use is currently a challenge due to possible concerns about toxicity for living organisms and contamination of the environment. In this work, two types of ash currently produced in a Spanish municipal waste incinerator have been characterized. These MSWI ashes have subsequently been used in the manufacture of cements with substitution levels of 30% and 50%. Their mechanical strengths have been determined; the reaction products have been characterized by XRD and microscopy. Finally, the possible leaching problems have been evaluated by the TCLP test.

Keywords

municipal solid waste incineration (MSWI) fly ash, valorization; blended cements, environmental impacts

PREPARATION AND CHARACTERIZATION OF CHITOSAN/MAGNETITE ADSORBENT BEADS AND THEIR EVALUATION ON CAFFEINE REMOVAL FROM AQUEOUS SOLUTION

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ABSTRACT

The rapid population growth, along with the expansion of industries such as agrochemicals and pharmaceuticals, has led to a critical environmental problem: the contamination of water bodies with emerging contaminants. These contaminants (e.g., pharmaceuticals, pesticides, textile dyes, flame retardants, and microplastics) are characterized by their high persistence and resistance to degradation, posing a significant challenge to conventional water treatment processes which lack the capacity to effectively remove them. Even at very low concentrations, these biologically active substances can adversely affect human health and aquatic ecosystems, causing chronic mutagenic, genotoxic, and ecotoxic effects. Consequently, there is an urgent need to develop innovative and sustainable solutions that not only achieve effective removal of these compounds but also minimize the environmental impact associated with treatment processes. Removing emerging contaminants from water through adsorption has gained significant attention in recent years. Adsorption, besides being an effective method for removing these chemical compounds, provides the benefit of enabling the use of low-cost, environmentally friendly biomaterials for synthesizing adsorbent materials. Biomass waste generated by the agri-food and fishing sectors can be utilized and valorized to produce bio-adsorbents applicable to the purification of water contaminated with emerging pollutants. One such example is chitosan, a biopolymer obtained from shrimp industry waste, which possesses exceptional properties such as high biocompatibility, biodegradability, and non- toxicity. In this study, adsorbent beads based on chitosan modified with magnetite were developed. The modification enhanced the adsorption capacity and structural stability of chitosan and enabled easy separation and recovery of the adsorbent beads due to their magnetic properties. The performance of the prepared adsorbent was evaluated using caffeine, one of the most abundant active pharmaceutical compounds in the environment, as a model pollutant. The adsorbent material was synthesized using the phase-inversion precipitation technique, and the synthesis conditions were optimized using a full factorial (2^3) design to maximize its adsorption capacity. The studied variables were the crosslinking agent (glutaraldehyde versus sodium tripolyphosphate), the drying method (forced-air oven versus freeze-drying), and the chitosan-to- magnetite ratio (1:1 versus 1:1.25). The caffeine concentration was quantified using high-performance liquid chromatography (HPLC) with a C18 column as the stationary phase and a 90:10 water-to- acetonitrile solution as the mobile phase. The optimal adsorbent was characterized using Fourier- transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), and scanning electron microscopy (SEM). Furthermore, its point of zero charge was determined by the pH drift method. The adsorbent performance was also assessed through batch adsorption tests, analyzing the effect of pH. Moreover, adsorption isotherms at 25°C, 35°C, and 45°C, adsorption kinetics, and adsorbent reuse over multiple regeneration cycles were determined. Additionally, fixed-bed continuous experiments were conducted to evaluate the effect of flow rate on adsorption parameters. The analysis of the experimental results revealed that optimal synthesis conditions were obtained using sodium tripolyphosphate as the crosslinking agent, freeze-drying as the drying method, and a 1:1 chitosan-to-magnetite ratio. Under these conditions, a caffeine removal efficiency of 90.5% was achieved after 24 hours, corresponding to an adsorption capacity of 29.16 mg/g. ANOVA of the data showed that the crosslinking agent and its interaction with the drying method significantly influenced the adsorption capacity, being the combination of sodium tripolyphosphate with freeze-drying the most favorable configuration for enhancing the adsorbent's performance. In this presentation, we will further detail the results obtained from batch tests, including adsorption isotherms and kinetics and the complete material characterization. Furthermore, we will discuss the findings from continuous operation studies, demonstrating the potential of this adsorbent as a sustainable and waste-valorizing solution to address a critical environmental issue that significantly impacts public health and contributes to the deterioration of aquatic ecosystems.

Keywords

Emerging contaminants, adsorption, chitosan, waste valorization

SELECTIVE PRECIPITATION OF GOLD FROM ELECTRONIC WASTE LEACHATE

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ABSTRACT

E-waste is a source of valuable base and precious metals, making its exploration a key step in reducing the environmental impact of modern electronics and establishing a circular market for critical and rare materials. Gold is one of such materials present in e-waste in greater concentrations than the primary ores from which it is mined, providing a strong justification for its recycling. In this work, the use of a commercially available quaternary ammonium salt as a precipitating agent for the selective recovery of gold from an aqua regia leachate from electronic waste was investigated. The precipitation was optimized considering several factors, with the precipitant to gold molar ratio and acid concentration identified as key factors. Optimized conditions using millimolar concentrations of the precipitating agent were applied to a real leachate sample of computer printed circuit board, resulting in a final product with a metallic content of over 90% gold and yield of 64%. The technique presented herein allows for the selective separation of gold using relatively simple materials and techniques with a lower reagent use than what is required with other gold separation techniques.

Keywords

Hydrometallurgy; Precious metals; Printed circuit board, Precipitation; Circular economy

DUAL RECOVERY OF MINERAL NUTRIENTS AND ORGANIC COMPOUNDS FROM SWINE SLURRY USING ELECTRODIALYTIC PROCESS

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ABSTRACT

The transition towards a circular economy in agriculture critically depends on closing nutrient loops. Currently, farmers spend approximately 30% of their production costs on fertilizers alone. Traditional mineral fertilizers rely on extracting limited natural resources – phosphate rocks for phosphorus, sylvinite for potassium, and energy-intensive processes to convert atmospheric nitrogen into ammonia. This linear "take-make-dispose" model needs transformation, and animal waste streams offer a promising solution as valuable secondary nutrient sources. Recent innovations in waste valorization demonstrate how livestock byproducts can be transformed into valuable resources. The electrodialytic (ED) technology represents a breakthrough in this field, enabling the extraction of essential plant nutrients (N, P, Ca, K, Mg) from animal waste such as swine slurry to create bio-based fertilizer alternatives. This sustainable approach uses minimal electrical current combined with ion exchange membranes for selective nutrient concentration. In this process, the anions (e.g. PO43-) present in the matrix will move towards the positively charged pole, crossing a selective anion exchange membrane, and the cations (e.g. NH4+, K+) will move towards the negatively charged pole, passing through a selective cation exchange membrane. While previous research focused primarily on mineral nutrient recovery, our study expanded the scope to examine organic compounds throughout the ED process. Using swine slurry in batch experiments, we achieved complete phosphorus recovery (100%) and substantial nitrogen recovery (57%). Importantly, we identified valuable organic compounds in both the original slurry and recovered solutions. The plant growth regulator 2,6-Diisopropylnaphthalene was present in the initial slurry (0.02%) and became concentrated in both electrode solutions (0.22%). Additionally, Junipene, a natural compound found in Juniperus and Stoebe essential oils, appeared in the processed solutions (0.03%). This research demonstrates ED's potential as a circular economy tool that not only recovers essential mineral nutrients but also concentrates beneficial organic compounds. The discovery of these bioactive molecules in the recovered matrix opens new possibilities for creating enhanced bio-based fertilizers, though their agricultural benefits require further field testing. This dual recovery of minerals and organic compounds represents a significant step toward more sustainable and resource-efficient agricultural practices.

Keywords

Waste valorization; Nitrogen recovery; Phosphorus recovery; Green fertilizers; Sustainability.

OPTIMIZATION OF THE COBALT EXTRACTION PROCESS FROM USED LITHIUM-ION BATTERIES

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ABSTRACT

Lithium-ion batteries (LIBs) are essential as portable energy storage sources. Their increasing use amplifies the demand for efficient recycling technologies. [1][2][3].The recovery of valuable metals such as nickel (Ni), cobalt (Co), manganese (Mn), and lithium (Li) is critical both for economic and ecological reasons. However, the diversity of batteries composition makes total recovery difficult through a single process. [2][4][5]. Due to the high metal concentrations in LIBs, they constitute a relevant secondary source. The combination of mechanical methods with hydrometallurgical techniques has proven to be an effective solution for their recovery.[6][7].

This study aimed to develop a process to optimize the extraction of Co from inorganic leachates (obtained from the treatment of lithium nickel manganese cobalt oxide cathodes with hydrochloric acid) using the solvent extraction method with the extracting agent Cyanex 272 in dodecane. Metal concentrations were quantified using Total Reflectance X-ray Fluorescence (TXRF) spectroscopy or Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) technique.

The study started with a synthetic solution containing Co and Ni. Various aqueous-to-organic phase ratios were tested to determine the optimal conditions for Co extraction. The results demonstrate successful Co recovery from used LIBs, with the best phase ratio identified for selective Co extraction. In addition, the study of the effect of pH indicated the ideal range for extracting the metals involved revealed an ideal range for metal extraction between 4.5 and 6. To better simulate the diverse composition of LIBs and its impact on the process under study, the contamination of the synthetic Co and Ni solution with aluminium (Al), iron (Fe), and copper (Cu) was also tested, providing further insight into the process optimization.

Keywords

Cobalt, Battery Recycling, solvent extraction, metal, Circular economy.

HYDROGEN CAPTURE FOR ENERGY SUPPLY IN ELECTRODIALYTIC RECOVERY OF P FROM SEWAGE SLUDGE ASH

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ABSTRACT

This research explores the application of electrodialytic extraction from sewage sludge ash (SSA) with a focus on utilizing the hydrogen gas produced at the cathode for energy supply. SSA originates from the incineration of sewage sludge from wastewater treatment. It contains both hazardous compounds (e.g., heavy metals) and agriculturally valuable elements (e.g., phosphorous). This study utilizes an electrodialytic setup involving the application of an electric DC field and the connected electrode reactions. Under varying conditions, the hydrogen production and P extraction are co-optimized. The generated hydrogen was captured and utilized in a Proton Exchange Membrane (PEM) fuel cell to produce electricity, demonstrating an innovative approach to waste-to-energy conversion. Experiments were conducted using two setups: a two-compartment (2C) and a three-compartment (3C). The 2C design included an additional ion exchange membrane to facilitate ionic migration and prevent metal precipitation on the cathode electrode surface. An electrolyte solution of NaNO3 with different pH and a platinum-coated electrode were tested. Applied currents ranged from 50 mA to 100 mA. Results showed that NaNO3 0.01M solution in the 2C setup gave the highest hydrogen production with a peak voltage of 875 mV in the PEM fuel cell. Moreover, the 2C setup performance in P removal was considerably more efficient than the 3C setup. These findings highlight the significance of an additional ion exchange membrane in reducing ion precipitation and optimizing both hydrogen capture and metal removal. The findings further revealed that hydrogen production was influenced by multiple factors: electrode material, electrode type, pH, and applied current.
This study explores the feasibility of integrating hydrogen recovery into the electrodialytic recovery process. It offers a sustainable strategy for utilizing SSA, transforming waste into renewable energy, and simultaneously extracting valuable elements such as P.

Keywords:

electrodialytic remediation, hydrogen, sewage sludge ash, heavy metals, cathode, electrolyte

SUSTAINABLE ETHYLENE GLYCOL PRODUCTION FROM CELLULOSE OVER FRUIT PEEL WASTE-DERIVED CARBON SUPPORTED Ni-W CATALYSTS

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ABSTRACT

The efficient use of renewable biomass is crucial for reducing CO2 emissions. Direct conversion of cellulose, the most abundant component of lignocellulosic biomass, to ethylene glycol (EG) is a promising pathway [1-2]. EG plays an important role in the synthesis of high-value chemicals with high market demand, such as polymers (e.g., polyester fibres), antifreeze products and cosmetics [3]. On the other hand, to address the pressing issue of waste accumulation, the synthesis of carbon materials from various waste sources has become a prominent area of research [1]. In particular, biomass-derived carbons have attracted considerable attention as a sustainable alternative to expensive commercial carbon catalyst supports, such as carbon nanotubes [4]. Therefore, this work focused on the synthesis of low-cost food waste-derived carbon supported Ni-W catalysts for the sustainable production of EG directly from cellulose.

Fruit peel-derived carbons were synthesised by hydrothermal carbonisation (HTC) of banana and orange peels, followed by a thermal treatment under N2 atmosphere for 2 h at 700 °C to develop the porosity of the resulting materials [5]. In addition, a carbon support was prepared by hydrothermal polymerisation of glucose followed by thermal treatment under the same conditions as above, resulting in the sample CG (carbonised glucose). Subsequently, Ni-W catalysts (20 wt.% Ni and 10 wt.% W) were prepared by incipient wetness impregnation on the previously carbonised banana (CB), carbonised orange (CO) and CG. The catalysts were evaluated in the one-pot hydrolytic hydrogenation of cellulose, for which 300 mL of water, 750 mg of ball-milled cellulose and 300 mg of catalyst were added to a 1000 mL stainless steel Parr reactor under stirring at 300 rpm. After heating under nitrogen to 205 ºC, the reaction was initiated by switching to hydrogen (50 bar) and the reaction mixture was analysed by high performance liquid chromatography (HPLC) and total organic carbon (TOC). The properties of the materials and catalysts were characterised by various techniques, such as N2 adsorption, ICP, TG, XPS, Raman spectroscopy, TEM, SEM, EDS and XRD.

Figure 1 shows the results of cellulose conversion and EG yields after 5 h. The synthesised catalysts showed remarkable activity in the conversion of cellulose (100 %), resulting in an impressive EG yield of up to 50 % over Ni-W/CG. Among the two waste-based catalysts, Ni-W/CB showed the best performance, allowing the production of about 45 % of EG in only 5 h. Furthermore, this catalyst showed an admirable reusability, resulting in similar EG yields during four consecutive runs.

Keywords

food wastes valorisation; hydrolytic hydrogenation; Ni-W catalysts; ethylene glycol

CATALYTIC CONVERSION OF LDPE POWDER INTO SUSTAINABLE AVIATION FUEL: A PATHWAY TO CIRCULAR ECONOMY

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ABSTRACT

The transport sector consumes approximately one-third of the world's total energy, with the majority derived from oil. Transition to renewable fuels can drastically reduce greenhouse gas emissions and provide a sustainable alternative to petroleum-based fuels. Among these, sustainable aviation fuel (C8-C16) – produced from waste – holds great promise, potentially reducing emissions by up to 80 % compared to fossil fuels. However, current technologies remain underdeveloped, and advances in efficient waste-to-fuel conversion systems are needed to combat climate change and secure the future of upcoming generations [1-5]. The development of integrated systems that convert waste into aviation fuel that meets stringent quality standards is, therefore, critical. The aim of this study was to develop heterogeneous catalysts for the production of aviation fuels from commercial low-density polyethylene (LDPE) powder. LDPE powder with two size ranges (from Goodfellow) was used as substrate: i) particles with a maximum size of 300 μm (LDPE300) and ii) particle sizes of 300-600 μm (LDPE600). Ru (2.5 wt.%) was supported on original carbon nanotubes (CNT, Nanocyl-7000) and CNT oxidised with HNO_3 (CNTox), using the incipient wetness impregnation method. After drying at 110 ºC overnight, the materials were thermally treated under N2 at 250 ºC for 3 h and subsequently reduced under H2 at the same temperature for 3 h. The catalysts were characterised by various techniques, such as nitrogen adsorption at -196 ºC, temperature programmed reduction, determination of total acidity by chemical titration, inductively coupled plasma-optical emission spectroscopy, elemental analysis and X-ray diffraction. The catalytic performance was evaluated in a 100 mL stainless steel Parr batch reactor. In a typical run, 5 g of LDPE and 0.5 g of catalyst were loaded into the reactor. After purging the reactor with N2, followed by H2, the reactor was set to an initial H2 pressure of 40 bar and operated at 300 ºC with stirring at 400 rpm for 4 h. The liquid products were analysed by gas chromatography-mass spectrometry (GC-MS) using a ZB-5MSPlus column and docosane as the internal standard. The results are summarised in Table 1. Although a high conversion of 90.6 % could be obtained over Ru/CNT, the carbon range of the products obtained was between 7 and 35. In contrast, when Ru/CNTox was used, its acidity favoured cracking, yielding products with carbon chain lengths ranging from 7 to 28 and achieving a high conversion of 95.8 %. Furthermore, although the product distribution was similar in both tests, the substrate's particle size significantly affected its conversion.

Table 1 – Catalytic results obtained after 4 h of reaction.

Substrate	Catalyst	Conversion (%)	Products obtained
LDPE300	Ru/CNT	90.6	C7-C35
DPE300	Ru/CNTox	95.8	C7-C28
LDPE600	Ru/CNTox	43.1	C7-C28

Keywords

Plastic waste valorisation, one-pot process, heterogeneous catalysts, jet fuel

AGRICULTURAL WASTE APPLIED TO MORTAR AND ITS POTENCIAL FOR 3D CONCRETE PRINTING

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ABSTRACT

The growing demand for new housing and infrastructure has fuelled the expansion of the construction industry, which contributes significantly to environmental impacts, especially due to the intensive use of cement and sand. The cement industry is responsible for global CO_2 emissions of between 5% and 8% annually, as well as consuming large amounts of energy and relying on the intensive extraction of raw materials for its production. The extensive exploitation of essential natural resources, such as sand, contributes to environmental degradation, generating problems such as soil erosion, flooding, water pollution, periods of drought, destruction of ecosystems, as well as market shortages and price fluctuations. To mitigate these impacts, there is a need for more sustainable alternatives, such as supplementary cementitious materials, recycled materials, demolition and construction waste, industrial and agricultural waste, among others. These materials can be used to replace cement or sand, or incorporated into cement mixtures. Among these possibilities, the use of agricultural waste, which also poses environmental risks due to improper disposal, has great potential. As well as mitigating environmental impacts and being able to replace materials or be incorporated into the mix, this waste can improve the material's properties. Although there are already studies on the use of agricultural waste in mortars, few refer to the use of this waste in conjunction with 3D printing in concrete (3DCP) technology. 3D concrete printing has established itself as an innovative technology with a strong technological, sustainable and social appeal, positioning itself as an ally to the construction industry in mitigating impacts. It offers benefits such as waste reduction, reduced use of raw materials, lower costs, greater construction efficiency and the possibility of creating more complex and organic structures. However, this technology requires large quantities of materials for printing, resulting in environmental impacts and an increase in the ecological footprint associated with the production of mortars. Thus, incorporating agricultural waste into the composition of these mortars could represent a viable alternative for reducing material consumption, as well as potentially improving the rheological properties of the cement required for 3D printing in concrete without causing additional environmental impact. The aim of this work is to compile information from studies on agricultural waste in cementitious matrices, analysing its potential for application in 3D printing in concrete. The research also seeks to identify existing studies that address the behaviour of this waste in the 3D printing technique and evaluate its performance. The research will be conducted using the Scopus, ScienceDirect and Web of Science databases, analysing studies published between 2018 and 2024. The search terms will include: 'agricultural waste', 'cementitious materials', '3D concrete printing', '3DCP' and 'sustainability'. This analysis aims to evaluate the feasibility of incorporating agricultural waste into cement mortars and support the identification of the most suitable agricultural waste for 3D printing, so that in the future it will be possible to study it empirically in practice. In this way, we hope to assist researchers and professionals identify these materials, promoting sustainability in the construction sector and broadening the portfolio of available alternatives.

Keywords

Agricultural Waste, 3D Concrete Printing (3DCP), Mortar, Sustainability, Cementitious Materials

PACKAGING, AND EXPLOSIVES AND PYROTECHNICS WASTE BALANCING SAFETY AND WASTE POLICIES

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ABSTRACT

In the life cycle of explosives and pyrotechnics, disposal operations become necessary once their expiration date has passed. Similarly, for explosive or pyrotechnic waste generated during daily production it is mandatory safety disposal to mitigate risks. Additionally, the packaging used for transporting and handling these materials can become contaminated, posing significant challenges to packaging waste management operations. European environmental policies for waste and packaging waste management encourage manufacturers and end-users to prioritize reuse, recycling, or biological and energy recovery. As of January 1, 2025, it became mandatory in Portugal to create a management entity constituted by the manufacturers of the product or packers of a specific flow of packaging to carry out, directly or indirectly, the collection, transportation and storage, and preliminary sorting of waste from its own collection network. This study aims to assess the feasibility of applying waste treatment and management practices, as outlined by general legislation for manufactured products, to explosive and pyrotechnic waste and their packaging. With this purpose, a survey was conducted on waste management practices and explosives packaging management across several European countries for a comparison with the practices and regulations in Portugal. The results indicate that open burning and detonation are the most employed methods for the disposal of explosives waste and explosives packaging. To determine the environmental impact of this practice it is estimated the number of explosives and pyrotechnics packaging items placed on the market annually. Furthermore, this paper explores the conflict between the waste management legislation, integrated rural fire management policies, and the safety regulations governing explosives and pyrotechnics for civilian use.

Keywords

Explosives and pyrotechnics, packaging, safety, waste management.

ACIDOGENIC FERMENTATION OF BIOWASTE COUPLED WITH A GAS PERMEABLE MEMBRANE TO PRODUCE A VFA-RICH LIQUID WITH HIGH C/N RATIO FOR POLYHYDROXYALKANOATES PRODUCTION

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ABSTRACT

Anaerobic bioprocesses driven by mixed microbial cultures (MMCs) can be used to produce valuable bioproducts from a wide range of organic waste. Volatile fatty acids (VFAs) can be produced by MMC acidogenic fermentation treating biodegradable organic wastes, such as the organic fraction of municipal solid waste (OFMSW). OFMSW could lead to VFA yields in the range of 0.32-0.82 g COD_{VFA}/g VS. Fermentation liquids usually have high total ammonium nitrogen (TAN) content, which limit most downstream applications such as the synthesis of polyhydroxyalkanoates (PHAs). This study evaluates (i) the acidogenic fermentation of OFMSW to obtain a VFA-rich liquid, (ii) the TAN recovery from the fermentation liquid using a gas permeable membrane (GPM) and (iii) PHA production using a nitrogen-spent VFA-rich fermentation liquid, simulating diluted OFMSW fermentation liquid previously treated by a GPM to reach a high C/N ratio. Source-sorted OFMSW was collected in a mechanical-biological treatment plant of Barcelona Metropolitan Area and meshed at 5 mm before its use. It was fermented in a semi-continuous lab-scale acidogenic fermenter (1.75 L) at 35 ºC, hydraulic retention time (HRT) of 4 days, and 9-17 g VS/(L d) of organic loading rate (OLR). The liquid fraction of the fermentation effluent was treated in a GPM commercial contactor to recover TAN as $(NH_4)_2SO_4$ using diluted H_2SO_4 as trapping solution. Afterwards, an aerobic sequencing batch reactor (SBR) of 3.75 L was operated in 6 h cycles at 35 ºC, HRT of 1.1 days, solid retention time of 4.2 days and an OLR of 3.1 g COD_{VFA}/L. The SBR had uncoupled feeding of VFA-rich synthetic wastewater (3.5 g COD_{VFA}/L; 52% acetic, 22% propionic and 26% butyric acids on COD basis) and a $(NH_4)_2SO_4$ solution (ratio 1 g $N\text{-}NH_4^+$/10 g COD_{VFA}) to select PHA-accumulating biomass. The PHA content of the purged biomass was subsequently increased in an aerobic batch reactor (1 L and 35 ºC) using five 80 mL dosages of the synthetic VFA-rich wastewater, taking 3 h per accumulation cycle. OFMSW acidogenic fermentation produced a stable VFA-rich liquid (32-44 g COD_{VFA}/L), mainly dominated by acetic, propionic and butyric acids. VFAs accounted the 52-82% of the soluble COD of the fermentation effluent, which had circumneutral pH values and a high TAN content (3.3-5.9 g $N\text{-}NH_4^+$/L). Its nitrogen content was successfully recovered as $(NH_4)_2SO_4$ using a commercial GPM, yielding TAN recoveries above 94% and producing a concentrated $(NH_4)_2SO_4$ solution with high purity. Finally, PHA contents on the purged biomass from the selection SBR reached 20-24% PHA (VSS basis). In the subsequent accumulation tests, the PHA content was increased up to 52-55% (VSS basis). To sum up, a stable VFA-rich effluent was obtained in a mesophilic acidogenic fermenter treating OFMSW at an HRT of 4 days. A GPM contactor efficiently recovered more than 94% of the TAN content of the fermentation liquid. PHA-accumulating biomass was successfully selected using an aerobic SBR with uncoupled VFAs and TAN feeding and its PHA content was increased in a subsequent aerobic batch accumulation reactor up to 50-55% (VSS basis).

Keywords

Acidogenic fermentation; Gas-permeable membrane; Nitrogen recovery; Organic fraction of municipal solid waste; Polyhydroxyalkanoates; Volatile fatty acids.

MADEIRA WINE COMPANY'S PATH TO CARBON MITIGATION: STRATEGIES AND PROGRESS IN GHG EMISSION REDUCTIONS (2021–2023)

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ABSTRACT

The wine industry faces increasing pressure to adopt sustainable practices due to its environmental impact, particularly concerning greenhouse gas (GHG) emissions. Viticulture and winemaking processes contribute significantly to carbon footprints through energy consumption, transportation, and agricultural inputs. In this context, the Madeira Wine Company (MWC) has prioritized sustainability as a core strategic objective, aligning with global efforts to mitigate climate change and promote environmental stewardship.

MWC conducted a comprehensive analysis of its GHG emissions for 2021–2023, adhering to the GHG Protocol and ISO 14064-1:2018 standards. Using 2022 as the baseline year post-pandemic, MWC achieved a 5% reduction in total emissions in 2023, lowering emissions from 2,149 tCO_2e to 2,039 tCO_2e, mainly through improved logistics and supply chain management.

Key sustainability measures include 100% cover cropping, livestock integration for weed control, oak barrel reuse, and waste valorisation through composting organic vinification waste. Additionally, 30% of MWC's energy demand is met by solar power, with plans to increase this to 35% by 2025, reducing reliance on the local energy grid.

MWC has also implemented waste management strategies to minimize environmental impact. Organic waste from vinification is composted and repurposed as natural fertilizer in vineyards, reducing reliance on synthetic inputs. Efforts to reduce packaging waste include optimizing material use and increasing the recyclability of packaging components. The company is exploring innovative waste-to-value opportunities, such as using vinification waste for cover cropping.

Scope 1 emissions rose by 2% (132 tCO_2e) due to stationary combustion and biogenic fermentation. Scope 2 emissions increased by 10%, reflecting ongoing dependence on external electricity. However, Scope 3 emissions from the value chain dropped by 7% (1,744 tCO_2e) due to supply chain optimizations.

Carbon intensity per litre of wine produced fell by 3%, from 2.14 to 2.08 $kgCO_2e/L$, reflecting operational efficiencies. Conversely, emissions per litre of finished wine rose 15% to 3.07 $kgCO_2e/L$ due to lower production volumes.

Natural carbon removals increased by 3% (30 tCO_2e), primarily through carbon sequestration by vines and ground cover, emphasizing the role of natural systems in emission mitigation.

Future strategies include expanding renewable energy capacity and adopting precision viticulture and oenology technologies to optimize resource use, minimize waste, and enhance energy efficiency. MWC also aims to promote sustainability practices across its supply chain.

MWC's integrated sustainability initiatives demonstrate measurable progress in reducing its carbon footprint, positioning the company as a leader in environmentally responsible winemaking.

Keywords

Carbon footprint, wine industry, GHG Protocol, circular economy, waste valorization, sustainable agriculture, Madeira Wine.

INNOVATIVE COVER CROP TECHNIQUES: EXPLOITING WINERY WASTE FOR SUSTAINABLE VITICULTURE IN MADEIRA – THE VITACOB PROJECT

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ABSTRACT

Madeira wine is exclusively produced in the Madeira Archipelago, which faces multiple increasing challenges, including pest and disease control, soil erosion, water management, and climate change. The Madeira Wine Company (MWC), with over 200 years of history, produces high-quality wines while prioritizing sustainability in its viticulture practices. As part of its commitment to environmental stewardship in a changing planet, the company integrates R&D to continuously enhance vineyard management and ensure long-term ecological and economic viability. For example, the VITACOB project explores innovative, sustainable vineyard management strategies that integrate winery waste, contributing to the company's mission of excellence and environmental responsibility in the Autonomous Region of Madeira. Adopting organic practices increases pest vulnerability, requiring non-chemical management. Mountainous terrain and heavy rain cause soil erosion, necessitating soil conservation. Irregular rainfall demands optimized irrigation. Diverse climates complicate grape production, needing adaptive practices. High labour costs challenge sustainability, making cost-effective solutions essential. Biodiversity in vineyards is crucial for ecosystem balance.

Using a circular economy approach, the VITACOB project tests the potential of winery waste materials, such as grape marc, as cover crops to improve Madeira vineyard sustainability. By integrating waste materials into vineyard management, the project seeks to enhance soil health, improve water-use efficiency, reduce soil erosion, increase biodiversity, and lower operational and labour costs. This research fills a critical gap by testing the viability of winery waste as cover crop material under Madeira's unique edaphoclimatic conditions.

Following a thorough review of cover crop techniques, experimental plots were established in a Bual vineyard at Quinta de Santa Luzia. The study is currently in its second phase, monitoring key parameters such as weed growth, soil quality, agronomic performance, biodiversity, soil microorganisms, water usage, and soil erosion. The third phase, set for March to June 2025, covering the vineyard budding to flowering stage, will include continued monitoring and laboratory testing to assess the effectiveness of winery waste as cover crops. The final phase, from July to September 2025, covering the ripening and harvesting stages, will focus on data analysis and formulating practical recommendations based on the findings.

In conclusion, the VITACOB project will provide valuable insights into the use of winery waste for sustainable vineyard practices in RAM. By offering circular economy-based innovative solutions for vineyard management, this project aims to influence agricultural practices in Madeira and beyond, contributing to the broader goals of environmental sustainability and economic resilience in viticulture.

Keywords

Winery Waste, Cover Crop Techniques, Sustainable Viticulture, Madeira Vineyards, Soil Health, Environmental Sustainability

MICRO-AERATION TO IMPROVE ANAEROBIC DIGESTION OF CATTLE SLURRY

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ABSTRACT

Effective management of cattle slurry is essential to mitigate its environmental impact, while simultaneously recovering valuable resources and promoting nutrient recycling. Anaerobic digestion (AD) offers a sustainable solution, allowing energy recovery through biogas production, which can be upgraded to biomethane as a renewable alternative to natural gas. Beyond its energy benefits, AD significantly reduces the organic load and greenhouse gas emissions associated with cattle slurry. Nevertheless, AD of cattle slurry is often constrained by low hydrolysis rate and is prone to inhibition by ammonia, H_2S or volatile fatty acids (VFA) accumulation.

In recent years, micro-aeration— consisting of controlled introduction of small amounts of oxygen (O_2) in AD process—has emerged as a promising approach to enhance microbial activity, promote the degradation of recalcitrant compounds, and improve methane yields. This study aims to investigate the effect of micro-aeration on AD of cattle slurry, as a strategy for process improvement. Cattle slurry samples were collected from a livestock farm in the central region of Portugal. Physical-chemical characterization of cattle slurry was carried out. Biochemical methane potential (BMP) assays were performed under strictly anaerobic and micro-aeration conditions (single dosing of air, corresponding to 2% O_2 in the headspace). BMP values (expressed as volume of methane at standard temperature and pressure conditions per mass unit of volatile solids, VS) of 292±12 L/kg and 232±9 L/kg were obtained in the anaerobic and micro-aerobic assays, respectively. In terms of methanization percentages, 57±2% and 45±2 of the chemical oxygen demand (COD) was converted to methane, respectively. Two semi-continuous bioreactors were operated, one under strict anaerobic conditions and the other with micro-aeration (12.5 mL/(L·d) O_2, by air pulses during feeding) at hydraulic retention time of 20 and 40 days. Cumulative biogas production, methane content, pH, COD, total and volatile solids (TS and VS), and VFA were monitored along the time. Both reactors achieved similar methane production percentages (around 60%) throughout the process. However, micro-aeration proved essential for higher total and soluble COD removal and TS reduction. On average, micro-aeration led to 6% and 16% higher total and soluble COD removal, respectively, compared to strictly anaerobic conditions. In terms of TS, micro-aeration increased their reduction in 2%. The addition of nanobubble (NB), another innovative micro-aeration technology, was also investigated. Characterized by a high interfacial area and prolonged stability in water (lasting over two weeks), nanobubbles enable efficient gas transfer. A new set of BMP assays was then performed using cattle slurry and NB. Methane yields of 388±7 and 343±7 L/kg (and methanization percentages of 64±1% and 56±1%) were attained in the assays with NB and in the controls, respectively. These results underscore the potential of NB technology to enhance AD performance. The applicability of NB technology In semi-continuous bioreactors is currently ongoing (20 days of operation). So far, micro-aeration has increased total and soluble COD removal in 7% and 2%, respectively, compared to strictly anaerobic conditions. TS and VS removal was increased as well, in 8% for both parameters. New data is expected soon, to validate the effectiveness of this approach and pave the way for sustainable livestock waste management solutions.

Keywords

Anaerobic Digestion, Micro-aeration, Cattle slurry; Sustainability; Biomethane

WASTE TRADE AND CIRCULAR ECONOMY – EXAMINING THE PLASTIC WASTE TRADE IN AFRICA

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ABSTRACT

Global waste trade is a significant and fast-growing economic activity, valued at about 410 billion dollars. The typical practice is 49oznan4949icz4949 by high waste recovery and exports from countries in the Global North and high waste 49oznan4949icz and imports from countries in the Global South. Due to regulatory and enforcement frameworks, the absence of adequate waste recovery infrastructures, and a fragile management system, waste trade has not been delivering its benefits to the Global South and has been pointed out as the leading cause of the growing and pervasive pollution. Africa has long been the dumping ground for legal and illegal waste imports, worsening the continent's environmental and public health conditions. This study quantitatively examines the African waste trade, focusing on plastic waste. Africa is reported to have the most significant share (after Southeast Asia) of land-based and ocean plastic pollution, even though the continent presents a relatively small global plastic consumption. In addition, after the PR China waste import ban, projections indicate Africa will be a potential new import destination by 2025. By presenting the global trade flows of plastic waste centring Africa, the expectation is to clarify governance, resource and sustainable waste management implications from a circular economy perspective.

Keywords

Waste trade; plastic pollution; Global South; circularity; Africa

CIRCULAR ECONOMY SYNERGIES: LEVERAGING AGRIFOOD WASTE FOR SUSTAINABLE SHOE MATERIALS

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ABSTRACT

The shoe industry faces a critical need for more sustainable practices to reduce its environmental impact not only in terms of processes and generated waste but also in its dependence on virgin raw materials. To address the last, there is an unconventional synergy that can prove to be disruptive. A synergy with the agrifood sector. While cascading use and food first principles mean that priority should be given to food and feed applications, there are several wastes generated by this sector that are not suitable for either application, and these are the ones that could be of particular interest for use to reduce raw material dependence by the shoe industry. Cork is a sustainable material commonly used in the footwear sector due to its lightweight, cushioning, and thermal insulating properties. However, there is increasing interest in enhancing it by incorporating additional materials derived from industrial byproducts. Beyond sustainability benefits, these modifications can potentially improve moisture absorption, alter microbial survival, and aesthetic design features, making them ideal for shoe insoles and similar applications where comfort and hygiene are critical. Thus, this study explores the potential of incorporating diverse industrial byproducts into cork-based shoe materials to improve both functional and design aspects, contributing to sustainability strategies within the footwear industry. It studies the integration of various industrial byproducts into cork-based composites, focusing on the materials' structural and microbiological performance. The structural modifications resulting from the incorporation of these byproducts were analysed using Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance (FTIR-ATR), Near-Infrared Spectroscopy (NIR), and Scanning Electron Microscopy (SEM) to facilitate the identification of chemical changes and microstructural alterations that may influence the functional behaviour of the modified cork composites. From a microbiological perspective, the study evaluated the behaviour of these modified materials in terms of moisture absorption and microorganism survival, given their intended use in shoe insoles where moisture management is essential. Initial microbiological tests indicated no significant differences in the microbial load at the starting point across the tested samples. However, the incorporation of industrial byproducts resulted in variations in water absorption properties and in microorganism survival rates, suggesting potential improvements in antimicrobial performance when certain byproducts were included.
The results demonstrated that the incorporation of industrial byproducts Into cork-based materials was successful, leading to differences in structural and functional properties. The modifications allowed the attainment of functional materials, while maintaining the sustainability advantages of cork. This study underscores the potential for sustainable innovation within the footwear industry, reducing virgin material dependence and promoting circular economy practices.

Keywords

Agri-food byproducts, cork-based composites, shoe-insoles, structural analysis, microbiological analysis

EXPLORING ANAEROBIC DIGESTION FOR TEXTILE EFFLUENTS TREATMENT AND VALORIZATION

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ABSTRACT

The textile industry ranks among the largest global consumers and contributors to water pollution, making the treatment of its effluents fundamental to mitigate environmental impacts and ensure public health. However, textile effluents are particularly challenging to treat due to their complex and variable chemical composition, recalcitrant nature, and high toxicity. Conventional wastewater treatment processes with activated sludge often prove to be inefficient due to biological degradation resistance, high pollutant loads, and extreme pH values. Anaerobic digestion (AD) has shown promise in degrading recalcitrant compounds present in wastewater, though the process is slow. The application of carbon materials (CM) improves AD by facilitating electron transfer, thereby accelerating the anaerobic reduction of pollutants, which act as final electron acceptors. In this work, a textile effluent collected from the equalization tank of a textile facility was characterized regarding its physico-chemical properties and the potential of AD treatment was investigated. Prior to biodegradation assays, the impact of the textile effluent on the activity of acetoclastic anaerobic community was assessed, since this is the most sensitive group to environmental stress. The impact of activated carbo' (AC), at concentrations of 0.5 to 1.5 g/L, on effluent toxicity was also evaluated. Specific methanogenic activity (SMA) was inhibited by the effluent at concentrations between 0.25-0.5 g_{COD}/L, resulting in SMA inhibition of 18±2% and 29±3%, respectively. The application of AC neutralized effluent toxicity at all tested concentrations, rendering all samples non-toxic. Furthermore, SMA appears to be stimulated by the presence of AC at all tested concentrations. This highlights the potential of AD supplemented with CM for both treating and detoxifying textile effluents. Biochemical methane potential (BMP) assays, performed to assess the anaerobic treatment and valorization of the effluent (0.07 g_{COD}/L), revealed methane production (MP) values lower than those obtained in the blank, only with de the inoculum. However, the addition of AC or carbon nanotubes (CNT) reduced this inhibitory effect, MP remained similar to the blank (0.38 ± 0.01 L_{CH4}), demonstrating the effluent's low biodegradability. On the other hand, the addition of supplementary substrate, 4 g_{COD}/L of volatile fatty acids (VFA), acting as electron donor, improved the effluent's biodegradability and MP was similar to the control (715 ± 4 $L_{CH4}/kg_{Vsinoculum}$) across all conditions. Additionally, the initial MP rates of the effluent supplemented with VFA (87 ± 4 $L_{CH4}/kg_{Vsinoculum}$/d) were higher than those in the control only with VFA (68 ± 1 $L_{CH4}/kg_{Vsinoculum}$/d), confirming that VFA contributed to increase the effluent's biodegradability. The effect of AC and CNT became evident after three days, with MP rates Improving by 15% and 20%, respectively, compared to the conditions without CM. AC was the best-performing CM, displaying a profile similar to the control. Furthermore, at the end of the assay, approximately 60% color removal was achieved, highlighting the potential of the proposed treatment for effluent decolorization. This work opens the possibility of joining two waste streams by combining easily biodegradable residues (e.g.,from textile waste) to effluent, aiming enhance biodegradability while promoting sustainable waste treatment and simultaneous energy production in the form of biogas.

Keywords

Textile effluents, anaerobic processes, carbon materials, biochemical methane potential

ENHANCING AEROBIC TREATMENT OF TEXTILE WASTEWATER WITH A CARBON-BASED MATERIAL – COMPARATIVE STUDY WITH TWO INOCULA

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ABSTRACT

The textile industry's main concern regarding wastewater is its safe disposal. Traditionally, textile industries use either biological or chemical treatment processes, but the resulting effluents often fail to attain the required quality standards. Applying pre-treatments or integrating different methodologies may enhance the efficiency of effluent treatment processes. This study investigates the impact of using carbon materials (CM) in activated sludge to increase textile wastewater treatment efficiency. Three real textile effluents (a, b and c) were collected from the homogenization tank of three textile companies in the North of Portugal, characterized in terms of pH, COD, color, conductivity, and salinity. The aerobic batch assays were conducted in 250 mL reactors with a working volume of 100 mL, incubated at 120 rpm, at room temperature. To assess the influence of inoculum type, two different inocula (3 gTS/L) were used: one non-adapted to textile effluent and another previously adapted, i.e., (1) sludge from a municipal wastewater treatment plant (WWTP) that treats domestic wastewater and (2) sludge from a WWTP that treats a mixture of domestic and textile wastewater. Both WWTP are located in the North of Portugal. Four different batch assays were performed, in duplicate, for each of the three textile effluents: (i) Effluent+Sludge1; (ii) Effluent+Sludge1+CM; (iii) Effluent+Sludge2, and (iv) Effluent+Sludge2+CM. Effluent a and c underwent six treatment cycles (addition of new effluent) while effluent b, just five. Results demonstrated great impact with the introduction of CM into the activated sludge process, particularly by improving color removal. For effluent a, no color change was observed in the absence of CM, but approximately 80 % of color removal was achieved in the 1st cycle with CM, with either inocula. However, no further improvement was observed in subsequent cycles. For effluent b, in the presence of the CM, color removal was between 95 % (cycle 1) and 60 % (cycle 5) with inoculum 1, and between 97 % (cycle 1) and 70 % (cycle 5) with inoculum 2, in either cases outperforming the results without CM, in which decolorization ranged from 37 % (cycle 1) and 42 % (cycle 5) with inoculum 1, and from 25 % (cycle 1) and 45 % (cycle 5) with inoculum 2. For effluent c, color removal in the presence of CM averaged 90 % across the entire assay, with both inocula, achieving complete removal in the last two cycles of operation. In the absence of CM, the color of the effluent decreased by an average of 50% with both inocula throughout the assay. Similar COD removal was achieved with both inocula, regardless of the composition of the effluents and the presence or absence of CM. Samples from the initial inocula and the microbial community at the end of each cycle were collected to assess microbial community changes during the process. In conclusion, the expected enhanced performance by inoculum 2 (adapted to textile effluents) was not observed. However, irrespective of the inoculum's suitability for treating textile effluents, the addition of CM significantly improved treatment efficiency, particularly in decolorization, for all effluents.

Keywords

Textile industry; Dyeing wastewater; Activated sludge; Carbon-based materials; Color removal

STRATEGIC METALS RECOVERY FROM INCINERATED BOTTOM ASH THROUGH BIOLEACHING AND LIQUID-LIQUID EXTRACTION

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ABSTRACT

The EU aims to achieve an economy with net-zero greenhouse gas emissions by 2050. With this goal in mind, the progressive transition to a "use-reuse" economy emerges, and the demand for metals, essential for clean energies, is increasing exponentially. Copper's key properties make it a strategic metal for achieving energy transition. However, traditional mining can no longer keep pace with the growing demand for copper, increasing the need for the exploration of secondary sources such as end-of-life residues and "stocked" raw materials. A particular example is the municipal solid waste incineration ash. The most recent data (2022) shows that an average of 513 kg of urban waste is produced per capita, with 25.9 % being incinerated. This process generates ash, mainly bottom ash (IBA), an alkaline waste that, despite its environmental hazards, contains trace amounts of critical and strategical metals essential for clean energy. Bioleaching, the natural ability of microorganisms to solubilize metals, is an environmentally friendly and cost-effective technique that has been explored for the recovery of metals from secondary sources. However, conventional extraction and purification steps of pregnant leach solutions (PLS) resulting from bioleaching processes may limit the overall success of metal recovery. Liquid-liquid extraction (LLE) processes using non-ionic hydrophobic eutectic solvents (HES) are emerging and have shown promising results for the separation and recovery of metals. The versatile and tunable nature of HES, coupled with their low viscosity and lower density, makes their use as solvents advantageous not only for metal extraction but also in terms of sustainability. This study aims to develop a sustainable and economically feasible process that combines bioleaching with LLE based on non-ionic HES to selectively recover Cu and other valuable metals from low-grade matrices. Preliminary results on the optimization of the pulp density for IBA bioleaching by *Pseudomonas* spp. Were obtained, using 1.25 %, 5 % and 10 % of IBA. Remarkable bioleaching extraction efficiencies of (100 ± 24) % for Cu, (72 ± 11) % for Zn and (13 ± 1) % for Fe were achieved with 1.25 % IBA. It was observed that a lower concentration of IBA results in higher bioleaching extraction efficiencies, while higher concentrations yield PLS richer in Cu. Furthermore, separation systems consisting of the mixture of PLS with the HES composed of thymol:capric acid were evaluated for Cu separation. Several experimental conditions were analyzed, such as HES composition, pH, HES:PLS ratio and the addition of salts. The studied systems presented high selectivity for Cu, with separation factors of ~ 5 for Cu/Zn separation and ~ 11 for Cu/Fe separation.

Keywords

Waste Valorization; Copper Recovery; Bioleaching; Hydrophobic Eutectic Solvents; Municipal Solid Waste Incineration

SUSTAINABLE AMORPHOUS POROUS CARBON FOR EFFICIENT ENVIRONMENTAL CONTAMINANT REMOVAL

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ABSTRACT

The global demand for sustainable solutions has driven efforts to valorize industrial residues, such as cork stoppers, to create high-performance materials. This study develops and characterizes activated carbon (AC) derived from cork stopper waste, focusing on its efficiency in adsorbing industrial dyes under varied experimental conditions. The cork-derived AC exhibits a high surface area of 1793 m^2/g, with a balanced microporosity (0.70 cm^3/g) and mesoporosity (0.17 cm^3/g), enabling adsorption of small and large organic molecules. Adsorption kinetics for methylene blue (MB) and Reactive Red (RR) dyes showed that pseudo-second-order and Elovich models describe the process effectively. MB reached equilibrium faster (<5 minutes) due to its smaller molecular size, while RR required ~75 minutes due to mesoporous diffusion. Thermodynamic analysis revealed that MB adsorption is endothermic, favoring elevated temperatures, while RR adsorption is exothermic, suggesting physical interactions. The column adsorption system demonstrated efficient MB removal (1992 mg/g), with breakthrough times exceeding 800 minutes, outperforming RR (652 mg/g). These findings highlight cork-derived AC as a sustainable adsorbent for industrial effluent treatment, aligning environmental and operational benefits. Future studies should expand on practical applications and long-term performance in variable industrial scenarios.

Keywords

Adsorption. Activated carbon. Sustainability. Industrial waste. Effluent treatment.

SECONDARY HIGH VALUE PRODUCT SYNTHESIS BY *CHLORELLA* SP. USING WATERMELON WASTE

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ABSTRACT

Italian watermelon cultivation, covering 9,510 hectares, is highly influenced by market demand. However during September, significant quantities of watermelons become waste, decomposing naturally in the fields. The chemical composition of watermelon liquid fraction waste (WLFW) reveals an imbalanced C/N ratio. This characteristic makes WLFW a potential alternative substrate for microalgae cultivation. The unbalanced C/N ratio can induce a metabolic switch in the microalgae cell, potentially enhancing the biosynthesis of high-value secondary products. This integration could lower the cost associated with microalgae production and, at the same time, provide an in-situ waste management solution for farmers, fostering a circular approach to agricultural waste management.

The objective of this research is to explore the integration of WLFW as a substrate for microalgae cultivation, with a focus on optimizing light conditions to maximize both biomolecular and biomass production.

To assess the effects of the substrate and light irradiation, *Chlorella* sp. Was cultivated on sterilized WLFW under different LED light conditions: white light (WL) and red/blue light (RLBL).

The WLFW was applied at a 1:10 dilution, with light intensities set at 1360 lux for WL and 3012 lux for RLBL.

The results demonstrated that light irradiation significantly influenced mixotrophic cultivation outcomes. Lipid storage was recorded at 20.34 ± 0.70% under WL and 17.01 ± 1.59% under RLBL. Although lipid storage levels were lower than control conditions (33.51 ± 8.16%), the use of WLFW as a carbon source induced a metabolic shift, leading to substantial extracellular polymeric substances EPS synthesis in the medium. Previous research has highlighted the impact of light irradiation on lipid storage, with notable increases observed under red or blue lights. Contrary, in this study, the WLFW and RLBL irradiation did not enhance lipid storage but instead promoted EPS synthesis.

Keywords

Chlorella vulgaris, Watermelon liquid fraction waste, exopolysaccharides, red-blue light.

TANGO-CIRCULAR PROJECT: AN OVERVIEW OF THE TRAINING ACTIVITIES IN CIRCULAR ECONOMY IN PORTUGAL

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ABSTRACT

The TANGO-Circular Project, funded by the Erasmus+ program, involves the participation of five Mediterranean countries (France, Greece, Italy, Portugal, and Spain) and aims to develop an educational program focused on cutting-edge technologies related to the collection, transport, and valorization of agricultural waste. The project also covers essential information on legislative, economic, social, and technical aspects, providing EU producers with knowledge ranging from basic to in-depth understanding. The TANGO-Circular approach follows a Quadruple-Helix model, involving public authorities, VET providers, private stakeholders, and civil society. In recent years, the digital transformation and growing concerns about sustainability in the agri-food sector have been central to governance decisions. The European Union has encouraged projects that develop training programs to empower farmers and facilitate sector intermediation through knowledge transfer. The TANGO-Circular project is an example of such an initiative, aiming to offer free training to farmers and breeders in agro-environmental technology for sustainable agriculture through a new curriculum based on Circular Economy principles. Throughout the project, 250 farmers in each involved country (totaling 1000 farmers) will be trained, as well as 50 stakeholders in each country, totaling 200 stakeholders. In Portugal, the project was implemented across eight regions of the Alentejo, adapting the training activities based on local characteristics, such as the predominance of certain crops and the harvest/processing periods. The training was highly successful, with 519 participants across three training cycles, exceeding the targets set for the second cycle. Local partners, such as the Association of Young Farmers of the Country, the Intermunicipal Community of Central Alentejo, and the University of Évora, played a key role in organizing the training in various areas of the Central and Southern regions of Portugal, focusing on agricultural waste management in an inclusive and comprehensive manner. This project represents an important step in transferring knowledge in agricultural waste management and promoting more sustainable farming practices, with a direct impact on the development of rural communities and the implementation of a circular economy in the agri-food sector.

Keywords

Circular Economy; Agricultural Waste; Training Program; Sustainable Agriculture; Rural Development.

VALORIZATION OF LIVESTOCK EFFLUENTS: INTEGRATION OF ANIMAL AND CROP PRODUCTION SURPLUSES INTO COMPOSTING

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ABSTRACT

Livestock effluents are surpluses generated by livestock activities, rich in nutrients and with high recovery potential, particularly in agricultural soils. They promote more sustainable and ecological farming practices while contributing to a circular economy. The composition of these effluents varies significantly depending on factors such as species, age, diet, water consumption, management practices, and bedding materials, among others. When handled improperly, livestock effluents pose risks to public and animal health due to their pollutant load, primarily associated with high nitrogen concentrations and the presence of pathogenic microorganisms. Moreover, their use without adequate treatment can lead to significant environmental impacts. To harness their potential, various treatment and valorization strategies can be applied, contributing to efficient management of these surpluses and transforming them into sustainable products with economic, agricultural, and energy value. Among these strategies, composting, although an ancient practice, remains essential for the valorization of livestock effluents. It is a controlled aerobic decomposition and stabilization process of organic matter, resulting in a stable, sanitized final product rich in humic compounds. This product, known as compost, improves soil fertility without posing environmental risks, thus supporting crop production. In this context of valorizing animal production surpluses, aligned with sustainability and circular economy principles, the present study was conducted to analyze the potential integration of different types of livestock effluents in composting processes, aiming at their valorization. The study involved the construction different of composting piles on a laboratory scale, incorporating surpluses from animal production, specifically cattle, sheep, pigs, and horse manure, along with surpluses from olive oil production, including olive leaves and olive pomace. During the composting process, the piles were monitored, including turning and irrigation them. At the end of the composting process, laboratory analyses were performed on the final composts to identify which livestock effluents contributed to the best fertilization characteristics in the final product.

Keywords

Agricultural Waste; Sustainable Agriculture; Circular Economy; Animal Production.

FROM WASTE TO WELLNESS: SARDINE BY-PRODUCTS AS RICH SOURCES OF BIOACTIVE INGREDIENTS

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ABSTRACT

The sustainable utilization of sardine by-products represents a valuable contribution to addressing global challenges in waste management and health nutrition. Sardine by-products, typically discarded or utilized as low-value inputs in animal feed and fertilizer, have demonstrated potential as a source of bioactive ingredients. This study highlights the composition and bioactive properties of sardine protein hydrolysates, derived through enzymatic hydrolysis, emphasizing their nutritional quality and biological potential.

Sardine protein hydrolysates exhibit diverse molecular weight ratios and amino acid compositions that are pivotal for fulfilling established health claims. The bioactivity of these hydrolysates was assessed across various parameters, including cytotoxicity, cellular antioxidant activity, lipolysis, and immunomodulation. At a concentration of 5 mg/mL, sardine hydrolysates were found to increase intracellular reactive oxygen species (iROS) production under basal conditions, while enhancing antioxidant activity in stimulated cells. Furthermore, they modulated adipocyte metabolism by reducing lipid accumulation, decreasing leptin secretion, and increasing adiponectin secretion, demonstrating potential for metabolic health applications.

The Immunomodulatory effects of sardine hydrolysates were particularly noteworthy. In lipopolysaccharide (LPS)-stimulated gut cells, these hydrolysates effectively reduce pro-inflammatory cytokine secretion while increasing TNF-α levels under basal conditions. Such properties underline their potential role in managing inflammation-related conditions.

Additionally, the mineral content of sardine by-products, particularly sodium, potassium, and phosphorus, aligns with European Food Safety Authority (EFSA) requirements for health claims. This positions sardine hydrolysates as a sustainable and nutritionally rich source of bioactive compounds that could be integrated into functional foods or nutraceutical formulations.

In conclusion, the findings underscore the potential of sardine by-products as sustainable, high-value bioactive ingredients that contribute to nutrition and health while addressing environmental concerns associated with fishery by-product waste.

Keywords

Sardine By-products, Bioactive Ingredients, Protein Hydrolysates, Sustainability

VALORIZING SARDINE BY-PRODUCTS: SUSTAINABLE FUNCTIONAL CANNED TUNA THROUGH PROTEIN HYDROLYSATES

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ABSTRACT

The development of novel functional foods is critical to addressing current consumer demands for health-promoting, sustainable products. This study explores the incorporation of sardine protein hydrolysates into the canned tuna sauce (tomato sauce), aiming to enhance its nutritional profile and functional properties while utilizing underexploited fishery by-products. Sardine protein hydrolysates were selected due to their rich nutritional composition, including 45.8 g/100 g protein, 30.3 g/100 g fat, and significant levels of essential minerals such as phosphorus (577.9 mg/100 g), calcium (284.6 mg/100 g), and potassium (757.9 mg/100 g). These components contribute to the bioactivity and functional benefits of the product. Technological assessments of sardine protein hydrolysates demonstrated their potential for integration into food systems, with noted emulsifying capacity (30%) and oil retention properties (12%). These attributes were leveraged to develop a stable, nutrient-rich sauce for canned tuna, ensuring compatibility with conventional production processes.
The59oznan5959nal benefits of the resulting product were evaluated, emphasizing its enriched protein content, enhanced mineral profile, and bioactive properties. The incorporation of sardine protein hydrolysates was shown to support key health claims, including potential contributions to bone health, cardiovascular wellness, and metabolic regulation. The product also aligns with sustainability objectives by valorizing sardine by-products, reducing food waste, and promoting circular economy principles. In conclusion, this work highlights the feasibility and benefits of incorporating sardine protein hydrolysates into canned tuna products, paving the way for the creation of innovative functional foods that meet both nutritional and environmental goals. Future research will focus on consumer acceptance, sensory evaluation, and scalability of the production process to further refine and commercialize this functional food innovation.

Keywords

Sardine By-Products, Functional Foods, Circular Economy, Protein Hydrolysates

FROM LANDFILL TO PORCELAIN STONEWARE: A SECOND LIFE FOR CATALYST WASTE

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ABSTRACT

The generation of industrial waste is a major challenge in terms of sustainability and environmental management. Among these, NiMo/Al_2O_3 spent catalysts are noteworthy as they originate from 60oznan6060icz6060on60ation (HDS) processes, which are widely used in the petrochemical industry to remove sulphur from fuels. The deactivation of these catalysts occurs by the adsorption of hydrocarbons and metals that inhibits the active sites which leads to their periodically replacement, resulting in the accumulation of significant quantities of spent material. Their heavy metal content, particularly nickel and molybdenum, classifies them as hazardous waste with potential environmental risks if not properly managed. However, the chemical and mineralogical composition of these residues makes them a promising candidate for valorisation in the ceramic industry, setting a new sustainable point of view that relies in the transformation of petrochemical waste into high added-value materials. This study investigates the feasibility of incorporating NiMo waste as a secondary raw material in the production of porcelain stoneware, a high-performance construction ceramic material widely used for wall and floor coverings. By reusing these 60oznan6060icz6060on60ation residues and integrating them into the ceramic manufacturing process, this research contributes to reducing waste disposal issues while promoting more sustainable and circular production practices. Experimental tests were carried out by incorporating different proportions (10-60 wt.%) of spent catalyst waste into standard porcelain stoneware formulations. The samples were formed by uniaxial pressing and subjected to sintering (1210-1300ºC) in a fast-firing thermal cycle to evaluate their behaviour during the sintering process. Technological properties such as bulk density, water absorption, flexural strength and porosity were 60oznan6060icz6060 according to international standards. In addition, microstructural and mineralogical changes were analysed using scanning electron microscopy and Xray diffraction, which provide a better understanding of the formation and growth of crystalline phases. The results show that the incorporation of NiMo/Al_2O_3 spent catalysts promotes the formation of desirable crystalline phases such as mullite. The addition of up to 10 wt.% of spent catalyst waste improves certain technological properties of porcelain stoneware, such as density and mechanical strength. However, higher levels of waste than 10 wt.% were found to cause excessive porosity. Nevertheless, the incorporation of more than 10 wt.% NiMo waste is also viable, as it results in materials that do not meet the stringent requirements of porcelain stoneware, but have properties similar to other types of ceramic tiles, such as stoneware or wall tiles. These materials have acceptable levels of water absorption, mechanical strength and aesthetic appearance, making them suitable for less demanding applications. This wider applicability highlights the versatility of NiMo waste as a raw material, further expanding its potential for reuse within the ceramics industry and supporting the development of sustainable practices in industrial waste management.

Keywords

Spent catalyst; NiMo waste; Ceramic tiles; Porcelain stoneware.

STUDY OF THE RHEOLOGY BEHAVIOR OF SANITARYWARE SLIP WITH WASTEWATER

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ABSTRACT

Reducing water consumption and minimizing wastewater generation are critical issues for achieving global sustainability. Water is a finite resource, and its overuse and pollution threaten ecosystems, human health, and industrial activities. Aligning with the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 (clean water and sanitation) and Goal 12 (responsible consumption and production), industries must adopt strategies to conserve water and recycle wastewater. Their reuse in production processes not only conserves resources but also reduces environmental impacts. The ceramic industry uses substantial amounts of water and the generated wastewater requires treatment before being discharged or reused. So, efforts to reduce water consumption and to promote the use of wastewater are increasing to minimize the industry's environmental impact promoting circular economy and ensure water availability for future generations. This study investigates the feasibility of using treated wastewater as a substitute for freshwater in the production of sanitaryware products – Fireclay and Vitreous. The primary goal was to study the effects of the use of wastewater on the rheological properties of the two ceramic pastes, which are critical for the conformation process, in this case, high-pressure casting. Firstly, Zeta potential measurements were performed to evaluate the electrokinetic stability of the ceramic particles in suspensions prepared with both wastewater and freshwater. Two commonly used deflocculants, sodium carbonate and silicate, were employed while a rotational rheometer was used in the rheological characterization. The effect of the shear rate and the type and amount of deflocculants was studied. The results revealed that the presence of residual ions in the treated wastewater influenced the deflocculation behaviour of the ceramic suspension. For instance, the carbonate-based deflocculant promotes an increase of the viscosity, instead of a decrease as expected and desired. The use of silicate-based deflocculants effectively mitigate this issue. So, this study demonstrates that treated wastewater can substitute freshwater in sanitaryware slip production, offering a practical solution to reduce the environmental footprint of ceramic manufacturing. Future research should explore the influence of using wastewater on the final properties of the ceramic products.

Keywords

Wastewater, rheology, sanitaryware, ceramic, sustainability, circular economy.

RICE HUSK ASH VALORIZATION IN ONE-PART ALKALI-ACTIVATED MATERIALS

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ABSTRACT

Annually, 7.4 million tons of rice husk ash (RHA) are produced worldwide, with most of it being disposed of in landfills. The chemical composition of RHA can differ based on the combustion conditions, but controlled burning temperature can yield a high amount of amorphous, reactive silica suitable for a wide range of applications. However, the industrial utilization rates of RHA in sectors such as construction and ceramics remains limited, which highlights an underexplored opportunity for recycling and valorization. Ordinary Portland Cement (OPC) stands as the predominant binder in the construction sector, serving as a key component in mortars and concrete. However, OPC production contributes to approximately 8 % of global CO_2 emissions. Alkali-activated materials (AAM) have emerged as promising sustainable alternatives to OPC, boasting a reduced carbon footprint and potentially reducing CO_2 emissions by up to 45% under optimal conditions. These materials are obtained by a chemical reaction of aluminosilicate materials with alkaline activators, utilizing either natural resources or industrial. Therefore, the aim of this work is to investigate the potential of using RHA as a replacement of the commercial alkaline activator, sodium metasilicate, in the formulation of waste-based one-part alkaliactivated materials. For this purpose, mortars were prepared with RHA substitution levels of 0, 25, 50 and 100 wt.%. The characterization of RHA revealed that it is composed of 90.7 % SiO_2, has a mostly amorphous character with some crystalline tridymite, and has a particle size ranging from 1 to 30 µm. SEM analysis reveals that RHA have irregular particle shapes. To achieve a standard paste spread (125 mm), the water/binder ratio was reduced compared to the standard formulation. Compressive strength increased with curing time from 7 to 28 days, with the standard sample reaching 21 Mpa at 28 days of curing. Samples with substitutions of up to 50 wt.% RHA achieved strengths above 12.5 Mpa, making them suitable for external walls and patios applications. Other properties like bulk density, mass loss, flexural strength, and water absorption were consistent with compressive strength results. This study demonstrates the feasibility of using RHA as a solid activator in ‘one-part’ geopolymers, offering a sustainable solution to reduce both the carbon footprint and the amount of landfilled RHA. These findings highlight the potential for integrating RHA into construction materials, promoting resource efficiency and environmental sustainability.

Keywords

Rice husk ash valorization, One-part alkali-activated materials, construction materials, carbon footprint, circular economy, industrial symbiosis

IMPACT OF BLOWING AGENT AND ALKALINE ACTIVATOR CONTENT ON THE PROPERTIES OF POROUS WASTE-BASED ONE-PART ALKALI-ACTIVATED MATERIALS

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ABSTRACT

The construction sector is a significant contributor to carbon emissions, primarily due to the widespread use of Portland cement, which is responsible for the release of 0.5 to 0.7 tons of CO_2 per ton produced. As global pressure to reduce greenhouse gas emissions intensifies, the development of sustainable construction materials has become increasingly urgent. In this context, porous one-part alkali-activated materials have emerged as a promising alternative. These materials not only offer enhanced performance but also provide notable environmental benefits, making them an effective solution to the challenges of reducing the carbon footprint in construction.

This study investigates the feasibility of producing porous one-part alkali-activated materials, cured at room temperature, using ground granulated blast furnace slag (GGBS) as the sole solid precursor, sodium metasilicate (SM) as the solid alkaline activator, and hydrogen peroxide (HP) as the blowing agent. The effects of varying the HP and SM content on the properties of the produced lightweight materials were examined.

GGBS was characterized in terms of its chemical composition (X-ray fluorescence, XRF), mineralogical composition (X-ray powder diffraction, XRD), particle size distribution (laser diffraction), and morphology (scanning electron microscopy, SEM). The influence of varying amounts of SM (0, 0.25, 0.5, and 0.75 wt.%) and HP (0, 1, 2.5, and 5 wt.%) on the volumetric expansion, density, porosity, water sorptivity (measured by capillary and immersion methods), compressive and flexural strength, thermal conductivity and hygrothermal performance of the resulting lightweight one-part alkali-activated materials were systematically evaluated.

The various combinations of HP and SM content led to the production of porous materials with varying mechanical performance while maintaining very low thermal conductivity, ranging from 0.130 to 0.176 W/m·K. Furthermore, all formulations were classified as exhibiting good to excellent Moisture Buffer Value (MBV >1.0 g/m^2 Δ%RH), according to the classification system defined in the Nordtest protocol, demonstrating their strong ability for indoor moisture passive modulation.

The results obtained demonstrate that these waste-derived one-part alkali-activated materials can be tailored for various applications by adjusting the incorporation of HP and SM content, depending on the specific requirements of the intended use. Additionally, they present a promising approach for the development of sustainable and energy-efficient building materials.

Keywords

Geopolymers; ground granulated blast furnace slag; lightweight materials; MBV; Thermal conductivity; waste valorization.

WASTE-BASED SOLAR PHOTO-FENTON PROCESS FOR PERSISTENT MICROCONTAMINANT REMOVAL AT PILOT SCALE

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ABSTRACT

Aquaculture has emerged as a key sector in addressing global food shortages, contributing to 50% of the world's food production. However, to prevent infections and diseases of the produced aquatic organisms, like mollusks and fish, and improve their reproductivity, chemicals such as antibiotics, pesticides, and hormones are used. Since these substances are not completely absorbed, they remain in the water generating large volumes of contaminated wastewater (around 200,000 m^3 annually), with significant environmental challenges due to their persistence. As they cannot be removed by the conventional treatments, sustainable advanced technologies that can effectively eliminate them are urgently needed. This study explores a sustainable solution using a waste-based zero-valent iron (ZVI) catalyst derived from olive mill wastewater (OMW, SMALLOPS S.L.) for aquaculture wastewater treatment. The research aimed to evaluate the efficacy of a waste-based solar photo-Fenton process for degrading persistent microcontaminants (MCs) in a simulated aquaculture wastewater matrix with a total inorganic carbon (TIC) of 13 mg/L. The MCs targeted in this study included Sulphapyridine, Trimethoprim, Caffeine, Sulfamethoxazole, and Flumequine, at 100 µg/L of each and circumneutral pH, measured using Ultra-Performance Liquid Chromatography with a UV detector (UPLC-UV). The catalyst was an innovative iron nanoparticle with a particle size of 150 nm ± 50 nm and a surface area of 14.7 m^2/g, containing 44.5% of total iron and 2.5% of ZVI, according to the manufacturer (SMALLOPS S.L., in Spain). Experiments were conducted using two reactor systems: a 2 L borosilicate glass reactor and a 17 L Raceway Pond Reactor (RPR) at Plataforma Solar de Almeria (PSA-CIEMAT) in Spain. Both systems operated under natural solar radiation in the presence of hydrogen peroxide (H_2O_2) at 3 and 5 mM. The goal was to achieve at least a 50% degradation of the mixture of the 5 MCs. Results showed that the borosilicate glass reactor achieved the target degradation of 50% after 45 minutes (0.80 kJ/L), while the RPR achieved 40% degradation in 60 minutes (2.04 kJ/L). The H_2O_2 consumption was 1% in the borosilicate reactor and 6% in the RPR. Persistence analysis of the contaminants revealed that Caffeine was the most resistant to degradation, followed by Sulfamethoxazole, Trimethoprim, Sulphapyridine, and Flumequine with H_2O_2 at 3 mM. Increasing the concentration of H_2O_2 from 3 mM to 5 mM did not significantly enhance the photodegradation rates. Between 1-3 mg/L of iron leaching from the catalyst was measured in this study, but it was demonstrated that the levels of dissolved iron in the solution had negligible effect on MC degradation.

Keywords

Emerging contaminants, photocatalysis, recalcitrant pollutants, solar-driven AOPs, sustainability, zero-valent iron.

SUSTAINABLE CARBON NANOTUBES DERIVED FROM PLASTIC SOLID WASTE

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ABSTRACT

The accumulation of mixed plastic solid waste (PSW), particularly polyolefins, poses significant recycling challenges, with declining recycling rates despite increasing per capita plastic waste generation. Polyolefins are the main composition of contaminated PSW due to their widespread use in single-use packaging. These materials, primarily composed of carbon – 85.6% polyethylene and polypropylene – can be repurposed into carbon-based products such as carbon nanotubes (CNTs). Transforming plastic waste into CNTs offers environmental benefits by mitigating climate change impacts, conserving fossil resources, and reducing toxicity caused by plastic accumulation in ecosystems. In this work, mixed and dirty PSW provided by a local waste management facility was used as a carbon source for the synthesis of CNTs. Prior to use, the PSW samples were manually separated into distinct fractions (low- and high-density polyethylene, LDPE and HDPE, and polypropylene, PP) and cut into small pieces (no control over the size of the pieces). The CNTs were grown by chemical vapor deposition (CVD) using 5 g of a mixture of LDPE, HDPE and PP over a nickel-iron catalyst (1 g) in a one-chamber oven (50 mL min^{-1} N_2 flow, temperature of 800 °C), leading to CNT-PSW. For comparison purposes, the same synthesis procedure was carried out for a mixture of commercially available polymers, leading to CNT-CS. The metallic particles remaining after CVD synthesis were removed in batch with acid washing (50 wt.% H_2SO_4, 140 °C, 3 h, 20 g_{CNT} L^{-1}), leading to CNTW-PSW and CNTW-CS. Samples were characterized in terms of textural properties (N_2 adsorption-desorption isotherms), morphology (TEM), surface chemistry (Raman), and elemental composition (CHNS-O). CNTs were successfully obtained using both precursors, with close yields (26-27 wt.%) and show similar composition: C (58.6-59.2 wt.%), O (2.3-2.6 wt.%), H (0.18 wt.%) and ashes (48-51 wt.%) prior to purification. The outer diameters of the purified CNT samples (CNTW-PSW and CNTW-CS) were also similar (24 and 28 nm, respectively). The defects in the CNTs surface was also similar in both cases, with a D/G ratio (obtained using Raman spectroscopy) of 0.67 and 0.87 for CNT-PSW and CNTW-PSW, respectively, and 0.64 and 0.91 for CNT-CS and CNTW-CS, respectively. BET surface area were 146,187, 144 and 148 m^2 g^{-1} for CNT-PSW, CNTW-PSW, CNT-CS and CNTW-CS, respectively. The main difference found in the commercially derived sample and the waste-derived sample is related to the increase in surface area upon purification (148 versus 187 m^2 g^{-1} for CNTW-CS and CNTW-PSW, respectively). Nevertheless, most characteristics remain in an acceptable range regardless of using commercial sources or waste sources. The results reported here indicate that the growth of CNTs is a viable alternative to upcycle PSW.

Keywords

Upcycling; chemical vapor deposition; nanomaterials; waste valorization.

EFFECT OF THE CRYSTALLINE OR AMORPHOUS NATURE OF SI-RICH WASTES ON THE SUSTAINABLE PRODUCTION OF ZEOLITES

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ABSTRACT

Zeolites are microporous materials with exceptional properties that are highly desirable for various industrial applications, including catalysis processes, gas purification and the treatment of polluted wastewater. The increasing demand for these versatile materials has led to their widespread use in the petrochemical, detergent, construction and 66oznan6666ic sectors, among others. Despite the availability of natural zeolites, there is a growing interest in synthetic zeolites, which are more suitable for commercial use due to the higher degree of purity and uniformity of these tailor-made materials. In recent years, various waste streams have been explored as unconventional aluminium and silicon precursors for the synthesis of zeolites instead of conventional chemical reagents. This approach not only provides a sustainable strategy for waste management, but also addresses the pressing need to preserve natural resources and reduce the environmental footprint of traditional production methods. Due to its aluminium-rich composition, salt slag is an excellent candidate as a raw material for zeolites production. This waste is the most abundant generated by the secondary aluminium industry, whose global consumption is expected to exceed 100 million tonnes this year. The huge quantities produced during the aluminium recycling process – approximately 0.5 tonnes of salt slag are produced per tonne of recycled aluminium – combined with its toxic, reactive, and hazardous nature, represent a significant environmental threat and make its disposal a major challenge. However, its reuse as an unconventional precursor in zeolite synthesis offers a promising alternative. Many silicon-rich wastes have also been explored to provide the silicon content required to form zeolitic materials, including rice husk ash (RHA) and calcine. RHA, the main agri-food waste, has emerged as an excellent candidate due to its wide availability and negligible cost, while calcine consists of very fine cullet produced during the glass processing. Its use has a positive environmental impact by reducing CO_2 emissions and conserving natural resources. In the present study, the influence of the mineralogical nature of these two different wastes in zeolite synthesis was reported: crystalline rice husk ash (RHA) and amorphous calcine. Different reaction times and hydrothermal temperatures were also evaluated. Hazardous salt slag was used as the aluminium precursor, while RHA or calcine provided the silicon. Different zeolite phases (LTA, NaP, ANA and Cancrinite) were obtained using a sustainable single-step hydrothermal process under mild conditions. The effect of the silicon source has been shown to significantly influence the 66oznan6666icz6666on process of zeolites. Thus, a crystalline waste requires a dissolution process before the formation of zeolite nuclei, whereas an amorphous waste undergoes a rearrangement that enables it to be combined with aluminium salt slag to produce waste-based zeolites. This innovative approach, applied to the zeolite production using unique combinations of industrial waste, represents a step forward in sustainability, circular economy and industrial symbiosis. The reuse of environmentally hazardous waste materials for the production of high value zeolites adds economic and environmental value while addressing the challenges of waste management. In addition, these 66oznan6666icz zeolites have shown potential for the treatment of other waste streams, such as the adsorption of pollutants from various effluents. This dual application closes a circle based on the principles of sustainability and offers practical solutions to current environmental and industrial challenges.

Keywords

Waste-based zeolites; hydrothermal synthesis; hazardous waste; salt slag; rice husk ash; calcine.

SUSTAINABLE PROCESSES FOR CHICKEN FEATHERS VALORISATION AND ADVANCED BIOMATERIALS DEVELOPMENT

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ABSTRACT

The poultry-processing industry generates a substantial amount of chicken feather waste, which is often inappropriately disposed of, causing environmental pollution and economic impacts. This problem can, however, be overcome by the valorisation of chicken feathers, which are predominantly composed of keratin, a fibrous protein with promising biological properties for biomedical applications. In that regard, an innovative and sustainable process using aqueous solutions of ionic liquids (Ils) was developed to dissolve chicken feathers, aligning with green chemistry principles. By IL screening, acetate-based Ils demonstrated exceptional effectiveness, and subsequently, the keratin recovery conditions were 67oznan6767i, achieving a keratin recovery yield of 93 wt%. The IL was successfully recovered and reused for at least four cycles without compromising the keratin yield. A detailed techno-economic evaluation was conducted to assess the industrial feasibility of this process. The minimum selling price of keratin was estimated at $22 per kg, supporting the economic viability of scaling this process. The recovered keratin was employed to develop advanced biomaterials for biomedical applications, including keratin films with remarkable antioxidant and anti-inflammatory properties, keratin: melanin hydrogels with UV-blocking capabilities and cell growth support, and 4D-printed scaffolds exhibiting excellent biocompatibility and shape-changing behaviour mediated by cellular traction forces. Overall, this study provides an effective way to valorise chicken feather waste while unlocking the potential of keratin for biomaterial processing and application in the biomedical field. Furthermore, these findings demonstrate significant promise for industrial-scale applications and reinforce the role of Ils as alternative solvents for waste valorisation, allowing the efficient recovery of compounds with added value.

Keywords

Biomaterials, keratin, ionic liquids, protein, waste.

NEW HYDROMETALLURGICAL PROCESSES FOR THE RECOVERY OF VALUABLE AND CRITICAL METALS FROM E-WASTE

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ABSTRACT

E-waste is the fastest-growing waste stream globally. Certain e-waste streams contain higher concentrations of valuable metals than primary ores, presenting an opportunity as secondary sources for these materials. However, it poses significant challenges for waste management due to its complex composition and hazardous nature. Furthermore, conventional hydrometallurgical processes for e-waste recycling are often inefficient, requiring aggressive digestion methods, generating significant waste streams, and utilizing flammable, volatile, and toxic solvents. Consequently, there is an urgent need for more efficient and sustainable alternatives.

The application of alternative solvents, such as Ionic liquids, eutectic solvents, and water-in-salt solutions, has shown promising results in the selective recovery of strategic and critical metals. The versatile and tunable nature of these solvents has significantly expanded the field of metal processing in both aqueous and non-aqueous media. In recent years, we have been dedicated to the development, characterization, and application of these solvents in integrated hydrometallurgical processes, encompassing the entire spectrum from leaching to metal recovery. Valuable and critical metals, such as transition metals, rare earth elements, platinum group metals, and gold, have been successfully recycled from e-waste streams, including nickel-metal hydride batteries, Li-ion batteries, CPUs, and spent automotive catalytic converters. The dynamic behavior of these systems enables the development of innovative and cost-effective strategies for metal recovery from secondary sources, contributing to more sustainable and efficient practices in metals recycling.

Keywords

Circular economy, recycling, critical metals, alternative solvents.

INTEGRATING WASTEWATER TREATMENT AND ENERGY RECOVERY: THE POTENTIAL OF MFC FOR MANAGING SAFRANINE-T CONTAMINATED EFFLUENTS

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ABSTRACT

Continuous population growth combined with accelerated industrialization has increased the demand for energy, the consumption of natural resources and the generation of waste and effluents, leading to an unprecedented energy and climate crisis. In recent years, the improvement of bioelectrochemical technologies based on the use of Microbial Fuel Cell (MFC) devices has attracted increasing attention as a strategy to reduce energy demands and mitigate environmental pollution. MFC are bioreactors that can directly transform the chemical energy stored in the bonds of organic and inorganic waste compounds into electricity. The treatment of wastewater using their pollutants as substrates for the metabolism of electroactive microorganisms is one of the most promising applications of MFC, thus coupling these bioremediation systems with the production of bioenergy. This dual functionality makes MFC a green and sustainable alternative to traditional treatment technologies, offering improved performance, lower greenhouse gas emissions, less sludge generation and minimal secondary pollution. Dyes, the predominant pollutants in textile wastewater – one of the most challenging and complex industrial effluents – are among the contaminants that can be remediated by MFC. The textile industry, one of the biggest sources of water pollution worldwide, generates approximately 200 billion liters of dye-contaminated effluents annually, contributing to almost 20% of global water pollution. These effluents, characterized by high biochemical oxygen demand (BOD), chemical oxygen demand (COD), and complex chemical structures, pose significant challenges to conventional treatment methods, which are often costly, inefficient, and energy-intensive. Despite their potential, the application of MFC to dye-containing wastewater remains underexplored, particularly in the treatment of complex textile dyes such as Safranine-T (ST). This study aimed to investigate the degradation of ST using a single-chamber membrane electrode assembly MFC (MEA-MFC) inoculated with a mixed anaerobic sludge culture. The effects of varying initial ST concentrations were evaluated with respect to color removal efficiency and bioelectricity generation. The findings demonstrated significant ST degradation, achieving high color removal efficiency (up to 93.84%) while simultaneously generating bioelectricity (current density of 11.65 $mA.m^{-2}$). These results highlight the potential of MFC as a versatile technology to address textile wastewater treatment issues. Moreover, the application of MFC in treating ST-contaminated wastewater underscores their ability to overcome the limitations of conventional treatment methods. Despite the need for further research to meet the challenges of scaling up, this study demonstrates the feasibility of MFC as an eco-friendly, cost-effective, and sustainable technology for dye-contaminated wastewater treatment.

Keywords

Microbial Fuel Cell; textile dyes; Safranine-T; bioelectrochemical technology; bioenergy generation; wastewater treatment.

WATER QUALITY MONITORING PROGRAM: INSIGHTS FROM COASTAL, BEACHES, MARINA, AND FRESHWATER-SEAWATER INTERACTIONS ON MADEIRA ISLAND, PORTUGAL

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ABSTRACT

Coastal environments face increasing pressures from anthropogenic activities, leading to pollution that endangers the ecosystems and human health. The Regional Agency for the Development of Research, Technology, and Innovation (ARDITI), through the Oceanic Observatory of Madeira (OOM; Portugal), developed a program to monitor key water quality parameters in response to the conservation and preservation of coastal ecosystems under sustainable development goals. The coastal water quality monitoring program aims to assess ecological health, detect pollution patches, protect biodiversity, public health, and recreational activities, evaluate the effectiveness of management strategies, comply with EU regulations, and monitor the impact of climate change. For this purpose, four distinct sites have been assessed: i) the south coastal area between Cabo Girão and Garajau; ii) recreational beaches (bathing waters); iii) an area designated for boat parking (Funchal-Marina); and iv) the confluence of *Ribeira de São João* with the coastal waters. Monthly and weekly comprehensive sampling campaigns have been conducted since February 2024 to measure physical-chemical parameters, including nutrient concentrations (NO_3^-, NO_2^-, PO_4^{3-}, $Si(OH)_4$), salinity (PSU), conductivity (µS/cm), temperature (°C), chlorophyll-a (µg/L), and dissolved oxygen (mg/L). The water samples for nutrient determination were filtered through a 0.22µm or 0.45µm pore size filter, frozen, and further analyzed by the QuAAtro39 autoanalyzer at the Marine Biology Station at Funchal. The remaining physical-chemical parameters were measured *in situ* with a CTD. The preliminary results indicate notable spatial variability in nutrient concentration, with higher concentrations at the river-seawater interface followed by the Marina, Beaches, and, lastly, the south coastal area, likely influenced by biogeochemical processes and/or anthropogenic activities from the island. On the other hand, salinity/conductivity, temperature, chlorophyll-a, and dissolved oxygen showed similar behavior in the entrance of Marina and the river-seawater interface due to the proximity between both sites. In the boating area (Funchal-Marina), nitrate, nitrite, phosphate, and silicate concentration showed higher variability, suggesting inputs from boat maintenance activities as well as the current construction activities around the boating area. Beaches exhibited lower values of nutrient concentrations but with some variability due to inputs from inland. Nutrient concentrations in the south coastal environment showed seasonal and spatial variability, significantly influenced by several streams and wastewater treatment plants' effluents. Besides this, beaches exhibit better water quality but show occasional exceedances. These findings highlight the need for further study of the source of the freshwater system's nutrient inputs and physical and chemical properties. At the same time, these results call attention to the necessity of a water quality baseline for the beaches and freshwater systems that will help indicate the moment of pollution input to the coastal environment due to the lack of information in the Portuguese environmental law. A continuous water quality monitoring program is required to target management strategies to address specific pollution sources and improve water quality in vulnerable coastal zones. The future results, with more than one year of monitoring, will contribute to understanding natural and pollution dynamics in marine environments and improve and adapt environmental policies for sustainable coastal management of Madeira's coastal waters.

Keywords

Water quality, Monitoring program, nutrients, physicochemical parameters, Madeira Island.

STUDY OF THE EFFECT OF ANAEROBIC DIGESTION ON WASTEWATER TREATMENT PLANT EFFLUENTS

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ABSTRACT

The anaerobic digestion process stands out as an alternative for clean energy production and energy efficiency to mitigate greenhouse gas emissions from production processes, in addition to recovering biofuels from lignocellulosic biological waste. For the digestion process to take place correctly, the chemical constitution and biodegradability must be within the parameters for the digestion process. Tests were carried out to determine the Biochemical Methane Potential (BMP) to verify the feasibility of using primary effluent from a wastewater treatment plant in a mono-digestion process and comparing it to the co-digestion process with dresche from a craft brewery and horse manure mixed with dresche as a way of optimizing the biomethane production process. BMP tests were carried out with different mixtures, incorporating the different materials as a way of optimizing the process and verifying the influence of each product on the final production of biomethane. Three mixtures were made in duplicate. The tests were divided into wastewater treatment plant effluent (WWTP), WWTP with horse manure (WWTP-Ma), and WWTP, manure, and dresche (WWTP-Ma-Dr). After 47 days of testing, the tests using WWTP effluent yielded a cumulative biogas production of approximately 1200 mL and a biomethane content of 60.5 mL. In contrast, the WWTP-Ma tests, which included horse manure, produced a significantly higher 2880 mL of biogas with 840 mL of biomethane. The WWTP-Ma-Dr tests, incorporating both horse manure and dresche, resulted in accumulated biogas production of around 2660 mL and 600 mL of biomethane. The tests showed that adding dresche to the mixture significantly reduced biogas and biomethane production compared to WWTP-Ma. This effect may be associated with the fact that the dresche has already been through the fermentation process to produce beer, where the material has already undergone degradation of the starch and protein. With the tests carried out, it was possible to conclude that incorporating 10 percent of horse manure into the WWTP water resulted in better biogas and biomethane production. This is a promising alternative for reusing WWTP water to produce sustainable energy.

Keywords

Anaerobic Digestion; Biochemical Methane Potential; Wastewater; Horse Manure; Dresche

KOMBUCHA-LIKE BEVERAGE PRODUCTION FROM BEER BAGASSE: EVALUATION OF FERMENTATION AND ANTIOXIDANT PROPERTIES

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ABSTRACT

Kombucha tea is obtained by fermentation of sugared tea (*Camellia synesis*) by a symbiotic consortium of bacteria and yeast (SCOBY). During fermentation, sugar is metabolized into organic acids lowering the pH of the beverage. At the end of fermentation, ideally for a period of 7-12 days, the drink acquires fruity, slightly acidic flavor. Throughout this process, the tea's phenolic content and antioxidant properties are further enhanced. Simultaneously, a biofilm, mainly composed of bacterial cellulose, forms at the liquid surface, where yeast and bacteria can also adhere. The aim of this study is to investigate the characteristics of a kombucha-like beverage, prepared using an alternative substrate, such as beer bagasse, an abundant lignocellulosic waste generated during beer production. Beer bagasse, often discarded as a byproduct, is rich in fiber and presents a potential low-cost material for producing sustainable fermented beverages. The beer bagasse infusion was prepared at a concentration of 1.0% (w/v), with 10% sucrose added before inoculating with SCOBY (3.0%). Additionally, 10% of a previously adapted kombucha-like beverage was used as a starter, providing the inoculum and the adequate acidic pH for fermentation, preventing contamination by unwanted microorganisms. The bagasse was sterilized prior to inoculation with SCOBY, to avoid contamination and competition among the different yeast species that may exist in the beer bagasse and the kombucha. Green tea was prepared under the same conditions. For comparison purposes, fermentation was carried out in green tea infusion, beer bagasse infusion, and a 50% mixture of each. This work describes antioxidant activity, pH, titratable acidity, total phenolic content, optical density and bacterial cellulose production after 0, 6 and 12 days of fermentation at 26 °C on the different substrates used for kombucha-like fermentation. The results of this study highlight the potential of beer bagasse as a sustainable and cost-effective alternative substrate for kombucha-like beverages, offering new possibilities for the production of innovative fermented drinks.

Keywords

Kombucha-like beverage, Beer bagasse, Fermentation, Bacterial cellulose, Lignocellulosic waste, Functional drink

A COMPREHENSIVE APPROACH USING SOLAR DRYING AND TORREFACTION OF SPENT COFFEE GROUNDS FOR ENERGY PRODUCTION

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ABSTRACT

This paper presents a proposed technological line that integrates a proprietary solar drying method, pelletizing, and torrefaction to prepare spent coffee grounds (SCG) for use in energy processes. The first step in the pretreatment of spent coffee grounds involved solar drying. Tests were conducted in a solar greenhouse dryer equipped with a custom-designed mixing system to determine the drying time and layer thickness of the spent coffee grounds under the weather conditions in the southwestern part of Poland. After drying to approximately 10% moisture content, the spent coffee grounds were subjected to the pelletizing process. Additionally, a portion of the produced pellets underwent torrefaction to compare their energy and mechanical properties. Torrefaction was performed in a laboratory-scale reactor, with tests conducted at temperatures ranging from 250°C to 350°C and durations of 30 to 45 minutes in a nitrogen atmosphere. Furthermore, thermogravimetric analysis (TGDTA) coupled with Fourier-transform infrared spectroscopy (FTIR) was used to investigate the differences in the combustion processes of raw pellets and torrefied pellets. The analysis focused on the reaction regions, the temperatures at which initial devolatilization and the final process occur, and the gas products, comparing these aspects between both materials.

Keywords

spent coffee grounds, solar drying, pelletization, torrefaction, TG-FTIR analysis

THE BENEFITS OF MECHANOCHEMISTRY FOR THE FUNCTIONALIZATION OF CO-PRODUCTS: THE EXAMPLE OF WALNUT SHELL AS A CLEAN LABEL EMULSIFIER

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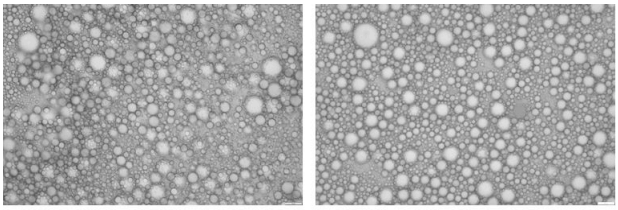
ABSTRACT

The formulation and stabilization of emulsions is an ever-present and crucial challenge, as these unstable dispersed systems are essential in diverse industrial sectors such as paints and coatings, the oil industry, environmental decontamination, agri-food, cosmetics and the pharmaceutical industry. Since the early 2000s, consumers and manufacturers have expressed a growing interest in cleaner, synthetic-free formulations, without being able to compromise on functionality or quality. Looking for functional bio-based substitutes is therefore more relevant than ever in order to provide solutions to this societal demand. In the agri-food industry, walnut cultivation is responsible for a large volume of co-products (husk, shell and skins) since only the kernel is consumed. To date, walnut shells have not been widely used in industries: at best as fuel and at worst discarded, like many other wood co-products rich in lignin and cellulose.

The valorization and functionalization of walnut shells through mechanochemical processing was studied in this work with a specific focus on emulsifying properties. The impact of mechanochemical treatment on composition, physicochemical characteristics and functional properties was highlighted. The applied mechanochemical process involves high-energy planetary ball milling, which reduces particle size while simultaneously catalyzing chemical reactions in the matter. The treatment of walnut shell powder resulted in the release of a significant part of water-soluble components (35%, x2.7 compared to untreated walnut shell powder) from depolymerization of the hemicelluloses present in the shell. This neo-formed fraction of soluble elements was associated with an interesting emulsifying function. Laser granulometry and optical microscopy analyses show that 40% w/v sunflower oil in water model emulsions formulated with depolymerized walnut shell powder proved to be stable over a two-month follow-up even for low walnut powder concentrations (0,6% walnut shell powder in emulsion) while standard walnut shell powder failed to emulsify and stabilize the systems after 24 to 48h.



D0 D56

Microscopic observations of emulsions stabilized with 0.6% depolymerized walnut shell powder on the day of production (D0, left) and after two months' storage at 20°C (D56, right).

Structural analysis using microscopy showed the emulsions were not stricto sensu Pickering emulsions. The soluble fraction appeared to be the main stabilizing agent, although the insoluble fraction proved to contribute to a reinforcing action on the emulsifying function of the powder to some extent. Depolymerized walnut shell has been tested as a clean-label emulsifier in fluid body lotions, confirming its excellent stabilizing properties. However, the color provided by the ingredient depending on the system's pH, could be a major obstacle to consumer acceptance, particularly in the world of cosmetics, still very attached to immaculate whiteness.

This work demonstrates the potential of mechanochemistry in functionalization strategies for the most difficult co-products to valorize and opens the way to industrial applications where naturalness and clean label are increasingly important considerations.

Keywords

Byproduct functionalization, emulsion, mechanochemistry, depolymerization, walnut shell, cosmetics

TRANSFORMING BIOWASTE INTO VALUABLE PRODUCT THROUGH DOMESTIC COMPOSTING

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ABSTRACT

Biowaste represents a substantial portion of municipal solid waste, making it crucial to promote its valorization through conversion processes that transform it into valuable products. In addition, the increasing production of biowaste poses significant environmental challenges, but composting has emerged as a sustainable solution to address this issue. This study evaluates the domestic composting process of biowaste generated at the canteen of a university and its gardens. The research addresses the critical need to valorize biowaste and divert it from landfills, aligning with sustainable waste management and circular economy principles. The methodology involved characterizing biowaste at the source, followed by conducting tests with aerobic thermophilic composting in small domestic composters and pre-digestion of food waste using *Bokashi* fermentation. "*Bokashi*-treated biowaste" was subsequently tested in two applications: aerobic composting and direct soil incorporation. Key parameters, such as temperature, moisture content and pH were monitored throughout the process. At the end, the composts were characterized by micro and macro-nutrients as well as heavy metals. Composting reduced the volume of biowaste by approximately 35%. Temperatures in the composters reached peaks of around 45°C, while moisture content records ranged from 57% to 80%. The final composts were rich in organic matter (around 80%), and essential nutrients for soil fertility (0.6%-0.7% of P, 4%-6% of K, 4%-13% of Ca and 0.3%-0.4% of Mg). The study also measured the production of leachate and identified significant differences among treatments. Aerobic composters generated higher volumes of leachate, while *Bokashi* pre-treatment reduced leachate production and enhanced nutrient recovery. Compost produced through *Bokashi* fermentation demonstrated reduced salinity and improved stability, making it particularly suitable for domestic use. Additionally, a phytotoxicity test conducted with radish seeds showed germination indices above 80%, indicating the absence of harmful substances and confirming the suitability of the compost for food production. This research provides valuable insights into the integration of domestic composting into sustainable waste management practices, highlighting the potential of *Bokashi* fermentation as an effective pretreatment method. The findings underscore the role of innovative techniques in reducing biowaste volume, improving compost quality, and promoting resource recovery at the household level.

Keywords

Biowaste; Bokashi; Composting; Waste valorization.

RECOVERY OF PLATINUM GROUP METALS FROM AQUEOUS SOLUTIONS USING MEMBRANE FILTRATION

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ABSTRACT

Platinum Group Metals (PGMs) are rare elements with unique properties used in various applications. The growing demand for PGMs has led to the development of innovative strategies to enhance their availability in the market. One such strategy involves recovering PGMs from secondary sources, such as spent automotive catalytic converters, offering an alternative to traditional mining processes, reducing environmental impacts and help meeting the market demands. Hydrometallurgy is a commonly used recycling approach, employing aqua regia for the leaching process. On the other hand, the environmental drawbacks of the aqua regia used have prompted research into alternative solutions, such as the use of aluminum salt mixtures solutions. Following leaching, purification processes, such as solvent extraction, ion exchange resins, and precipitation, are employed to separate individual metals. Recent studies suggest membrane separation as a promising alternative, offering a reduction in reagent consumption and environmental impact in hydrometallurgical processes. Although well-established technology in water treatment, it is now being investigated for its potential in metal separation. Previous work has demonstrated that nanofiltration membrane can achieve heavy metal rejection rates superior to 90% for Ni^{2+} and Cr^{6+}. Building on this knowledge, this study develops a methodology for separating and purifying PGMs from aluminum-salt-based leaching solutions using membranes. The research began with a screening of various membrane types, including microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), to assess their overall performance. Subsequently, aluminum salt rejection profiles ($Al(NO_3)_3$ and $AlCl_3$) were evaluated. Results indicate that RO membranes provide the highest salt rejection rates—82.38% for 1% $Al(NO_3)_3$ solutions and 68.66% for 1% $AlCl_3$ solutions—though with significantly lower flow rates. Conversely, NF membranes achieve moderate salt rejection for at least one solution while maintaining higher flow rates, offering a more practical balance for industrial applications. The study also evaluates PGM rejection and identifies membranes with promising selectivity for aluminum salts, contributing to the optimization of separation and purification processes for practical applications.

Keywords

Platinum Group Metals (PGMs) | Recycling | Commercial Membranes | Filtratio

CREATING INCENTIVES TO REDUCE PLASTIC IN INDUSTRIAL WASTE BOUND FOR INCINERATION USING THE MEASUREMENT SYSTEM FOSSILEYE

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ABSTRACT

The use of plastics is continuously increasing because of its flexible properties that make it suitable for many products and applications. However, the plastic use has been increasingly questioned due to its fossil origins, linear flows, and leakage to nature. Most of the plastic ends up in the waste bound for incineration after its first use, which leads to greenhouse gas emissions and takes the edge of other initiatives for improved circularity, such as improved product design and new recycling processes. To reach the European union's recycling targets and achieve a more sustainable use of plastics, there is a need to develop effective policy instruments to change the flows of plastics. Different types of feedback to waste generators have the potential to provide incentives for increased sorting of plastics, but it is seldom used towards industries and other enterprises that use plastic. A key reason for this is the lack of reliable and cost-effective methods to continuously measure the plastic content of specific waste generators' waste. Against this background, the measurement system FossilEye was developed on behalf of three waste-to-energy plants in Sweden. FossilEye quickly scans and measures the plastic content of entire truckloads of waste. This technology enables continuous measurements of the plastic content of different waste deliveries and creates completely new opportunities for feedback and guidance to specific plastic users, waste generators, and recycling companies upstream of the waste-to-energy plant. This study investigates how different approaches for feedback and control of upstream actors should be designed to incentivise increased recycling of plastic based on measurements with FossilEye. The study consists of three parts: mapping and quantification of plastic flows, measurements with FossilEye, and interviews with waste generators. First, all waste streams entering a waste-to-energy plant in Sweden are mapped and waste generators are categorised according to the industry they belong to. A selection of companies representing different industrial sectors is measured with FossilEye and the companies are interviewed about their current management and sorting of plastics, opportunities and constraints for changed plastic management, and response to different types of feedback. This study gives insights into the plastic content in waste from different types of industries, as well as opportunities and barriers for changed plastic management experienced by different industries. The results also contribute to the scientific understanding of how feedback can be implemented in the plastic value chains and the advantages and disadvantages of different feedback approaches.

Keywords

feedback; industrial waste; plastic management; plastic measurements; plastic waste; scanning system

VALORIZATION OF WASTES FROM THE CODFISH-PROCESSING INDUSTRY: COLLAGEN TYPE I RECOVERY USING EUTECTIC SOLVENTS

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ABSTRACT

Collagen is a widely studied and highly valued macromolecule, sourced from various origins and recognized for its biocompatibility, low cellular toxicity, and excellent water-absorption capacity. These properties make it a versatile biomolecule with applications spanning cosmetics, nutraceuticals, and biomedicine. The fish processing industry generates substantial amounts of by-products, accounting for approximately 70% of total fish weight and amounting to an estimated 28 million tons annually, including waste materials like fish skin. The growing demand for collagen derivatives such as native collagen, gelatin, and collagen hydrolysates coupled with concerns over religious restrictions, zoonotic diseases from terrestrial animal sources, and the environmental impact of biomass waste, has driven the market value of collagen to a projected $20.5 billion by 2030. This has positioned marine collagen as an increasingly attractive alternative to mammalian sources. Fish collagen, with its low molecular weight, is highly bioavailable, making it easily absorbed by the body. Its superior water-binding properties promote hydration and moisturization, both essential for maintaining healthy, youthful skin. The extraction of collagen from fish by-products involves multiple stages, including biomass pretreatment, collagen extraction, and recovery. Collagen's insolubility in water, due to its triple-helix fibers stabilized by hydrogen bonds, require the use of chemical solvents, enzymes, or specialized techniques to enhance solubility and improve extraction efficiency. Different extraction methods yield distinct results, with factors like solvent selection, pH, extraction time, and temperature significantly affecting the efficiency, purity, and quality of the extracted collagen. Although enzymatic and low-temperature extraction, often around 4°C, is commonly used to minimize collagen degradation and preserve its biofunctional properties, these methods have considerable drawbacks, mainly high operational costs. Therefore, optimizing extraction methods and parameters is essential to achieving high yields of biofunctional collagen while balancing efficiency and cost. Our research aims to examine how solvents and methods influence the extraction of collagen type I from codfish skins, an abundant waste produced in a daily base by the codfish-processing industries. The most performant process, this based in Eutectic Solvents was optimized focusing on achieving the highest yield and purity to develop different products whether undenatured collagen, gelatin, or collagen hydrolysates that are not only economically feasible but also scalable for commercial purposes.

Keywords

Marine Collagen, Marine Biomass, Biorefinery, Green Solvent

DEVELOPMENT OF A GEODATABASE TO PROMOTE CIRCULARITY IN WATER AND NUTRIENT RECOVERY FROM MICROALGAE-TREATED WASTEWATER

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ABSTRACT

The world's growing population, combined with increasing urbanisation and environmental degradation, is putting excessive pressure on safe and sufficient water supplies. This is having a profound impact on the availability of water for direct consumption, agriculture and industry, with implications for human well-being, public health and economic development. To tackle this problem, an important part of the solution is to reduce pollution and improve wastewater management and treatment. This will reduce pressure on freshwater resources and help protect ecosystems, while avoiding the waste of nutrients, especially nitrogen and phosphate, both of which are essential for agriculture. In this sense, wastewater treatment (WWT) becomes an opportunity not only to improve water availability, but also to create value in the form of multiproduct generation.

This work analysed the value chain of a microalgae-based WWT process, based on a modular and scalable solution for the treatment of industrial and municipal wastewater. This system includes a set of tubular photobioreactors with a unitary working volume of 1 m^3, optimised light exposure to support the growth of microalgae, and allows the injection of CO_2-containing off-gases. The value chain studied was designed for the dual purpose of producing clean water for agricultural purposes and recycling nutrients from the wastewater in the form of biofertilisers and biostimulants. The methodology used focused on characterising the WWT process in terms of unit operations, key players, primary inputs and outputs, and potential interactions with other related value chains. The identification of value losses (e.g. materials, energy, waste, transport, etc.) along the process value chain enabled the identification of circular economy opportunities for new products across the main life cycle stages: sourcing, production, use and end-of-life. These data were then integrated into an ArcGIS geodatabase to create a map that would serve as the basis for a georeferenced multi-layered tool.

The geodatabase and maps developed in this study should facilitate collaboration and symbiosis between regional stakeholders involved in wastewater bioremediation. An additional benefit will be to promote opportunities for the establishment of new local value chains based on the exploitation of co-products generated in the microalgae-based WWT process. Ultimately, this work aims to design an intuitive interface that encourages map-driven interactions and engages citizens and businesses in regional circular practices.

Keywords

Bioremediation; Biofertilizer; Biostimulant; Clean water; Circular economy

BIOFERTILIZERS BASED ON CIRCULAR SOLUTIONS FOR SUSTAINABLE AGRICULTURE: NUTRIENTS AND LEGAL RESTRICTIONS ON MANURE

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ABSTRACT

The Farm-to-Fork strategy, integrated into the European Green Deal, calls for a significant reduction in the use of chemical fertilizers and pesticides, accelerating the transition to a sustainable food system. Based on data from the Agriculture and Rural Development Department of the European Commission, the European Union (EU) depends on imports for 68% and 30% of its consumption of inorganic phosphates and nitrogen, two essential macronutrients to ensure global food security. On the other hand, the new EU Fertilizing Products Regulation (EU 2019/1009) allows the inclusion of all fertilizers produced from bio-based circular solutions, namely organic waste streams, in the EU market. This approach may significantly reduce EU dependency on chemical fertilizers and promote a more sustainable agricultural system. Biofertilizers use can have several advantages compared to chemical fertilizers, such as low-cost production, physical-chemical properties of the soil improvement (e.g., water retention), and versatility with multiple uses (e.g., soil and seed treatment).
Farm animal waste can be included in this category. About 1.4 billion tons of manure are produced each year in European agriculture, including for example poultry manure. These wastes can be produced in quantities that are not completely consumed by local agricultural land, which can be a problem namely due to storage, transportation, and processing requirements. Biological treatment such as composting can be a valuable option to stabilize these materials, allowing the recovery of nutrients and humified organic matter. However, the composting process must be optimized to eliminate pathogens, while there may be difficulties in eliminating contaminants and emergents (e.g., pharmaceuticals).

This work is within the activities of the I3-4-BIOFERTILIZERS project, which aims to promote interregional cooperation in the biofertilizers and circular bioeconomy sectors. An industrial solution based on a cylindrical closed reactor will be operated and validated to convert poultry manure into a safe compost to be used in agriculture. Lab-scale experiments will be conducted to support the industrial formulation and operating conditions. The stable compost will be valuable in improving soil conditions by adding organic matter, improving water retention and nutrients, and reducing the use and dependency of the EU on chemical fertilizers. This work will provide a circular overview of this case study, considering the application of this innovative industrial solution compared to others, while a techno-economic and environmental assessment will be conducted considering this new biofertilizer before being placed on the market, ensuring compliance with legislation.

Keywords:

biofertilizers; manure; composting; soil application; nutrient recovery

BIOPOLYMERS RECOVERY FROM RESIDUAL BIOMASS OF UASB REACTORS

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ABSTRACT

Wastewater treatment plants (WWTP) generate large amounts of residual biomass (sludge), which poses a challenge for industry professionals, as sludge management accounts for a significant portion of total operating costs. These treatment processes lead to the formation of biopolymers, mainly composed of polysaccharides, proteins, and humic substances, which have potential applications in various sectors. In addition to their hydrogel properties, biopolymers contain enzymes that could be recovered and used for environmental purposes. Currently, biopolymers are extracted from residual sludge using high temperature and chemical agents, which enzyme denaturation and the loss of catalytic function. This study aimed to evaluate and compare biopolymers extracted at two different temperatures (50ºC and 80ºC) from residual biomass obtained from a full-scale UASB reactor. Sludge samples were collected from the USAB rector of the sanitation company in Florianópolis, Brazil. Biopolymer extraction was performed according to Felz et al. (2016). Approximately 3 g of centrifuged sludge pellets (3,100 g, room temperature, 25 min) were transferred to 250 mL baffled flask containing 50 mL of distilled water and 0.25 g of Na_2CO_3. The flask was stirred in a water bath (80°C or 50ºC) for 35 min at 400 rpm. Afterward, the flask's content was centrifuged (3,100 g, room temperature, 25 min) to recover the soluble EPS in the supernatant fraction. The temperature reduction from 80ºC to 50ºC resulted in a decrease in the concentration of biopolymer compounds, including proteins and humic substances (36%), polysaccharides in terms of glucose (47%), and glucuronic acids (25%). Additionally, the biopolymer concentration in terms of volatile solids was reduced by 29%. In both extractions, the formation of ALE with hydrogel properties was confirmed. However, a notable difference observed in the images was the greater consistency of the spheres formed with biopolymers extracted at 80ºC compared to those extracted at 50ºC.

Keywords

Biopolymers, UASB, Sludge, Biomass, Temperature, Resource Recovery

ENHANCING SUSTAINABILITY IN AGRICULTURE AND FORESTRY THROUGH THE PYRAGRAF PROJECT: A HOLISTIC APPROACH

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ABSTRACT

This paper addresses the critical challenges faced by agriculture and forestry in the European economy, emphasizing the threat posed by climate change-induced events. These sectors, contributing significantly to the GDP, face increasing vulnerability due to extreme climate events. The PYRAGRAF project proposes a comprehensive solution by focusing on the pyrolysis of agricultural and forestry residues, introducing innovations such as a mobile solar-assisted gasifier-burner and a decentralized, modular system. The project aims to mitigate the substantial carbon footprint of these sectors, enhance resilience, improve soil quality, and develop decentralized renewable energy solutions. Its methodology involves the validation of a mobile solar-assisted slow pyrolysis unit, product applications, and project sustainability, whilst the concept integrates renewable sources for the efficient valorization of biomass wastes, aiming to develop agriculture and forestry sustainability. The PYRAGRAF project focuses on enhancing economic and environmental sustainability through optimized production of biochar, wood vinegar, bio-oil, and gas from the pyrolysis of agricultural and forestry residues. PYRAGRAF introduces an innovative mobile solar-assisted gasifier-burner, supplying high-temperature process heat for biomass drying and pyrolysis. The project addresses innovation gaps, aiming to integrate a solar dish concentrator, high-temperature gasifier, and air burner to increase the sustainability of biochar production. Also, addressing the energy-intensive nature of biomass drying, PYRAGRAF introduces a mobile screw conveyor dryer (SCD) utilizing waste heat from the pyrolysis module and solar-assisted gasifier-burner. While existing mobile pyrolysis units face challenges, PYRAGRAF leverages renewable heat sources and innovative solar reactors, advancing slow pyrolysis technology. Utilizing agricultural and forestry residues as feedstock, the project applies biochar to diverse soils and crops (namely in Portugal, Turkey, and Germany), aiming to restore arable land and enhance environmental benefits. Furthermore, this project also entails several specific objectives that include selecting biomass wastes for the project, determining optimal process parameters for waste feedstock pyrolysis, building and demonstrating the operation of a mobile, solar-assisted integrated pyrolysis unit, demonstrating the potential of bio-char and wood vinegar for agriculture and forestry applications, demonstrating the potential of pyrogas and bio-oil in energy applications, validating increased sustainability in economic, environmental, and social domains, and creating business plans for the PYRAGRAF approach while identifying potential market opportunities. Successfully achieving these objectives would position PYRAGRAF at the forefront of sustainable agricultural and forestry practices, marking a significant stride towards innovation and resilience in both sectors.

Keywords

Pyrolysis; Agricultural and Forestry Sustainability; Renewable Energy; Carbon Footprint Reduction; Climate Change Mitigation

VALORIZATION OF FISHERIES AND AQUACULTURE WASTES IN MADEIRA ISLAND: ADDRESSING CHALLENGES AND OPPORTUNITIES

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ABSTRACT

Madeira Island, with a significant fishing and aquaculture industry, faces challenges in managing the waste generated by these sectors. The local fishing fleet, landing roughly 5,000 tons annually, supplies the local market and exports significant amounts overseas. The aquaculture sector produces around 1,500 tons per year, with approximately 85% exported. Despite previous attempts at fish meal production, which were unsuccessful, the island still generates substantial waste. This study investigates the characteristics and volumes of waste produced by these sectors, considering the island's specific context, including limited infrastructure and the logistical challenges associated with waste collection and transportation.

The study focuses on identifying and evaluating the feasibility and economic viability of various waste valorization pathways, such as:

- Processing for alternative food products: Using trims and undersized/deformed fish to produce emergent food goods.
- Composting and organic fertilizer production: Utilizing organic waste from fish processing and aquaculture to produce high-quality compost for agricultural use.
- Biogas production: Anaerobic digestion of organic waste to generate biogas for energy production and reduce greenhouse gas emissions.
- Extraction of valuable compounds: Exploring the extraction of high-value compounds such as omega-3 fatty acids, collagen, and chitin from fish processing waste.
- Feed production: Developing animal feed from fish processing waste and aquaculture by-products, contributing to a circular economy approach.
- Integrated multitrophic aquaculture: Producing lower trophic level species (macroalgae, marine invertebrates), taking advantage of organic enrichment of sea water around sea bream offshore fish farms.

By identifying and implementing sustainable waste management strategies, Madeira Island can minimize the environmental impact of its fisheries and aquaculture sectors, create new economic opportunities, and promote a circular economy while addressing the challenges associated with previous attempts at waste valorization.

Keywords

Fisheries and aquaculture waste, valorization, composting, biogas, circular economy, Madeira Island

QUERCUS ROTUNDIFOLIA AND *QUERCUS ROBUR* SHELLS: NUTRITIONAL VALUE AND CIRCULAR ECONOMY POTENTIAL

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ABSTRACT

Acorns, the fruit of oak trees, are produced abundantly across Portugal's Portugal's landscapes, yet remain vastly underutilized, with only 1% incorporated into human nutrition. *Quercus* trees, which occupy approximately 34% of Portugal's forested land—covering 1,107,600 hectares—contribute to a significantly to acorn production. As Portugal is a net food importer, wasting this nutrient-rich resource is impractical, especially given its proven nutritional value. Additionally, acorn by-products hold significant potential as sources of bioactive compounds, supporting efforts to reduce food waste, promote upcycling, and introduce innovative health-focused applications. Rich in fatty acids, phenolic compounds, tocopherols, and minerals, acorns hold promising antioxidant properties, enhancing traditional foods with functional and health-promoting benefits.

This study aimed to valorize the shells of *Quercus rotundifolia* (QT) and *Quercus robur* (QB), two endemic species, as byproducts of acorn processing from LandraTech, promoting their use in circular economy applications. For that purpose, the two shell samples were ground as flour and then analyzed regarding the physicochemical characteristics and nutritional value, complemented by determining their antioxidant activity through ABTS and DPPH.

Regarding its physicochemical characteristics, QT and QB flours revealed a low water activity value (0.531 ± 0.000 and 0.374 ± 0.001), and a slightly acidic pH (4.97 and 4.95), respectively. The nutritional composition of QT and QB showed a humidity content of 10.91 ± 0.01% and 10.98 ± 0.00%, ash content of 1.30 ± 0.24% and 1.64 ± 0.05% DW, protein content of 3.95 ± 0.23% and 2.49 ± 0.16% DW, and a carbohydrate content of 79.37 ± 0.20% and 83.22 ± 0.31% DW, respectively. The total lipid content was 4.47 ± 0.02% and 1.67 ± 0.79% DW, respectively and the fatty acids composition indicated the prevalence of C18:1 n-9c, C16:0, and C18:2 n-6c. Also, QT is richer in vitamin E (8.89 ± 0.62 mg/ 100 g DW), then QB (2.57 ± 0.04 mg/ 100 g DW). Furthermore, the mineral levels evaluated by ICP-MS indicated mainly the presence of potassium, calcium, magnesium, manganese, and phosphorus.

The total phenolic compounds (TPC) and total tannins (TT) in the RT and RB aqueous extracts were assessed using the Folin-Ciocalteu method. The extract of QT contained 14.73 ± 1.26 mg GAE/g DW of TPC and 14.45 ± 0.98 mg GAE/G DW of TT, while the QB extract held 13.34 ± 1.12 mg GAE/g DW of TPC and 11.23 ± 0.70 mg GAE/g DW of TT. In addition, the extracts also demonstrated promising antioxidant activity in ABTS (QT: 101.30 ± 2.10 µmol TE/g DW; QB: 108.96 ± 13.34 µmol TE/g DW), DPPH (RT: 84.75 ± 6.31 µmol TE/g DW; QB: 77.37 ± 15.17 µmol TE/g DW), and ORAC (QT: 187 ± 13.47 µmol TE/g DW; QB: 158.53 ± 20.08 µmol TE/g DW) assays.

In summary, these findings highlight the value of *Q. rotundifolia* and *Q. robur* flour not only as nutritional ingredients but also as promising candidates for applications in food, pharmaceutical, and nutraceutical industries, promoting a circular economy.

Keywords

Acorn; shells; upcycling; nutrition; antioxidants

MAXIMIZING MATERIAL AND ENERGY RECOVERY PROCESSES THROUGH INDUSTRIAL SYMBIOSIS WITHIN THE WASTE-WASTEWATER–ENERGY NEXUS

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ABSTRACT

This work represents a step forward in the proposal of a new approach aimed at maximizing material and energy recovery processes through Industrial Symbiosis (IS) within the "waste-wastewater–energy nexus". The proposed IS enhance the closing of the loops in recovery of waste and wastewater while providing low-cost energy (electricity and heat) which can significantly support novel industrial opportunities for the development of existing and new companies in a modern industrial district.
It is presented a comparison of the sustainability, through a Life Cycle Assessment (LCA), of three different management scenarios of waste, wastewater, and their related energy systems management in in a large metropolitan area representative of Southern European region regions where there is an unsustainable approach in waste and wastewater management with effects on environmental impact, energy demand and economic activities.
The results highlight the beneficial effects of the integration of different plants (Waste to Energy - WtE, Anaerobic digestion - AD, wastewater treatment plant - WWTP) in a symbiotic nexus. The results show that the recovery of separately collected wastes leads to an important reduction in the impact of Municipal Solid Waste (MSW) management but a synergic introduction of energy recovery (by means of AD and WtE) and its symbiotic use to support the anaerobic digestion, wastewater reuse, and sludge recovery processes significantly increase the sustainability.
A quantitatively assessment of the potential for residual heat exploitation for the creation of an industrial symbiosis network or district according to the logic of the eco-industrial park was conducted. The waste heat produced in different production sectors was then evaluated to identify companies that could potentially become part of the industrial symbiosis district with reference to the possibilities of using thermal energy for district heating and cooling or within production processes for the transformation of agricultural and food products.
The proposed integration is particularly suitable to bridge the gap in Southern European regions which continue to have disjointed and unsustainable management of waste, wastewater and sludge, unacceptable levels of material recovery, waste of potentially exploitable energy and significant environmental burdens. In addition, the proposed symbiotic model should be intended as an evolved material and energy community, able to self-producing new products, electricity, heat, and biomethane to be used both in the same industrial districts and in surrounding cities, efficiently favouring the increase of a sustainable circularity and a rapprochement toward the New Green Deal required by the European Union, which are clearly lagging behind in these regions.

Keywords

Industrial Symbiosis; sustainable waste management, waste-wastewater–energy nexus, wastewater reuse; Anaerobic digestion, Energy recovery.

THE POTENTIAL OF MICROALGAE FOR WINE EFFLUENT VALORISATION

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ABSTRACT

Winery wastewater (WWW) is generated during several steps of the wine production process, including cleaning and pressing of grapes, water utilized for tanks, transfer lines, floor washing, and wine losses.
These effluents have a high pollutant load which have a negative environmental impact due to their large production volumes (up to 14 liters per liter of wine), high levels of chemical oxygen demand (COD), total solid content, nitrate, phosphate, sulfate, and polyphenols. The most common WWW treatments include the conventional physicochemical and biological processes for the removal of major pollutants and their coupling with advanced oxidation processes for the removal of color and recalcitrant compounds. Biological treatment of effluents involves the application of microorganisms, being broadly used. Activated sludge process used for WWW treatment removes the major contaminants, but involves high operating costs, due to the large sludge production and high energy consumption for maintaining aerobic conditions in the bioreactors. Furthermore, the final by-products have no significant market value. For this reason, alternative processes have been presented in the literature for the simultaneous treatment and valorization of WWW. Recently, attention has been paid to the use of microalgae for these purposes and the simultaneous production of high value bioproducts. Autotrophic microalgae are efficient in fixating inorganic compounds (carbon dioxide, nitrate, and phosphate), while heterotrophic microalgae are efficient in removing organic carbon from the medium. Both can assimilate organic compounds which are difficult to treat by conventional methods (e.g. polyphenols), and the final biomass is suitable for several applications (e.g. biofuels production, nutritional compounds, and biofertilizer). Several microalgae species are versatile and robust, being able to grow on these effluents, simultaneously producing a wide range of valuable biocompounds. The presence of high-value bioactive compounds such as lutein, β-carotene, chlorophyll, and tocopherols in the microalgae biomass has great interest due to the heath beneficial and colorant properties of these compounds and their applications to food, pharmaceuticals, and cosmeceuticals industry, contributing to accomplish the circular economy principles, as well as to improve the profit of the whole process. The present study describes the benefits of using WWW for microalgae production, the strategies and approaches that have been used, as well as the efficiency of the WWW treatment by the microalgae, as well as the bioproducts that have been obtained at the end of the whole process.

Keywords

Microalgae, winery effluents, circular economy, bioproducts.

SUSTAINABLE VALORIZATION OF WHEAT BY-PRODUCTS THROUGH A GREEN BIOPROCESSING

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ABSTRACT

Cereals, particularly wheat, are a fundamental part of the global diet, but their processing generates significant by-products, namely wheat bran (WB) and wheat germ (WG), yielding, annually and globally, approximately 150 million tonnes and 25 million tonnes of by-products, respectively. These by-products remain largely underutilized. Wheat bran is a valuable source of dietary fiber and minerals, while wheat germ contains proteins, lipids, and bioactive compounds, making both by-products promising for sustainable valorization. Their applications range from functional foods and high-protein pasta to oil-in-water cosmetic formulations and biodegradable packaging materials.

So, the wheat by-products can be divided into three categories: wheat bran (WB), wheat germ oil (WGO) and wheat germ proteins (WGP).

This study aims to achieve a complete valorization of wheat by-products through an innovative green bioprocessing strategy. The first stage focuses on wheat germ valorization by developing an enzymatic extraction process combined with a micellar phase designed to recover proteins, bioactive peptides, and wheat germ oil (WGO) in a single step. This study aims to optimize this extraction method and evaluate the physicochemical properties and bioactivities of the resulting extracts.

The extraction process began with the incorporation of Viscozyme to degrade the cell wall matrix, facilitating the release of proteins and lipids and enhancing the overall efficiency of the valorization process. Subsequently, enzymatic hydrolysis was performed using Alcalase (0%, 1%, and 2%), while different strategies were applied to mitigate lipid oxidation in WGO. Vitamin E and rosmarinic acid (1% and 2%) were tested as antioxidants, and Tergitol 15-S-7 (1% and 5%) was used to improve lipid phase separation. Following hydrolysis, the physicochemical parameters were assessed, including soluble protein content, lipid quantification, and the degree of hydrolysis. Additionally, functional properties such as antioxidant and antidiabetic activities were evaluated. Based on these analyses, the optimal conditions for maximizing protein solubility, lipid recovery, and bioactivity were identified.

These results will enhance the value of these products, contributing to the transition toward a zero-waste wheat valorization system. By demonstrating the potential of bioactive wheat compounds, this approach will drive the scalability of bioprocesses for industrial applications, support the development of functional ingredients, and promote more sustainable and circular agro-industrial practices. Furthermore, the insights gained from this study will serve as a foundation for future research on bioavailability, consumer acceptance, and regulatory feasibility, further strengthening the potential impact of wheat-derived bioactive compounds.

Keywords

Wheat valorization, wheat by-products, wheat bran, wheat germ, bioactive compounds, sustainable extraction.

HYDROGEN PRODUCTION FROM SUGARCANE VINASSE VIA AQUEOUS-PHASE REACTION

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ABSTRACT

Sugarcane vinasse is a byproduct of sugar production and is used for soil remediation. This study addresses its valorization through aqueous-phase reforming for H_2 production. Aqueous phase reforming of sugarcane vinasse for hydrogen production was conducted in two stages using a Ni-Cu/Al_2O_3 catalyst. In the first part, three alumina supports were synthesized and compared with commercial alumina using a completely randomized experimental design. In the second part a 2^3 factorial design, considering pH (4.5 – 9), catalyst-to-vinasse ratio (2 – 10%), and metal composition in the catalyst (10 -20 %) as factors. The supports were γ-alumina, exhibiting similar characteristics and H_2 production. In the second part of the study, commercial alumina was used. H_2 production is favored at low pH level, metal composition in the catalyst, and high catalyst-to-vinasse ratio. The temperature was 513 K and reaction time 60 minutes. The rate of H_2 production was 182 μmol $h^{-1}gcat^{-1}$, similar to other studies. The liquor after the reaction shows a 51% reduction in chemical oxygen demand (COD) and a 61% to 100% reduction in the principal sugars of the sugarcane vinasse. A significant portion of the vinasse transformation results in the formation of CO_2 and CH_4. Under the best reaction conditions, the catalyst was reused for 5 cycles. After the first cycle, the rate of H_2 production decreased by 84.5%, and by the fourth cycle, it was 97.3% with a rate of 2.93 μmol $h^{-1}gcat^{-1}$. In the fifth cycle, the catalyst was regenerated, and the production rate increased to 8.11 μmol $h^{-1}gcat^{-1}$. An analysis of the exhaust catalyst revealed carbon deposition, metal leaching, metal oxidation, and increased sulfur, associated with poisoning processes. The XRD analysis also showed a phase change of support to boehmite.

Keywords

Sugarcane vinasse, hydrogen production, biomass valorization, aqueous-phase reforming.

ECOTOXICOLOGICAL ASSESSMENT OF THE POTENTIAL IMPACT ON SOIL POREWATER, SURFACE AND GROUNDWATER OF THE USE OF AGRI-FOOD WASTES AS SOIL CONDITIONERS OR FERTILIZERS

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ABSTRACT

A significant amount of food waste is generated during the processing of raw materials from the agrifood sector. The disposal of these wastes in landfills or through incineration is costly and has negative environmental impacts. Furthermore, agri-food wastes often contain valuable properties from the agronomical perspective and their direct application as soil conditioners and/or fertilizers can be advantageous and cost effective. Nonetheless, these organic wastes may contain potentially toxic compounds that, from their soil application, can reach different environmental compartments, such as soil porewater, surface and ground water, causing severe impacts. Ecotoxicological tests are a sensible approach for assessing the intrinsic toxicity of a material in the environment, as a complement to chemical analysis. This study has the purpose to assess the environmental risks and the potential contaminant effect on soil porewater, surface and groundwater, which can be affected through solubilization, runoff or leaching from four agri-food wastes, when they are used as soil conditioners/fertilizers: two by-products from the yeast industry, a) spent dried yeast (SDY) and b) condensed molasses solubles (CMS); c) spent curd (SC), a by-product from the cheese industry; and d) spent coffee grounds (SCG), from restaurants. A series of bioassays, evaluating the soil retention function, with seeds and aquatic organisms from different trophic levels were used:) relative seed germination and roots elongation of lettuce (*Lactuca sativa*) (7d); b) *Daphnia magna* acute immobilization tests (48h); and c) *Vibrio fischeri* bioluminescence inhibition (15 and 30 min). The bioassays tested the water-extract obtained from the soil (1:10 w/v, dm basis), after its amendment with a gradient of application rates of those materials, starting on the maximum application rate possible for the liquid materials (CMS and SC), which was 120 g kg-1, while for solid materials (SDY and SCG), that application rate was used to establish the dilutions from there on (50, 25, and 12.5% w/w of the maximum), eventually increased or decreased, depending on the toxicity response found. The water extracts obtained from the soils amended with the higher application doses of SDY and CMS (120 g kg^{-1}), leaded to total immobilization of the *D. magna*, while, also for *L. sativa*, the germination index (GI (%), the product of the relative seed germination (%) to the relative seed growth (%), compared to the control) evidenced a high toxic response for both yeast industry wastes, with EC50 values in the range 15 – 30 g kg^{-1}. The results of the seed germination and root elongation of *L. sativa* indicated a lower toxic response from SC (EC50 ~120 g kg^{-1}), although higher than for SCG, the least toxic of the materials. In fact, SCG application rate could be increased above 120 g kg^{-1} without a detected toxic response from *L. sativa* (EC50 ~960 g kg^{-1}). These results suggest that, despite the potential benefits of these agri-food wastes, for some materials, their direct soil application should be limited to a concentration that would not affect terrestrial and aquatic organisms by leaching.

Keywords

Ecotoxicity assessment; Agri-food wastes; soil-water extracts; seed germination; aquatic organisms

ECO-FRIENDLY EFFLUENT TREATMENT FOR THE CORK INDUSTRY VIA ELECTROCOAGULATION USING METALLIC WASTE ELECTRODES

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ABSTRACT

The reuse of industrial waste materials is a cornerstone of sustainable development and circular economy practices. This strategy not only benefits the environment but also offers economic advantages, enabling industries to cut waste management costs, avoid disposal fees, and showcase their commitment to environmental responsibility while meeting regulatory and sustainability goals. This study explores the innovative application of aluminum shavings waste - an abundant by-product of machining processes - as sacrificial electrodes in an eco-friendly electrocoagulation (EC) treatment for cork industry effluent. By repurposing aluminum waste, this approach reduces reliance on raw materials and mitigates the environmental burden associated with aluminum disposal.

Key parameters, including initial pH, current density, distance between electrodes, stirring and aeration. were optimized to achieve high pollutant removal efficiency. Within 30 minutes, experimental results showed substantial reductions in chemical oxygen demand (COD), total nitrogen (TN), total suspended solids (TSS), and phenolic compounds, meeting the environmental standards for industrial effluent discharge into municipal collectors. The energy consumption was approximately 0.90 kWh m^{-3}. Additionally, the process generated minimal sludge, which was analyzed for potential secondary applications, further enhancing sustainability.

This research highlights the dual benefits of aluminum waste valorization and effective effluent treatment, offering a cost-effective, scalable, and environmentally conscious solution for the cork industry. The findings underscore the potential of waste-derived materials to drive innovation in wastewater management technologies, contributing to a greener and more sustainable industrial future.

Keywords

Sustainability, Circular economy, Waste recovery, Electrocoagulation, Aluminium

TURNING LIGNOCELLULOSIC RESIDUES INTO HIGH-PERFORMANCE NANOMATERIALS: UNLOCKING THE POTENTIAL OF NANOCELLULOSE AND NANOLIGNIN

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ABSTRACT

Current demand for bio-based nanoparticles as a substitute for synthetic nanoparticles has increased due to their physicochemical properties, biodegradability and biocompatibility, and lignocellulosic wastes can be exploited for the production of cellulose and lignin derived nanoparticles. Nanocellulose (NC) and nanolignin (NL) have applications in many different areas, ranging from automotive manufacturing, agricultural, medicine, food industry, biotech industry and extending to the energetic field. Yet, the recalcitrance of the lignocellulosic material to deconstruction, requires pre-treatments as an earlier and necessary step in the process to get NC and/or NL. Therefore, the aim of the work focuses on the recent developments about the valorization of those lignocellulosic wastes as a source of NC and NL, by discussing (i) how the characteristics of different biomasses and residues influence the NC and NL properties, (ii) treatments and extraction procedures, and (iii) its categorization in terms of eco-friendly and green principles. Results show that progress has been made in greener pretreatment methods for lignocellulosic biomass, but challenges remain. The sustainability and efficiency of these methods vary by biomass type, making a universal solution impractical. While more sustainable techniques are emerging, their industrial use is limited by high costs and technical complexities, requiring specialized equipment. Overall, scaling up these developed greener methods (e.g. Deep Eutectic Solvents, steam explosion, biological/ enzymatic methods) to an industrial level requires better energy management, cost reductions, and continued innovation.

Keywords

Nanocellulose; Nanolignin; Lignocellulosic waste; Sustainable pre-treatment; Green chemistry.

SUSTAINABLE GEOPOLYMER MATERIALS FROM MINE WASTE FOR CONSTRUCTION AND DYE REMOVAL APPLICATIONS

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ABSTRACT

With millions of tons of tailings and other by-products posing risks to ecosystems and human health, mine waste is a significant global environmental issue worldwide. Effective management and recycling of these wastes are critical to mitigate their impact, reduce pollution, and promote sustainable development. Alkali activation has emerged as a promising approach for replacing conventional materials and valorising waste. In this study, mine tailings from an abandoned Pb-Zn site in Northern Tunisia was selected as an inexpensive additive with high adsorption capacity. It was used to replace metakaolin at varying proportions (0, 5, 10, 20, and 30%) in the synthesis of geopolymers containing Portuguese Vicente Pereira (VP) Metakaolin.

During the geopolymerization process, the SiO_2/Al_2O_3 and Na_2O/Al_2O_3 molar ratios were maintained at 1, minimizing the use of sodium silicate and sodium hydroxide to obtain geopolymers with a low environmental impact. The study compared the effects of VP metakaolin on the microstructure, mechanical properties, and Methylene Blue dye adsorption capacity of the resulting geopolymers. The results indicated that the mine tailings contain high levels of potentially toxic elements necessitating stabilization to prevent leaching. For the synthesized geopolymers, Scanning Electron Microscopy (SEM) observations revealed varying degrees of geopolymerization across formulations, with a predominance of the amorphous phase. Geopolymers based on VP metakaolin exhibited good compressive strengths reaching 30 MPa after 28 days of curing. Additionally, the synthesized geopolymers were tested for Methylene Blue adsorption, evaluating the effects of the adsorbent amount and shaking period. The batch kinetics study fit best with the pseudo-second-order reaction kinetic model. In isotherm modeling studies, the Langmuir isotherm model provided the best fit, describing the adsorption mechanism effectively. Samples containing 30 wt.% metakaolin exhibited the highest adsorption capacities.

This study highlights the positive impact of mine tailings on enhancing the properties of alkali-activated metakaolin-based geopolymers and its potential for metakaolin restitution, demonstrating a sustainable approach to mine waste recycling.

Keywords

Mine Waste Recycling, Geopolymers, Metakaolin, Alkali Activation, Compressive Strength

ASSESSING THE CURRENT SITUATION TO DESIGN A SUSTAINABLE MANAGEMENT MODEL FOR AGRICULTURAL PLASTIC WASTE

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ABSTRACT

The widespread use and mismanagement of Agricultural Plastic Waste (APW) have significant environmental consequences. Collecting APW presents a challenge, with substantial amounts often left in the fields, where they fragment into microplastics that persist in the environment, contaminating soil, water, and plants, while also negatively impacting agricultural yields. However, the full extent of APW leakage into the environment remains unclear and varies depending on the type of plastic product, its application, and the availability of collection and recycling infrastructure. In Portugal, in particular, farmers often lack a structured solution for the collection and sustainable management of APW. At the same time, they are legally responsible for managing the waste they generate, but face difficulties in identifying viable recycling options and managing the associated costs. This research project aims to propose management and organisational solutions for APW, taking the Portuguese reality as a case study. The study will, for example, assess the feasibility of integrating APW management within the framework of extended producer responsibility, or alternatively, explore a model based on organised cooperation between farmers and farming organisations. To address this challenge, a collaborative processes involving stakeholders from the agricultural plastic value chain will be implemented. This process will include farmers, farming organisations, recyclers, and decision-making bodies, such as the Portuguese National Waste Authority. Through this collaboration, the aim is to identify the real barriers in APW management, explore opportunities and constraints related to the use of alternative solutions to conventional plastics, determine which tools would be useful for managing this waste, and co-develop proposals to address these challenges, ultimately mitigating the environmental impacts outlined above. The assessment will also incorporate data on the quantities of plastics used and discarded in the agriculture sector, highlighting gaps and challenges in the end-of-life management of these products. This includes assessing the capacity for collection and recycling, the technical specifications of the recycling industry, and the constraints involved in these processes. Such data is crucial for managing APW more efficiently, with reduced environmental impact, and for operating agricultural production towards more sustainable and competitive practices. In this context, it is anticipated that the results of this research will contribute with valuable insights to close knowledge gaps in the scientific literature on this topic, support the implementation of best practices, and inform future policy decisions, with the potential for replication in similar contexts.

Keywords

Agricultural Plastic Waste (APW), Production Organization, Organizational Models, Stakeholder Capacitation and Engagement, Extended Producer Responsibility.

IMPACTS OF AGRICULTURAL PLASTIC WASTE IN PORTUGAL - MICROPLASTICS PRESENCE IN FARMLAND SOIL SAMPLES

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ABSTRACT

Plastics pose a significant environmental challenge. A 2021 report by the OECD and FAO highlights that plastic waste in soil now exceeds that in oceans, affecting the food chain and requiring urgent action. Mismanagement of agricultural plastic waste (APW) results in soil contamination, where plastics degrade into persistent macro-, micro-, and nanoplastics, polluting both terrestrial and aquatic ecosystems. Over 80% of marine plastic litter originates from land-based sources, harming aquatic organisms. Furthermore, microplastics (MP) from agricultural materials present additional risks, such as bioaccumulation and biomagnification, which may potentially impact human health.

In Portugal, there is no integrated solution for managing APW, and knowledge about the agricultural plastics value chain, its impacts, and potential management strategies is limited. The use of plastic films in agriculture has significantly increased APW production, however, there is a lack of innovative and organisational approaches for proper APW disposal, raising concerns about the generation and fate of MP from agricultural plastics.

To tackle this issue, the Agri-Plast Project, involving 14 national entities, aims to develop solutions for agricultural plastics production and introduce innovation for their reduction, developing management and organisational plans for APW. To achieve its aim, there is a need to develop a state-of-the-art diagnosis of the current reality of agricultural plastics use and fate, and baseline data on APW is necessary, namely on MP presence in agricultural soils.

Initial experiments focused on soil sampling and analysing macro- and microplastics in the topsoil layer of land farms from six partner agricultural companies that produce fruits and vegetables. These preliminary analyses enhance the understanding of APW pollution by quantifying plastics presence in the soil, their polymeric composition, and other parameters like their colours and size.

Preliminary findings from samples collected showed the existence of microplastics in all sampling sites. Polymeric analysis through FT-IR spectroscopy confirmed the presence of polymers such as polyethene (PE) and polypropylene (PP). MP size ranged from 175 μm to 5000 μm, and the most prevalent colours were black, green and blue.

These findings will support the development and implementation of improved APW management practices and promote the use of sustainable alternatives to fossil fuel-based plastics, helping to prevent plastics from entering the environment and becoming a threat to land and aquatic ecosystems, thus reducing their associated negative impacts and effects on animal, environmental and human health.

Keywords

Agricultural Plastic Waste, Microplastics, Plastic Waste Management, Agricultural Soil

PRODUCTION OF SUGAR MONOMERS VIA THE DECOMPOSITION OF LIGNOCELLULOSIC BIOMASS DERIVED FROM CASSAVA UTILIZING ALKALINE HYDROGEN PEROXIDE PRETREATMENT

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ABSTRACT

The valorization of lignocellulosic biomass (LCB) has gained space for discussion in the current scenario because it is possible to obtain value-added products (VAP) and fuels while reducing fossil fuel consumption. LCB consists of cellulose, hemicellulose, and lignin, which due to their structure not well accessible to fermentative bacteria. Therefore, LCB pretreatment is necessary to improve the bioavailability of substrates to microorganisms. In this sense, cassava peel biomass is a rich source of cellulose and hemicellulose, and due to the large quantity generated in the processing industry, it is a strong ally to the biorefinery concept. In this study, cassava peel was subjected to alkaline pretreatment with H_2O_2 at different concentrations (1%, 2%, and 4%) and contact times (2h, 4h, and 8h) at 75°C, to determine which condition yielded the highest concentration of sugar monomers in the liquid medium for subsequent application in dark fermentation. Sugar monomers were quantified by HPLC. The surface structure of cassava peel before and after pretreatments was analyzed by SEM. The condition of 1% H_2O_2 and 8 hours of contact obtained the highest sugar yield, reaching 0.11 g·L-1 of glucose, 0.71 $g \cdot L^{-1}$ of mannose, 0.36 $g \cdot L^{-1}$ of arabinose, and 1.06 $g \cdot L^{-1}$ of fructose. This result can be explained by the contact time and peroxide concentration applied at this condition, which acted on the recalcitrant structure and decomposed the biomass into sugars with low conversion into inhibitors. There is also strong evidence that the chosen temperature contributed to the non-generation of inhibitor compounds, since it has been reported that high temperatures (i.e., >100°C) can contribute to this generation. On the other hand, SEM analysis suggested that higher peroxide concentration intensified the breakdown of the biomass structure. While the surface structures under 1 and 2% peroxide were very similar, the structure at 4% peroxide was strongly modified. The condition of 4% peroxide and 8 hours of contact obtained the second-best sugar production yield. It is hypothesized that higher peroxide concentration increases the sugar degradation rate, leading to greater production of inhibitory compounds compared to the condition of 1% and 8 hours. With the results obtained, the best cassava peel pretreatment condition for future dark fermentation applications will be chosen based on input consumption, time, sugar yield, and inhibitor concentration. In this case, the 1% and 8-hour contact conditions have an advantage over the others. Thus, cassava peel has significant potential to contribute to the biorefinery concept by achieving excellent sugar yields, maximizing alternatives for residue valorization, and obtaining value-added products.

Keywords

Biorefinery concept, waste valorization, dark fermentation, pretreatment biomass, inhibitory compounds.

EFFECTS OF ENVIRONMENTAL ACTIONS ON THE TENSILE BEHAVIOUR OF A GEOSYNTHETIC EMBEDDED IN RECYCLED AGGREGATES COMING FROM CONSTRUCTION AND DEMOLITION WASTE (C&DW)

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ABSTRACT

Construction and demolition wastes (C&DW) are generated in construction, demolition and renovation of buildings and civil engineering works, and represent a major challenge to the modern society, mainly because their high generation rates and heterogenic composition. In addition to the high consumption of natural resources and energy (up to 40 % of the raw materials extracted globally), construction activities generate significant amounts of wastes, corresponding to an average of 35 % of the total solid wastes produced worldwide.
The reduction in the exploitation of non-renewable natural resources is nowadays widely recognized as a pressing need for a more sustainable society. Moreover, the increase in waste valorisation and reuse of waste materials are undoubtedly important steps forward for environmental sustainability. Geotechnical design being part of typical civil engineering projects can play a major role in the sustainability of the built environment.
Recycled aggregates coming from C&DW have been considered as alternative materials in different civil engineering applications, such as unbound pavement layers and structural embankments, in which geosynthetics are also frequently applied. If the durability of geosynthetics is an important issue when conventional materials are used, it becomes more relevant when utilising alternative materials.
A laboratory study was undertaken to investigate the effect of wetting-drying (W-D) cycles on the tensile behaviour of a geosynthetic (geogrid) embedded in recycled aggregates coming from C&DW. W-D cycles simulate changes in climate over the service life of the geotechnical structure and are considered capable of simulating scenarios of inducing damage to structures.
This paper presents the degradation induced by W-D cycles in the tensile behaviour of a geosynthetics (commonly used in reinforced steep slopes and retaining walls) embedded in a recycled aggregate from C&DW. The geometrical, physical, mechanical and environmental characterization of the recycled C&DW is presented. Wide width tensile tests were performed on exposed and intact (as-received) samples and their tensile behaviour is compared.

Keywords

Sustainability; Construction and Demolition Waste; Recycled Aggregate; Geosynthetic; Wetting–drying cycles; Tensile behaviour.

OPPORTUNITIES AND CONSTRAINTS ASSOCIATED WITH THE PRODUCTION OF OILSEED CROPS IN MARGINAL SOILS

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ABSTRACT

Dedicated crops represent an important feedstock to decarbonise the energy sector and to meet the no net emissions of greenhouse gases by 2050, as set by the European Green Deal. Dedicated crops are renewable and sustainable feedstocks, associated with energy supply diversification, greenhouse gas savings and mitigation of problems related with materials biodegradability. However, the greenhouse gas performance of biomass to energy, biofuels and bio-based products, can be negatively impacted by Indirect land use change (ILUC) effects. The increasing demand for biomass, associated with the technological development and the Green Deal European targets, may increase the competition for land, threatening food security. Consequently, cultivation of industrial crops on marginal land is suggested as an approach to minimize land use competition with food crops and land use change controversies. In this framework, selected oilseed crops were studied, given their tolerance to marginal soils and potential for bioenergy, biofuels and bioproducts production. Therefore, the objective of this work was to identify the opportunities and constraints associated with the cultivation of these industrial crops in marginal soils. Data on case-studies on marginal soils to source feedstock for the biobased industry was used. In the study, crop management options were assessed, namely, amount of fertilizers and pesticides applied, type of soil marginality, among others. Effects of the cultivation of those crops in the marginal soils were addressed towards yields, impact on soil and water and on the biodiversity and landscape. Results obtained suggest that growing these crops in marginal soils provide benefits regarding soil properties and erodibility, although yields are affected by the degree of marginality. Oil crops show benefits due to blossoming. Impacts associated with water resources and fertilizer related emissions were high, but impacts associated with pesticide related emissions were low. The use of appropriate management practices (e.g. adequacy between crop and location, fertilizers balanced application) established on marginal land at farm level may reward biological diversity, soil quality index, impact on water resources and on emissions. Lessons learned will help to optimize sustainable low-ILUC feedstock to support feasible bio-based value chains.

Keywords

Biofuels, oilseed crops, sustainability, marginal soils, phytoremediation, polluted soil

ENVIRONMENTAL RISKS OF THE USE OF AGRI-FOOD WASTES AS SOIL AMENDMENTS: AN INTEGRATED CHEMICAL AND ECOTOXICOLOGICAL ASSESSMENT

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ABSTRACT

Some agri-food industry's by-products can be transformed into value-added products, but some are only seen as waste, without an obvious valorisation strategy. For those materials, it is important to assess their use as potential organic fertilizers, because of their nutrients content, or as soil conditioners, because of their organic matter content or pH value. The integration of information from the chemical composition of those materials with their ecotoxicological assessment is essential, for a more reliable evaluation of the environmental impacts arising from their soil application. This study aimed to evaluate the potential benefits and environmental risks associated with the use of four agrifood industry's by-products as potential soil fertilizers/amendments: two by-products from the yeast industry, a) spent dried yeast (SDY) rich in N, P and K and b) condensed molasses solubles (CMS) rich in N and K; c) spent curd (SC), a by-product from the cheese industry, rich in N, Ca, and P; and d) spent coffee grounds (SCG), from restaurants, with potential for soil conditioner. The materials were characterized for their physicochemical characteristics, namely pH, electrical conductivity (EC), organic matter content (OM), and total macro- and micronutrient concentrations, and using direct toxicity bioassays, with terrestrial organisms from different trophic levels, to evaluate the potential impact of the materials on soil phytotoxicity and "habitat function". Tests included sub-lethal and lethal bioassays: (a) plant germination of lettuce (*Lactuca sativa*) and cress (*Barbarea verna*); (b) plant growth of maize (*Zea mays*); (c) avoidance behaviour with the earthworm *Eisenia fetida*; and d) acute mortality with *E. fetida*. Tests were performed with a gradient of application rates, to assess the higher doses that can be applied to soil without a risk. For liquid materials (CMS and SC), the higher application rate was limited by the maximum amount of material that can be added to a reference soil without exceeding its 70% water holding capacity, which was 120 g kg^{-1}, while for solid materials (SDY and SCG), that application rate was also used to establish the dilutions from there on (50, 25, 12.5, 6.3% w/w of the maximum), increasing or decreasing the application rates, depending on the toxicity response. Both by-products from the yeast industry, SDY and CMS, exhibited higher toxicity responses from the tested organism, when compared to the other tested materials, as indicated by some ecotoxicological bioassays (e.g., earthworm mortality), with EC50 values in the range 30 to 15 mg kg^{-1} (w/w, dm), or even lower. As for SC and SCG (the least toxic), no detectable toxic effects were observed towards the organisms tested in the bioassays, and positive effects were even observed at concentrations below 30 g kg^{-1} in some tests, supporting their potential soil application as amendments/fertilizers, with minimal ecological risk. Given the complexity of soil in agroecosystems, integrating ecotoxicological bioassays with chemical analysis is strongly suggested to ensure a more accurate evaluation of potential environmental risks associated with the land application of agrifood waste materials.

Keywords

Agri-food wastes; yeast industry; fertilizers; ecotoxicity assessment; terrestrial organisms.

GRAPE STEMS VALORIZATION: POLYPHENOLIC COMPOSITION AND THEIR POTENTIAL APPLICATIONS IN THE COSMETIC AND PHARMACEUTICAL INDUSTRIES

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ABSTRACT

In 2023, the estimated global wine production was approximately 237 million hectolitres, with France, Italy, and Spain as the top three leading producers. This process inherently generates a substantial amount of material, designated by winery by-products (WBPs), such as grape pomace, grape stems, wine lees, and vine pruning woods, which harbor valuable bioactive compounds often overlooked, yet with substantial potential for application in various industries with a global annual production of 20 million tons of these materials.

This high seasonal production of by-products worldwide, particularly in Portugal, results in their significant accumulation within a short timeframe. Consequently, initiatives aimed at promoting the sustainable valorization of these by-products are essential, especially given the significance of winemaking companies and the substantial volume of underutilized materials they generate, creating a pressing need to explore innovative applications for these resources. The WBPs are recognized for being rich sources of polyphenols, namely hydroxybenzoic acids, hydroxycinnamic acids, stilbenes, flavonols, flavan-3-ols, flavones, flavanones, flavanonols, proanthocyanidins, anthocyanins, among others. One way to reduce these by-products, is by giving them added value and creating products for several industrial sectors, such as cosmetic, pharmaceutical, and food industries, thus contributing to the circular economy.

Among these WBPs, grape stems remain underexplored in the development of new products incorporating their extracts, despite their significant biological potential. In this sense, the main objective of this work is to deepen the chemical composition and biological properties of grape stems, with a focus on the identification of polyphenolic compounds using chromatographic techniques and the assessment of their antioxidant, antimicrobial, anti-aging, anticancer, anti-diabetic, and anti-inflammatory activities, among other biological activities.

Keywords

grape stems, polyphenolic compounds, biological activities, valorization

ENZYMATIC TREATMENT OF APPLE POMACE: ENHANCING BIOACTIVE PROPERTIES FOR FOOD AND NUTRACEUTICAL APPLICATIONS

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ABSTRACT

During apple juice production, a solid by-product known as apple pomace is generated. Despite being rich in valuable nutrients and bioactive compounds, it is often discarded, leading to economic losses and environmental concerns. To reduce waste and enhance its potential applications, this study aimed to evaluate the effects of enzymatic treatment (using Rapidase Fiber) on the composition and bioactive properties of apple pomace. The phenolic profile, antioxidant capacity, and nutritional composition of apple pomace flour were analyzed before and after enzymatic treatment. The results showed that enzymatic hydrolysis altered the dietary fiber composition, increasing soluble polysaccharides and enhancing the phenolic compound content in hydrolyzed pomace, which was 19.6% higher than in non-hydrolyzed pomace. Consequently, the antioxidant capacity of the hydrolyzed product improved. Additionally, enzymatically treated apple pomace exhibited significantly lower ash content, while protein and fat levels remained largely unchanged. Characterization by high-performance liquid chromatography with photodiode array detection revealed similar phenolic profiles in both hydrolyzed and non-hydrolyzed pomace, with the hydrolyzed sample displaying significantly higher levels of phenolic compounds. Both types of pomace were characterized by a high carbohydrate content and a similar free sugar composition, with fructose being the most abundant, followed by glucose. Treatment with Rapidase Fiber modified the insoluble dietary fiber, increasing soluble fiber content, as indicated by the rise in arabinose (Ara), galactose (Gal), and uronic acid (UA). These findings highlight enzymatic treatment as a promising strategy for enhancing the bioactive properties of apple pomace, offering potential applications in the development of innovative food and nutraceutical products.

Keywords

Apple pomace, enzymatic treatment, phenolic compounds, food by-products, nutraceutical applications, sustainable valorization.

OPTIMIZED VINEYARD WASTE BIOCHAR FOR CONTINUOUS FIXED-BED ADSORPTION OF MICROPOLLUTANTS IN WASTEWATER

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ABSTRACT

The increasing presence of pesticides in water sources has raised environmental concerns, requiring the development of efficient treatment strategies. In this study, the adsorption performance of metalaxyl in a continuous fixed-bed column was evaluated using activated biochar derived from vineyard shoot prunings. The biochar was produced through pyrolysis at 800°C for 80 minutes, followed by deashing with a 2.5 M HCl solution for 12 hours. The prepared biochar was packed into a fixed-bed column to investigate its adsorption potential under continuous flow conditions.

A Doehlert experimental design was employed to study the adsorption process, considering three key variables: the influent flow rate (2-5 mL/min), the initial pollutant concentration (0.3-0.45 mmol L^{-1}), and the mass of biochar within the column (0.4-1.2 g). Response variables such as breakthrough time, adsorption capacity at equilibrium, and Thomas and Yoon-Nelson model parameters were analysed to evaluate the performance of the column. The breakthrough curves indicated a significant dependence on the influent flow rate and pollutant concentration, with slower flows and higher adsorbent masses favouring extended adsorption cycles. Under optimized conditions, with a flow rate of 2 mL min-1, an initial concentration of 0.3 mmol L^{-1}, and 0.8 g of biochar, the column operated for 34.5 hours before reaching 95% saturation. Experimental trends demonstrated that adsorption efficiency could be enhanced under controlled flow conditions, pointing to the role of residence time in maximizing metalaxyl uptake

To assess competitive adsorption effects, continuous adsorption experiments were further conducted in a multicomponent system containing both acetamiprid and metalaxyl. Competitive interactions influenced the adsorption dynamics, with a notable decrease in the adsorption capacity of metalaxyl due to acetamiprid's co-presence, highlighting potential preferential adsorption mechanisms. The extended fixed-bed model adequately described the competitive behavior, suggesting that molecular interactions and steric hindrances played a role in adsorption efficiency.

Finally, the applicability of the optimized adsorption system was tested using real wastewater sourced from an Integrated Fixed-Film Activated Sludge (IFFAS) system. The wastewater was pre-filtered and spiked with metalaxyl and acetamiprid to simulate real contamination scenarios. Results demonstrated that the biochar-packed column maintained high adsorption performance despite the presence of background organic matter, confirming its potential for real-world applications. The findings suggest that this approach could provide a sustainable and cost-effective solution for pesticide-contaminated water treatment, and further studies should focus on scaling up the process and assessing long-term performance under field conditions.

Keywords

Vineyard waste, Fixed-bed adsorption, Micropollutant removal, adsorption, Wastewater treatment

BIOREFINERIES SCHEMES BASED ON SEQUENTIAL STAGES OF HYDROTHERMAL TREATMENT AND DELIGINIFICATION WITH DEEP EUTECTIC SOLVENTS

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ABSTRACT

According to the Sustainable Development Goals of Agenda 2030, the transition from a linear economy to a circular economy is essential. In this context, advances in lignocellulosic biorefineries using environmentally friendly treatments enable the production of a platform of chemicals, materials, and energy, contributing to the achievement of these targets.

The processing of lignocellulosic biomass, such as eucalyptus residues, with deep eutectic solvents (DES) aligns with the lignin-first pretreatment approach, prioritizing lignin integrity and sugar production. However, while DES significantly affects lignin, it only partially solubilizes hemicelluloses. To fully utilize lignocellulosic components, a preliminary hemicellulose solubilization step could be beneficial. Hydrothermal processing, which uses high-temperature water to extract hemicelluloses without harsh chemicals, presents an environmentally friendly alternative. Combining these methods within a biorefinery framework supports a circular economy by converting lignocellulosic biomass into valuable products such as biofuels, biochemicals, and biomaterials.

The aim of this study was to evaluate alternative strategies for the fractionation of lignocellulosic residues from the pulp and paper industry, specifically eucalyptus bark and wood, to obtain bio-based lignin materials within a circular economy framework. For this purpose, the biomasses underwent hydrothermal treatment at temperatures of 190–210 ºC, followed by delignification using eutectic mixtures (choline chloride and organic acids: lactic acid and formic acid) at molar ratios of 1:5 and 1:10, under a temperature of 121 ºC for 1 hour. Lignin recovery was characterized for further utilization in biomaterials, and hemicellulose-derived compounds were also analyzed. Additionally, the susceptibility of cellulose to enzymatic hydrolysis was assessed to evaluate its potential for biofuel production. The main results of this study revealed cellulose recovery in the range of 81–96%, hemicellulose solubilization (mainly composed of xylan) between 78–87%, and delignification in the range of 71–92%. The precipitated lignin exhibited promising properties for use in bio-based materials, while cellulose was proposed to obtain nanocellulose fibres. This work shows new routes of valorization of forest residues in order to obtain value-added compounds, namely oligosaccharides, cellulose and lignin for the development of materials.

Keywords:

Lignocellulose feedstocks, biofuels, biomaterials, biorefinery, hydrothermal treatment, and DES delignification

SUSTAINABLE VALORIZATION OF VINE PRUNINGS VIA STEAM EXPLOSION FOR BIOFUELS PRODUCTION

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ABSTRACT

The depletion of fossil resources and environmental concerns drive the search for sustainable energy alternatives. In this context, bioethanol is one of the most relevant liquid biofuels globally and can be produced from the cellulosic fraction of agro-industrial residues, such as those generated in the wine industry. Vine prunings are the main by-product of this sector and have a composition that allows not only bioethanol production but also the recovery of other value-added compounds within a biorefinery framework. The integral valorization of these residues through environmentally friendly technologies contributes to the transition from a linear to a circular economy.

A key aspect of lignocellulosic biomass valorization is the selection of an efficient pretreatment that maximizes fractionation while minimizing energy and material costs. Steam explosion is considered an environmentally friendly method and a suitable first step in a biorefinery.

This study aimed to valorize vine prunings through steam explosion to achieve hemicellulose solubilization while obtaining a solid fraction highly susceptible to enzymatic hydrolysis for bioethanol production. Steam explosion experiments were performed at severities (S_0) ranging from 2.76 to 4.42 to optimize fractionation. A severity of 4.24 was selected for ethanol production, applying two strategies: (i) SSF (simultaneous saccharification and fermentation) and (ii) SHF (separate hydrolysis and fermentation). Under these conditions, approximately 70% of the glucan remained in the solid fraction, while around 70% of the hemicelluloses were solubilized in the liquid phase, mainly as glucooligosaccharides and xylose.

Saccharification and fermentation assays were conducted at high solid loadings (>10%) with an enzyme dose of 20 FPU/g, using an industrial Saccharomyces cerevisiae strain. Results showed that steam explosion effectively solubilized hemicelluloses while preserving a glucan-rich solid, leading to high ethanol yields in the enzymatic-fermentative process.

This work presents a sustainable approach for the valorization of vine prunings, aligning with circular economy principles and supporting biofuel production as part of a more sustainable energy system.

Keywords

Lignocellulose feedstocks, biofuels, pretreatment, circular economy

ENHANCED STABILIZATION OF PHENOLIC COMPOUNDS FROM RED GRAPE POMACE VIA ELECTROHYDRODYNAMIC PROCESSING WITH HYDROXYPROPYL METHYLCELLULOSE

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ABSTRACT

The valorization of food by-products through innovative technologies is emerging as a key strategy for enhancing sustainability. This approach not only reduces waste but also mitigates the environmental footprint of food production, actively contributing to climate change mitigation. Furthermore, the transformation of food waste into high-value functional ingredients aligns with circular economy principles, promoting resource efficiency and a more resilient, sustainable food system.

In this study, the stabilization of phenolic compounds extracted from red grape pomace was explored due to their susceptibility to degradation under gastrointestinal digestion and environmental conditions such as light and temperature. To overcome these challenges, electrohydrodynamic processing was employed as an innovative encapsulation technique to enhance the stability and bioavailability of phenolic acids, flavonoids, stilbenes, and anthocyanin's, using hydroxypropyl methylcellulose (HPMC) as a protective carrier matrix.

The optimized encapsulation conditions— with a formulation of 3% HPMC, 5 mg GPE/mL (grape pomace extract), and a electrospray conditions of 14 cm injector-to-collector distance, 12 kV applied voltage, and 0.5 mL/h flow rate—resulted in the formation of spherical microparticles with a mean diameter of 1011 ± 453 nm. The incorporation of HPMC, *i.e.* microparticles formation, significantly enhanced phenolic preservation, antioxidant capacity, and resistance to degradation during gastrointestinal digestion, as confirmed by High-Performance Liquid Chromatography-Mass Spectrometry (HPLC-MS) analyses.

Rheological studies demonstrated that the bioactive incorporation did not have a noticeable effect on the polymer (3% HPMC) properties, since they maintained similar viscosity values to those of polymer solutions without GPE incorporation. Moreover, Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) confirmed the effective encapsulation of the polyphenols within the HPMC matrix.

This study highlights the potential of electrohydrodynamic processing, combined with biopolymer-assisted stabilization, as a sustainable approach for valorizing grape pomace and other food by-products. By integrating advanced analytical techniques and *in-vitro* digestion models, this study provides a robust strategy for developing functional ingredients with enhanced shelf stability, bioavailability, and bioefficacy, paving the way for broader applications in the food, nutraceutical, and pharmaceutical industries.

Keywords
Electrospray; Microparticles; Wine by-products; Polyphenols; Gastrointestinal digestion; Circular economy

HEPATOPROTECTIVE ANTIOXIDANT EFFECTS OF BIOACTIVE COMPOUNDS FROM VINE PRUNING BY-PRODUCT EXTRACTED VIA STEAM EXPLOSION

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ABSTRACT

In recent years, there has been an increasing demand for biofunctional products derived from natural resources, especially by-products due to their sustainability and renewability. In this sense, researchers and industries have focused on the search for new raw materials rich in bioactive compounds of interest to the food, pharmaceutical and cosmetic industries. This work addresses the chemical characterization of the vine pruning of the white grape variety Treixadura (harvested from Ourense in 2022) and a study of the extraction of phenolic compounds and oligosaccharides with antioxidant properties through steam explosion (SE) treatment. Different SE conditions were evaluated, varying the temperature (170 to 210 °C) and time (5 to 15 min). The content of total phenols (TPC) and flavonoids (TFC) was quantified spectrophotometrically, and their antioxidant activity was determined by DPPH, ABTS and FRAP methods. The oligosaccharides and phenolic compounds of the vine pruning extracts (VPE) were determined and quantified by high-performance liquid chromatography (HPLC). For hepatocyte cell studies, the mouse hepatocyte cell line (AML12) was used. Cell cytotoxicity was conducted using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay (MTT) after exposure to different concentrations of VPE (10 – 4000 µg/mL) for 24, 48, and 72 hours under both basal and oxidative stress (10 mM H_2O_2) conditions. The intracellular level of ROS was assessed by dichlorofluorescein diacetate (DCFH-DA) assay. The results of SE extraction showed that at short durations (5 min) and high temperatures (210 °C), the maximum recovery of antioxidant oligosaccharides and phenolic compounds was achieved. HPLC analysis of VPE revealed a high concentration of gluco- and xylo-oligosaccharides, as well as phenolic compounds such as gallic acid, vanillic acid, *p*-coumaric acid, 3,4-dihydroxybenzoic acid, rutin, salicylic acid and 4-hydroxybenzoic acid. The MTT assay revealed cytotoxicity in AML12 cells at VPE concentrations higher than 2000 µg/mL. ROS levels, measured via DCFH-DA assay, showed that VPE significantly decreased oxidative stress, especially at higher doses and longer exposure times. Under H_2O_2-induced oxidative stress, the extract exhibited protective effects by reducing ROS accumulation and preserving cell viability. These findings suggest that VPE has potential antioxidant properties, mitigating oxidative damage in liver cells while maintaining cellular health at optimal concentrations. The use of wine (and other) by-products, combined with alternative technologies such as steam explosion for the recovery of bioactive compounds, can be a sustainable and innovative strategy to valorise agro-industrial waste, promoting the circular economy and the production of functional ingredients with potential applications in the food, cosmetic, and pharmaceutical industries.

Keywords

Green extraction; Wine by-products; Phenolic compounds; Oligosaccharides; Cytotoxicity; Oxidative stress; Sustainability

SUSTAINABLE VALORIZATION OF RED GRAPE POMACE THROUGH DEEP EUTECTIC SOLVENTS FOR BIOACTIVE COMPOUND EXTRACTION

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ABSTRACT

The wine industry generates significant amounts of waste, making it a relevant example of the agro-food sector's contribution to by-product production. In Europe, around 75% of the 27 million tons of grapes (Vitis vinifera) harvested are used for winemaking. Approximately 20% of the grape material becomes grape pomace, a biodegradable solid by-product composed mainly of skins, seeds, and some stalks. Adopting circular economy strategies for the valorization of grape pomace could lead to the development of extracts rich in bioactive polyphenols (e.g., phenolic acids, stilbenes, catechins, flavonols, and anthocyanins), which exhibit several functional properties, such as antioxidant, anti-inflammatory, and antimicrobial activities.

The extraction strategy for these ”ompo'nds Is crucial, as It must preserve the functionality of the target compounds while ensuring a low environmental impact. Currently, the utilization of green solvents as a substitute for conventional organic solvents presents a promising approach in the field of extraction techniques. Among these, deep eutectic solvents (DES) have gained attention for their safety, eco-friendliness, and low synthesis cost. This study aimed to optimize the extraction of phenolic compounds from red grape pomace using a DES composed of choline chloride, acetic acid, and water (1:1:10 molar ratio). A Box-Behnken experimental design and response surface methodology (RSM) were applied to optimize the liquid-solid ratio, temperature, and extraction time. The extraction efficiency was assessed by determining total phenolic content (TPC), condensed tannin content (CTC), and antioxidant activity (DPPH, ABTS, FRAP, CUPRAC).

The optimal conditions for maximum phenolic compound recovery were 14.86 mL/g GP (liquid-solid ratio), 60 °C, and 275.85 min. Under these conditions, the experimental results were: TPC, 113.71 mg gallic acid equivalents/g GP; CTC, 132.89 mg catechin equivalents/g GP; antioxidant activity (DPPH, ABTS, FRAP, and CUPRAC) values were 160.47, 161.56, 207.31, and 367.79 mg Trolox equivalents/g GP, respectively. The strong correlation between the experimental and predicted results validated the proposed model for optimizing phenolic compound extraction from red grape pomace.

Keywords

Grape pomace, deep eutectic solvents, bioactive compounds, circular economy

ENHANCING SUSTAINABILITY IN ADDITIVE MANUFACTURING: FEEDSTOCK FROM METAL CHIPS

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ABSTRACT

Using metal chips as a sustainable feedstock in additive manufacturing has emerged as a promising approach to reducing environmental impact and costs in the steel industry. Conventional powder production methods, such as atomization, require significant energy consumption. In contrast, powder from metal chips through solid-state processes offers an energy-efficient alternative by refining particle size without excessive energy consumption. This study focuses on AISI H13 steel chips obtained from the mold industry. It explores the micronization of chips by a mechanical milling process under optimized conditions to maximize efficiency in particle size reduction. During milling, high plastic deformation leads to chip fracture, producing powder particles with a flake-like shape. However, particles exhibit a size, size distribution, structure, and surface that makes them suitable for use as feedstock in additive manufacturing. Material Extrusion (MEX), an indirect additive manufacturing process, is selected for this study due to its challenging powder requirements and efficient utilization of metal powders in final product manufacturing. This approach combines the most demanding powder characteristics with effective material use, presenting a pathway towards more sustainable and cost-effective additive manufacturing practices. By repurposing metal chips as feedstock, this method offers a promising solution for reducing waste and energy consumption in the steel industry while simultaneously addressing the growing demand for sustainable materials in advanced manufacturing processes.

Keywords

Tool steel chips; Additive Manufacturing; Sustainability.

VALORIZING WINERY WASTEWATERS AND WINE FERMENTATION CO_2 FOR SUSTAINABLE SOLUTIONS AIMING AT IMPLEMENTING A NEW CIRCULAR ECONOMY BUSINESS MODEL: A MINI-REVIEW

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ABSTRACT

The H2020-BBI RED WINE project (Application Number: 101023567) aims to implement a new circular economy business model for wine producers, enabling them to become microalgae biomass producers by utilizing their own gaseous and liquid effluents. This diversification allows wine producers to generate additional revenue streams by converting microalgae biomass into food, cosmetics, agricultural products, and new wines.

Winery wastewaters present several challenges due to their unique characteristics, such as high organic loads from sugars, alcohols (notably ethanol), and organic acids (especially acetic acid), resulting in high biochemical oxygen demand (BOD) and chemical oxygen demand (COD). These wastewaters are subject to seasonal variability, composition and pH fluctuations, and contain inhibitory compounds like phenols, tannins, and sulfites. Additional issues include nutrient imbalance, salinity from cleaning agents, high suspended solids, unpleasant odor, turbidity and strong color due to organic compounds. Furthermore, wine fermentations release biogenic CO_2, contributing to greenhouse gas (GHG) emissions and global warming, a significant global concern that impacts climate, resource availability, and food production.

However, winery wastewater and CO_2 generated during the winemaking process can be repurposed for economic and environmental benefits. Through sustainable and innovative approaches such as anaerobic digestion, nutrient recovery, bio-based product production, microbial biomass production, polyphenol extraction, soil amendment, composting, constructed wetlands, water reuse, and circular economy models, these byproducts can be valorized. Research and innovation further enhance these processes. Additionally, several options to increase the value of CO_2 from wine fermentation include Carbon Capture and Utilization (CCU), production of chemicals and fuels, microbial conversion (notably with microalgae), mineralization, Enhanced Oil Recovery (EOR), renewable energy storage, and carbon credits and offsetting.

Key strategies for valorizing winery wastewater and CO_2 are reviewed here to increase profitability and diversify revenue streams, providing insights into the potential for large-scale applications. By integrating these strategies, the wine industry can turn waste into valuable resources, contributing to a more sustainable and circular bioeconomy.

Keywords

Biorefineries, winery wastewater treatment, bioremediation, circular economy, bioeconomy, biogenic CO_2, bio-based products

PRE-TREATMENT OF WINERY WASTEWATER FOR MICROALGAE CULTIVATION: A SUSTAINABLE APPROACH USING ALKALINE RESIDUES

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ABSTRACT

The winery industry generates a large volume of effluent characterized by high concentration of phenolic compounds, ethanol concentration around 14 g/L, acidic pH (close to 4), and intense coloration. These effluent characteristics pose environmental challenges, require treatment before discharge and can inhibit biological remediation processes. This study proposes an integrated pre-treatment strategy for winery wastewater, aiming to mitigate its toxicity and enable its reuse as a culture medium for microalgae. The approach focuses on reducing the use of chemical agents and minimizing the need for effluent dilution by employing sustainable techniques, such as air bubbling and pH neutralization using alkaline residues from biomass thermoelectric plants and from meat and bone meal incineration.

The pre-treatment was conducted in two main stages. First, ethanol removal was achieved through air bubbling for five days. Second, pH neutralization and organic load reduction were performed using alkaline residues. The effectiveness of biomass ash and bone and meal ash was compared regarding their capacity to neutralize the medium, precipitate organic compounds, and retain essential nutrients.

The results indicate that biomass ash was more effective in neutralizing the effluent, requiring 10 g/L to reach pH 7, while bone meal ash demanded approximately four times this amount. Biomass ash also achieved a significant reduction in chemical oxygen demand (COD) and phenolic compounds (around 90 %). However, it caused a considerable depletion of key nutrients, particularly nitrates and phosphates, which are essential for microalgae growth. In contrast, bone meal ash preserved these nutrients more effectively due to its high phosphorus content, which not only prevented phosphate depletion but also enriched the medium. Additionally, bone ash resulted in a less colored effluent (52.3 – 67.7 % color reduction), which is critical for light penetration and microalgae photosynthesis.

This study demonstrates that the use of alkaline residues for winery wastewater pre-treatment can effectively mitigate the toxic effects while promoting resource valorization. Bone meal ash emerged as a promising agent due to its ability to maintain nutrient availability and reduce turbidity, enhancing the effluent's suitability as a microalgae culture medium. This approach aligns with circular economy principles by repurposing industrial residues that are still being deposited in landfills and providing a sustainable solution for managing winery waste streams while facilitating microalgae-based biotechnological applications.

Keywords

Winery wastewater, pre-treatment, alkaline residues, microalgae.

BIOCHAR PRODUCED FROM SHEEP WOOL – ENERGY, ADSORPTION AND SOIL AMENDMENT APPLICATIONS

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ABSTRACT

In the textile sector, the use of sheep wool has decreased gradually as these natural fibers have been progressively replaced by polymeric ones. Nonetheless, sheep wool must be regularly removed from milk producing herds, for hygiene and health reasons. Storage of the collected wool is also a challenge due to its low density and some contamination with biomass residues and fecal matter. In the absence of alternative valorization processes, sheep milk producers have resorted to non-sustainable processes such as landfill deposition or incineration to eliminate the material removed during the shearing operations.
In this work, we evaluated dry carbonization as an alternative method to convert sheep wool into a biochar that could be further used for energy production, as an adsorbent material or for soil amendment.
A fraction of the raw wool was extensively washed with tap water and another fraction with sodium hydroxide and hypochlorite solution, followed by extensive rinsing with tap water, to remove external contaminants. Some debris materials (leaves and small twigs) were manually removed. Both wool samples were carbonized at 300 ºC during 1h, in closed crucibles. The washed wool samples and the obtained biochars were characterized by determination of elemental and mineral composition, ash content and low heating value. Biochar yields varied from 60.7 to 65.5%. The carbon content and nitrogen contents of the biochars varied in the ranges of 58.7-63.2 % and 13.0 – 13.4 %, respectively. The high heating value of the chars estimated using an empirical equation was between 23 and 25 MJ/kg, which are values comparable to other solid biofuels, but the high nitrogen content of these chars may be a negative characteristic for combustion applications, leading to excessive Nox emissions. On the other hand, the presence of these nitrogen atoms may be an advantage if soil amendment applications or CO_2 capture applications are considered. The potential use of the produced biochars as soil amendment agents was addressed through leaching experiments to evaluate the removal of minerals and nitrogen species and by determination of the biochar water adsorption capacity. The agro-industrial application of these biochars for soil amendment has the advantage of promoting circular economy, by upcycling a locally produced waste to stimulate agricultural production. The biochars were further activated with 2M KOH and characterized as the raw biochars. The adsorption capacity of the biochars towards cationic and anionic species was evaluated through adsorption tests performed with methylene blue and methyl orange solutions. The results obtained demonstrate that dry carbonization can be an alternative to sheep wool incineration or deposition in landfills, since it produces a biochar with properties adequate for multiple valorization pathways.

Keywords:

Sheep wool; Dry carbonization; Calorific value; Adsorption; Soil Amendment

SUSTAINABLE PRODUCTION OF CELLULOSE ACETATE USING COCOA HUSK WASTE BIOMASS

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ABSTRACT

Cellulose acetate (CA) is a versatile biopolymer widely used in textiles, coatings, membranes, and biomedical applications. Traditionally, its production relies on cellulose sources such as cotton and wood pulp, raising environmental concerns due to resource depletion and the impacts of extraction. This study explores an alternative and more sustainable approach by synthesizing CA from cocoa pod husk, an agro-industrial waste by-product. Poor management of this waste can contribute to environmental pollution, particularly in regions where many cocoa producers operate informally and lack proper plant and fruit maintenance techniques. Consequently, infected cocoa pods can contaminate the soil and spread diseases to other plants, affecting future harvests. To mitigate this impact, this study proposes the utilization of cocoa husk as a raw material for CA production is proposed. Notably, Colombia does not currently have industrial production of this biopolymer.

The process began with cellulose extraction, involving chemical treatments to remove non-cellulosic components, followed by a bleaching step to enhance purity. The extracted cellulose was then acetylated using acetic anhydride as the main reagent and sulfuric acid as a catalyst under controlled conditions. The physicochemical and mechanical properties of the resulting CA were evaluated according to international standards, specifically ASTM D-1104 for characterization and ASTM D-638 for mechanical testing.

The results demonstrated that using cocoa husk as a feedstock yielded CA with a conversion efficiency of 62.94%. Material characterization confirmed the produced CA exhibited properties consistent with values reported in the literature. Mechanical testing revealed that the synthesized CA is brittle yet highly ductile, supporting low loads of 365.89 N and exhibiting a hardness (HB) of 37.2. The efficiency of the acetylation process was confirmed using Fourier Transform Infrared Spectroscopy (FTIR) to monitor the bands associated with hydroxyl and carboxyl groups. Additionally, the mechanical properties of the obtained material could be further enhanced through addition of plasticizers that were not included in this study.

These findings confirm that cocoa pod husk is a viable raw material for CA production, contributing to the valorization of this abundant agricultural waste Mitigating its negative environmental impact. Utilizing biomass waste as a cellulose source also supports the bioeconomy reducing dependence on dedicated biomass production and associated land use.

Keywords

Cellulose acetate; cocoa pod husk; biomass wastes; sustainability

CREOSOLVE PROJECT – DISPOSAL OF USED WOODEN RAILWAY SLEEPERS AND OTHER CREOSOTE OIL TREATED COMPONENTS USING VARIOUS BIOLOGICAL METHODS

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ABSTRACT

Forecasts indicate that the modernization of railway infrastructure in Poland over the next two decades will generate approximately 1.1 to 1.5 million tonnes of waste in the form of used wooden railway sleepers. On a broader scale, Europe is projected to face disposal challenges involving about 12 to 16 million tonnes of similar waste material. The wooden railway sleepers present unique waste management challenges due to impregnation with creosote oil, a highly carcinogenic substance containing 50-90% polycyclic aromatic hydrocarbons (PAHs), including benzo(a)pyrene. Given these toxic components, disposal through conventional methods poses technological, environmental, and health-related difficulties.

Currently, Poland's existing infrastructure for neutralizing hazardous wood waste remains inadequate, predominantly relying on thermal or physico-chemical treatment methods. Biological approaches, either alone or in combination with conventional treatments such as thermal processing, are still not widely applied. Recognizing the limitations and ecological risks associated with traditional disposal practices, this research aims to develop innovative, sustainable, and scalable technologies specifically designed for the effective utilization of creosote-impregnated wooden railway sleepers, telecommunication poles, and other similar wooden structures.

The112oznan112t's central objective is to introduce novel disposal methods characterized by high efficiency, cost-effectiveness, scalability and significantly reduced environmental impact. Three distinct utilization methods will be investigated and optimized within the scope of this initiative:

1) A hybrid pyrolytic-biological method combining thermal pyrolysis to initially break down creosote-impregnated wood and subsequent microbiological treatment for decomposing the resulting pyrolytic oils.
2) A bioremediation technique leveraging the natural metabolic capabilities of selected microorganisms and plant species, specifically targeting PAH degradation to mitigate environmental contamination risks effectively.
3) A composting process aimed at converting impregnated wooden waste into high-quality compost, suitable as a fertilizer, thereby turning hazardous waste into a valuable resource.

Each method undergoes comprehensive laboratory and pilot-scale testing to determine its effectiveness in contaminant degradation, operational feasibility, economic viability, and environmental sustainability. A critical part of the project involves conducting a life cycle assessment (LCA) for each approach, providing robust comparative data to guide the selection of the most promising method for industrial-scale implementation.

Ultimately, the project aims to deliver a practical, environmentally responsible solution to the pressing problem of hazardous wooden waste management, aligning with the European Union's circular economy strategy and sustainability goals.

Keywords

Creosote oil; railway sleepers; environmental biotechnology; microorganisms; wood; PAH

TURNING WASTE INTO PERFORMANCE: THE TRIBOLOGICAL POTENTIAL OF FRUIT PITS-REINFORCED POLYAMIDE COMPOSITES

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ABSTRACT

In recent years, there has been a dynamic development of materials used in tribological applications, particularly in the context of sustainable development trends. The use of composite materials with matrices composed of polymers, metals, and ceramics has significantly improved process efficiency, reduced operating costs, and extended the lifespan of mechanical components. By utilizing composites, individual components can be selected to tailor the resulting material for specific applications, such as improving mechanical properties or reducing the coefficient of friction. The use of waste materials as fillers/reinforcements to obtain composites with desired tribological properties, which could serve as an alternative to traditionally used fillers, offers several advantages: ecological benefits from converting waste into raw materials, improved mechanical and tribological properties, and economic benefits due to lower production costs and longer service life (reduced wear rate). Poland, as one of the largest producers of stone fruits in Europe, particularly cherries and plums, faces not only challenges related to their sale and processing but also the issue of waste management, including fruit pits. Every year, thousands of tons of pits are generated in the fruit industry as a byproduct of juice, jam, frozen fruit, and other processed food production. Improper storage of these pits can lead to environmental issues, such as decomposition and methane emissions, as well as pose a threat to local ecosystems if not properly disposed of. However, fruit pits can be a valuable raw material that, with proper management, can have various applications, including tribological uses. In the research described in this study, composites were produced with a polymer matrix—polyamide—and agricultural waste materials as fillers: depending on the variant, 15% ground plum pits with a granulation of 200-400 μm and 15% ground cherry pits with a granulation of 200-400 μm. The composites were subjected to friction tests using the block-on-ring system under dry friction conditions, with a counter-sample made of AISI 1045 steel at a speed of 150 rpm. Each test lasted 30 minutes, with a load of 250 N. The study showed that the coefficient of friction for the variant containing ground plum pits did not differ from the control sample (pure polymer), whereas the composite containing ground cherry pits exhibited a 9% lower coefficient of friction compared to the control. The lower coefficient of friction may be attributed to the possibility of “squeezing out” residual fatty acids, indicating a potential self-lubricating effect. Such biocomposites could serve as an alternative to currently used materials, such as polymer bearings.

Keywords

Agricultural wastes, coefficient of friction, adhesive wear, block-on-ring test**,** polyamide (PA)

DESIGN OF A BALL VALVES TEST BENCH FOR FOOD INDUSTRY

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ABSTRACT

This paper presents the development of a test bench for valves, structured in two main modules: the control module and the support and fixation module. The project arose from the critical analysis of the company's certification facilities, identifying limitations and opportunities for improvement. The methodology included an evaluation of the current configurations, research on the state of the art in control benches, valve and hydraulic press technologies, and a conceptual design phase that defined specific solutions for each module. The control module is designed for certification tests, including monitoring the valve opening percentage, while the support and clamping module has incorporated hydraulic technology in a horizontal layout, to ensure efficiency and precision. Prototypes were developed during the design phase in alignment with detailed specifications: a horizontal press for the support and clamping module and a reduced one for the control module, with the aim of carrying out preliminary tests. The project concludes that the proposed bench effectively addresses the company's requirements, establishing bases for future expansions and improvements, with emphasis on the effectiveness of the support and fixation module that allowed to validate the horizontal arrangement and use of hydraulics. The development of the functional prototype of the clamping press and support was the main focus of the project in order to validate the technical feasibility of the project, especially the application of hydraulic technology and the horizontal arrangement for fixing valves. The project was conducted in two main phases: the construction of the control bench and the assembly of the prototype of the press. The development of the valve test bench, structured in the control and support modules, proved to be a strategic solution to meet the needs of Vinco Valves. The introduction of hydraulic technology and horizontal arrangement in the clamping module stood out as a robust and efficient solution, laying a solid foundation for future larger benches. The functional prototype developed for this module served as a valuable tool for preliminary testing, allowing for concept validation and design refinement. Despite the progress made, some limitations have been identified. The functions of checking the percentage of valve opening and monitoring the coolant level remained at an early stage, due to the priority given to the clamping module and the need to purchase additional components. These limitations provide an opportunity for future developments, allowing the functionality and versatility of the system to be expanded.

Keywords

Ball Valves; Certification; Mechanical Design; Test Bench; Food Industry

CEMENT AND CONCRETE ARTIFACTS AS A WAY TO PROMOTE SUSTAINABLE WASTE MANAGEMENT

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ABSTRACT

The increasing pressure to divert waste from landfills has driven the search for viable alternatives for its valorization. In this context, incorporating waste into cementitious matrices can, in certain cases, allow for the reuse of materials, giving them a new purpose. Some types of waste not only find a disposal pathway within these materials but also contribute to improving their properties, whether in terms of mechanical, acoustic, thermal, or even aesthetic performance. In other cases, material substitution is limited to the inert fraction of the mixtures (sands, gravel, and additives), resulting in a less significant valorization but still relevant from an environmental perspective and in terms of natural resource conservation.

Acknowledging the challenges associated with implementing in practice these solutions on an industrial scale, the consortium led by Farcimar, in collaboration with W2V, University of Minho, and Itecons, launched the WasteCrete project, co-funded by the Portugal 2030 program (COMPETE2030-FEDER-01181800). The project's objective is to develop concrete formulations that incorporate waste as substitutes for conventional raw materials, promoting both technical, economic, and environmental benefits in the production of precast concrete products.

This presentation will outline the project's general guidelines and present some preliminary results regarding the use of waste from the metallurgical, metalworking and other manufacturing industries (e.g. steelmaking furnace dusts, foundry sands, wastewater treatment sludges, stone-cutting sludges, used blasting media, ceramic sludges, and glass waste) as replacements for inert aggregates. Finally, the potential applications and anticipated benefits of these solutions in an industrial setting will be examined.

Keywords

Foundry sands, dusts, cementitious materials

OXIDATIVE CARBONIZATION OF REFUSE DERIVED FUEL

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ABSTRACT

Refuse derived fuel (RDF) has limited application in energy production due to low density, heterogeneity and high chlorine content. Carbonization has been proposed as a pre-treatment to obtain a more homogeneous fuel with higher density and heating value than raw RDF and with lower particle size and chlorine content. In order to achieve these goals, dry carbonization must be performed at temperatures typically above 400 ºC, that cause extensive carbon devolatilization, thus reducing biochar yield and requiring a significant energy input. In this work, oxidative carbonization of RDF pellets was evaluated as an alternative carbonization technique, using macro-thermogravimetry (macro-TGA), at the temperatures of 250, 300, 350, 400 °C and equivalence ratios of 0.5 and 1.0. The original pellets and the produced chars were characterized by elemental and mineral composition and ash content. Among the less favorable fuel properties of the RDF pellets, we highlight their ash content (10.4%) and fixed carbon content (6.0%).

The low calorific value of the solid products was determined using an empirical equation based on elemental composition. The results obtained indicate that it is possible to obtain carbon rich-chars at yields higher than 50%, at temperatures lower than 400ºC. Temperature was the parameter that showed the highest influence on the carbonization process. The influence of the equivalence ratio was insignificant. The use of oxidative conditions enables operation at lower temperatures, reducing the energy consumption of the carbonization process.

Keywords

Refuse derived fuel; Oxidative carbonization; Calorific value; RDF char

MIXED POLYMERIC WASTE: CHALLENGES AND VALORIZATION THROUGH PYROLYSIS

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ABSTRACT

Mixed polymeric waste is an abundant type of industrial waste whose recyclability is hindered by the wide variety of polymers present, often mixed together and possessing distinct chemical characteristics. These wastes frequently contain halogenated compounds, such as polyvinyl chloride (PVC), and brominated additives used as flame retardants. Due to these factors, the valorization of such waste is rare, with landfilling being the most common disposal method.

This category includes waste from coated foams, composite textiles, and materials resulting from waste sorting and separation, as well as metal fragmentation residues, such as those generated in the treatment of end-of-life vehicles.

Pyrolysis emerges as a viable solution for the valorization of these materials. When properly designed, the pyrolysis process enables the extraction and potential recovery of volatile organic solvents at low temperatures, along with the retrieval of hydrochloric acid and brominated compounds. Additionally, the process promotes the formation of combustible gases and oily and carbonaceous fractions with potential energy applications.

To advance knowledge in this field, the PW4E – Plastic Wastes for Energy project is currently underway, led by A Eléctrica, in co-promotion with W2V and Rduz, and with Endutex as a partner. The project, co-financed by the Norte 2030 program, aims to study and develop suitable processes for the main types of currently unexploited mixed polymeric waste, as well as to design and demonstrate prototype equipment to facilitate the implementation of these processes at various scales.

This study presents the results of pyrolysis experiments conducted on mixed waste from the textile coating industry, as well as on mixtures derived from waste sorting. The main findings and conclusions will be analyzed from the perspective of energy recovery from gases, oils, and char, as well as chlorine recovery. The experiments have allowed for the definition of suitable conditions for processing these wastes, providing guidelines for the development of treatment methodologies to be considered in the equipment design phase.

Keywords

Polymeric wastes; pyrolysis; PVC; hydrochloric acid

RECYCLABILITY ASSESSMENT OF PLA-BASED 3D PRINTING FILAMENTS WITH MICRONISED CELLULOSE AND A WAX-BASED ADDITIVE

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ABSTRACT

There's been a growing focus on finding more sustainable options for materials used in 3D printing. One of the approaches that has been gaining attention is the use of PLA reinforced with natural fibres like cellulose, due to its renewable origin and lower environmental impact. These types of biocomposites are increasingly being explored as realistic alternatives to fossil-based materials. Still, when it comes to understanding how these materials behave after several recycling and reprocessing steps, there's a lot left to explore — and that's precisely what this work sets out to do.

This work aims to evaluate the recyclability of a filament composed of polylactic acid (PLA), bleached micronised cellulose (10%) and a commercial wax-based additive. A similar formulation had already shown promising results regarding printability, although some brittleness was observed. To address this, the wax-based additive was incorporated into the formulation to improve flexibility, surface finish and overall processability.

The objective is to assess how well this filament performs after several reprocessing cycles using a co-rotating twin-screw extruder. After each cycle, new filament will be produced and wound onto commercial-style spools. Key properties such as diameter stability, spool winding, printability, surface finish, colour uniformity, brittleness, surface defects and melt flow index (MFI) will be evaluated. These indicators are essential for determining whether the filament remains usable in real printing conditions after each recycling step.

In addition to these assessments, thermal analysis using differential scanning calorimetry (DSC) and flexural testing will be carried out where appropriate to track changes in the material's mechanical behaviour. Based on previous experience with biopolymer reprocessing, noticeable degradation is expected to occur between the third and fifth cycles. However, up to nine cycles will be performed depending on process stability and material performance.

Ultimately, this study aims to determine the extent to which a PLA-based biocomposite filament retains its performance throughout repeated recycling cycles, thereby contributing to more sustainable practices in additive manufacturing.

Keywords

3D printing, recyclability, PLA, cellulose, biocomposites, additive manufacturing

WASTEINMOTION: A DIGITAL BRIDGE BETWEEN AGRO-WASTE AND SUSTAINABLE CONSTRUCTION

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ABSTRACT

Among the most waste-intensive industries, the agricultural sector generates vast amounts of waste, much of which is currently disposed of in landfills or incinerated, leading to significant environmental and economic consequences. Similarly, the construction industry relies heavily on raw materials, contributing to resource depletion, high energy consumption, and excessive waste generation. Instead of conventional waste management practices, it is crucial to adopt more sustainable approaches that promote the efficient use of resources. Addressing these challenges requires innovative and interdisciplinary solutions that integrate circular economy principles, creating synergies between industries and fostering a more responsible material flow. This project introduces WasteInMotion, a digital platform designed to facilitate the valorization of agro-waste for construction applications. Research has demonstrated that incorporating these by-products can improve the physical, mechanical, and durability properties of building materials while reducing their environmental footprint. By systematically analyzing and classifying agro-residues according to their potential use in construction, this initiative strengthens cross-sector synergies and promotes resource efficiency. A key element of this work is the WasteInMotion platform, which is currently under development. This digital tool serves as an intelligent matchmaking system, automatically identifying available agro-waste and suggesting its most suitable construction applications. By centralizing and digitizing this information, the platform enhances efficiency, reduces logistical barriers, and accelerates the implementation of circular economy principles. The integration of digital transition technologies, such as real-time resource tracking, plays a crucial role in optimizing material flows and decision-making processes. The accessibility and automation provided by this digital approach empower industries, policymakers, and researchers to make informed decisions, streamlining the transition toward sustainable material management.

The benefits of this project extend across multiple stakeholders:

- Agricultural sector: Gains a sustainable and cost-effective alternative for waste management, reducing disposal costs and environmental impact.
- Construction sector: Gains access to innovative, sustainable raw materials that improve material performance while aligning with green building regulations.
- Policy makers and regulatory bodies: Receive valuable data to support the creation of policies that encourage circular economy practices.
- Researchers and academia: Benefit from an extensive digital database that advances knowledge on sustainable material applications.
- Society and the environment: Experience reduced landfill waste, lower CO_2 emissions, and the conservation of natural resources, contributing to climate change mitigation.

Beyond theoretical advancements, the project includes two real-world case studies, selecting specific agro-waste based on criteria such as availability and physical-chemical properties. These studies will provide practical validation, demonstrating the technical, environmental, and economic benefits of the proposed solutions. By integrating digital innovation with sustainable waste management, this work represents a paradigm shift in how industries approach resource utilization. WasteInMotion fosters collaboration between the agricultural and construction sectors and serves as a scalable model for circular economy adoption in the digital age. Ultimately, it contributes to reducing waste, preserving natural resources, and advancing sustainability across multiple industries, benefiting businesses, policymakers, researchers, and society as a whole.

Keywords

Agro-waste; Sustainable construction, Digital transition, Circular economy, Industrial symbiosis

ECOTOXICOLOGICAL STUDY OF CANNED TUNA ORGANIC WASTE

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ABSTRACT

The fish processing industry presents significant environmental challenges due to the generation of various by-products, including heads, tails, fins, frames, viscera, and skin. Currently, the most common valorisation way of these by-products is through their transformation into animal feed. Nevertheless, a large portion of this waste still ends up in landfills, which is the least desirable waste management option, according to the Waste Hierarchy. Tuna species are widely consumed in canned form, contributing significantly to this issue, since about 60–70% of the fish is discarded due to the selective use of light muscle. This large-scale waste production not only leads to resource inefficiency but also raises concerns regarding pollution and ecosystem degradation. The Blue Economy emphasizes sustainable and inclusive economic development that safeguards natural resources. To align with this principle and the waste management hierarchy, it is vital to prioritize the study of fish processing by-products and their environmental impact. According to the 2023 Fishery Statistics Compendium by Statistics Portugal and the Directorate-General for Natural Resources, Safety, and Maritime Services (DGRM), canned fish production in 2022 reached 56 624 tons, representing an increase of 25,8% comparatively to the 2012 production. Furthermore, there is also a notable lack of research on the ecotoxicological effects of the organic waste produced by the canning industry.

Thus, this study aims to address this gap by performing an ecotoxicological assessment of the organic waste generated by a local Azorean canning company. It will be using organisms from three different trophic levels to mimic the effects of the discharge of this waste in the environment. The findings will be critical for understanding the environmental impact of this waste and the importance of developing sustainable strategies to mitigate its effects. Additionally, the study will provide valuable insights for policymakers, industry stakeholders, and researchers in advancing circular economy initiatives and promoting responsible waste management practices.

Keywords

Canned Tuna Waste; Organic Fish Waste; Ecotoxicological study; Toxic tests; Marine Sustainability

PLASMA GASIFICATION OF SEWAGE SLUDGE - MASS AND ENERGY BALANCE

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ABSTRACT

The increasing need for sustainable waste management solutions has driven the search for technologies that minimize environmental impacts while promoting resource recovery. Sewage sludge, a byproduct of wastewater treatment, poses significant challenges due to its high moisture content, complex composition, and disposal difficulties. In line with EU environmental policies that prioritize waste circularity and landfill reduction, plasma gasification emerges as a promising thermochemical conversion technology for transforming sewage sludge into a valuable energy resource.

This study investigates plasma gasification as a viable method for sewage sludge treatment, focusing on mass and energy balances to evaluate process efficiency and syngas quality. The methodology includes physicochemical characterization of different sewage sludge samples, such as proximate and ultimate analyses, thermogravimetric assessments, and thermal conductivity measurements. A theoretical mass and energy balance model was developed based on the principles of mass and energy conservation, considering an Equivalence Ratio (ER) of 0.29, a commonly applied value in sewage sludge gasification.

The results indicate that domestic sewage sludge presents a higher lower heating value (LHV) and higher heating value (HHV) compared to other sludge types, making it a more suitable feedstock for plasma gasification. Additionally, its lower ash content contributes to a cleaner and more efficient conversion process. Theoretical energy balance calculations suggest an overall process efficiency of approximately 75%, demonstrating the potential of this technology for energy recovery. However, further experimental validation is required to optimize process parameters and assess real-world performance.

In conclusion, plasma gasification offers a promising solution for sewage sludge management by reducing landfill dependency and generating syngas for energy applications. While the preliminary results highlight its feasibility, further research is needed to refine operational conditions, enhance system efficiency, and evaluate syngas composition under different scenarios. Future work will focus on validating the theoretical models and optimizing key parameters to facilitate the large-scale application of this technology in wastewater treatment plants.

Keywords

plasma gasification, sewage sludges, syngas, thermochemical conversion, waste valorisation.

ECOFISHVAL – INTEGRATED STRATEGY FOR THE VALORIZATION OF FISH BY-PRODUCTS TOWARDS A ZERO WASTE APPROACH

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ABSTRACT

Fishing production has grown by 60% over the last two decades, generating by-products that represent a significant fraction that is still underutilized. Around 26% of the total fish biomass stream is discarded as waste, resulting in a significant environmental footprint.

EcoFishVal's primary goal is to optimize the utilization of marine resources by ensuring that every part of the catch is used efficiently and sustainably. The initiative is dedicated to minimizing waste in the fishing industry by promoting innovative processing techniques, repurposing byproducts, and implementing circular economy principles. By advocating for a zero-waste approach, EcoFishVal aims to enhance the economic value of marine harvests while reducing environmental impact. Through collaboration with industry stakeholders, research institutions, and policymakers, the project seeks to foster a more responsible and resource-efficient seafood sector that supports both ecological preservation and long-term profitability.

The project aims not only to valorize waste, but also to implement innovative computational tools, employing advanced approaches to design and optimizing extraction processes. This integration of advanced computational technologies will allow us to boost operational efficiency, representing a significant step towards the digital transition and ensuring a holistic and sustainable approach in all phases of the process. In this way, the project promotes the reduction of environmental impact, contributing to future advances in marine biotechnology, unequivocally promoting sustainability in the management of marine natural resources.

Keywords

Sustainable fishing, Marine resource optimization, Zero-waste approach, Circular economy, Waste minimization

MAPPING THE LANDSCAPE OF AGRICULTURAL WASTE IN THE EU

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ABSTRACT

In today's global context, the agricultural sector faces a pressing dual challenge: meeting the growing demand for food to sustain an expanding population while ensuring the sustainable management of agro-industrial waste. As food production intensifies, so does the generation of waste from agriculture, forestry, and fishing activities. This surge in waste poses significant environmental, economic, and logistical challenges, making effective waste management not just an option but an urgent necessity. Addressing this issue is critical to preventing environmental degradation, optimizing resource use, and advancing the transition toward a circular economy.

Understanding the direct link between population growth, agricultural expansion, and waste generation is essential for policymakers, researchers, and industry stakeholders. Beyond the sheer volume of waste produced, it is equally important to examine its distribution across European Union countries and identify the agricultural sectors that contribute most to its accumulation. Such insights are vital for crafting targeted policies and fostering technological innovations that minimize waste, enhance resource efficiency, and promote sustainable agricultural practices. This work aims to offer a comprehensive statistical analysis of waste production within the agriculture, forestry, and fishing sectors across the European Union. It provides detailed insights into both the quantities of waste generated and the extent of agricultural land dedicated to crop production in each EU country. These data lay the groundwork for future research to refine waste classification by crop type and geographic region, ultimately enabling the development of more efficient waste recovery and recycling systems. Waste valorization plays a pivotal role in reducing environmental impact and fostering a more sustainable food production system. According to EUROSTAT, in 2020, the European Union generated over 21 million tons of waste from agriculture, forestry, and fishing activities. Spain emerged as the largest contributor, accounting for 30% of the total waste produced. Notably, more than two-thirds of this waste originated from just five EU countries: Spain, the Netherlands, France, Sweden, and Germany. In terms of land use, agricultural activity was most extensive in France, Spain, Germany, Poland, Romania, and Italy, which together accounted for approximately two-thirds of the total cultivated area in the EU. These numbers highlight the urgent need for efficient waste management strategies at both national and EU levels. The high concentration of waste production in a handful of countries suggests that region-specific policies and targeted technological investments could yield significant benefits. By integrating precision agriculture, advanced waste treatment technologies, and circular economy principles, the agricultural sector can substantially reduce its ecological footprint while maintaining productivity and economic viability. The transition to a more sustainable agricultural system demands a fundamental shift in how waste is perceived and managed. Rather than viewing agricultural waste as an unavoidable byproduct, it should be recognized as a valuable resource with potential applications in bioenergy, soil enrichment, and even bioplastics. Investing in research, innovation, and policy frameworks that promote waste reduction, recycling, and repurposing will be crucial in mitigating climate change, preserving natural ecosystems, and ensuring food security for future generations.

Keywords

Agricultural waste management; European Union (EU), Agricultural sustainability, Circular economy, Resource efficiency

CANNED TUNA WASTEFLOW: ANALYTICAL DATA AND CHEMICAL CHARACTERIZATION

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ABSTRACT

The global demand for canned tuna has led to an increase in their production, making it a significant sector in the seafood processing industry. However, the industrial process generates substantial amounts of waste, both organic and inorganic, at various production stages. Therefore, proper management of these residues is crucial for minimizing environmental impacts and optimizing resource utilization. Nevertheless, specific public data on the quantities of waste generated from the canned tuna process remains scarce. Thus, this study aimed to analyze the production process of an Azorean canning tuna company, identifying the key waste generation points and characterizing the chemical composition of the organic residues. The research involved a comprehensive assessment of each stage of the production process, from raw material reception to packaging. The main sources of waste were identified, including solid organic wastes such as fish remains (heads, bones, viscera, and skin), wastewater from cleaning and cooking, and non-organic materials like packaging scraps. The material flow analysis evaluates the waste movements and management procedures within a specified time and space framework.

On the other hand, the chemical characterization of organic waste revealed their potential for valorization in by-product industries, such as animal feed and bioenergy production.

The chemical characterization of organic canned waste was performed to determine their composition and potential applications. The results obtained indicated that organic waste contained high levels of proteins, lipids, and minerals, making them suitable for valorization in secondary industries such as bioproducts extraction, animal feed production, biodiesel generation, and fertilizer manufacturing. Additionally, the high moisture content and biochemical oxygen demand (BOD) levels in wastewater highlighted the need for effective treatment solutions before discharge. It also showed that wastewater has great lipidic extraction potential. These findings contribute to a better understanding of waste management in the canned tuna industry, promoting sustainability and resource efficiency.

Keywords

Canned Tuna Waste; Material Wasteflow; Chemical Characterization, Blue Economy

ENHANCING ASPHALT PERFORMANCE: VALORISING POLYURETHANE WASTE AS A BITUMEN MODIFIER

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ABSTRACT

The increasing demand for sustainable solutions in road infrastructure highlights the need to develop innovative approaches for incorporating waste materials into asphalt pavements. Given the high material consumption of pavements, their potential for waste valorisation is significant, particularly through bitumen modification with polymers. One of the most promising materials in this context is polyurethane, widely used in footwear manufacturing but often discarded in landfills at the end of its lifecycle. This study investigates the feasibility of using polyurethane waste as a bitumen modifier to enhance asphalt performance while reducing environmental impact. Bitumen was modified with 3% and 5% polyurethane, and its properties were evaluated through Penetration, Softening Point, Rheology and Apparent Viscosity tests, comparing conventional and modified bitumen. The results indicate that the addition of 3% polyurethane significantly improved the mechanical performance of the bitumen, suggesting that polyurethane-modified bitumen could be a viable alternative for more durable and sustainable road pavements. This approach contributes to circular economy principles and offers a potential solution for the disposal of footwear waste. Further studies should assess long-term pavement performance and field applicability.

Keywords

Polymer waste, modified bitumen, sustainable pavement, footwear waste, bitumen rheology, circular economy.

FOOD WASTE AND CLIMATE CHANGE: A VIEW THROUGH LIFE CYCLE ASSESSMENT

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ABSTRACT

Global food systems are facing unprecedented strain in the context of intensifying climate crises and the increasing frequency of natural disasters. Food waste, roughly 30% of worldwide production according to the Food and Agriculture Organization, poses a multidimensional threat. It intertwines environmental degradation, social inequity, and systemic inefficiencies. Beyond its direct consequences, including greenhouse gas emissions and resource depletion, it exposes structural vulnerabilities in supply chains and distribution networks. This study conducted a life cycle assessment to quantify the environmental impacts of food waste within a university canteen under the “Dose Certa” initiative. Using the ReCiPe methodology, three critical stages were analyzed: service provision, transportation, and end-of-life management. The results identified fossil resource depletion, freshwater ecotoxicity, and climate change as the most salient impact categories, emphasizing the criticality of the situation and the need for operational reforms in institutional food services.

Keywords

Life Cycle Assessment, food waste, circular economy, greenhouse gas, Recipe methodology.

TECHNO-ECONOMIC ANALYSIS (TEA) OF PIG MEAT PROCESSING WASTES VALORISATION

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ABSTRACT

The pig meat industry generates large volumes of by-products like blood, bones, skin, trimmings, organs, viscera, and skulls, among others, during slaughtering and meat processing and must be treated and disposed of ecologically. It was selected for further valorisation, the principal wastes produced throughout the value chain of pig meat production: Pig Manure, Pig Bones, Fats, Skins, Pig Hair, Wastewater, Wastewater sludges, and other animal subproducts type III. According to the potential valorisation options, these wastes will be converted into Biomethane, Fertilizers (phosphorus and digestate), Hydroxyapatite, and protein hydrolysates (Keratin and Collagen). This work includes a comprehensive technical and economic analysis (TEA) for each valorisation route or applied technology. Metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and payback periods were used to evaluate economic feasibility. From this analysis, it can be concluded that, for Biogas Production, the scenarios using pig manure, wastewater sludges and mixed grass and leguminous wastes presented a remarkably high economic feasibility. Scenarios showed high economic feasibility with a positive payback period, NPV, and IRR. The optimal scenario combining pig manure with mixed grass and leguminous wastes had a payback period of 1.2 years and produced 427,6269 m³ of biomethane annually. Regarding the Chemical Extraction of Phosphorus and Nitrogen, results proved that the process is economically unviable due to negative cash flows despite high recovery rates. The TEA of Hydrolysis and Extraction of Keratin Hydrolysates indicate that a unit processing and valorising 10 tons of pig hair per year for the production of keratin hydrolysate has an NPV of 907,940 €, an IRR of 13.07%, and a Payback period of 5.41 years. All of these indicators suggest a highly potential project to explore in the future. In contrast, the results of Hydrolysis and Extraction of Collagen Hydrolysates showed a process economically unviable with negative cash flows in all scenarios due to the high-fat content in raw materials. In fact, the results from the valorisation of 10 tons of pig skin had a negative cash flow of 453 743,88 €. TEA results of Extraction and purification of Hydroxyapatite from Pig Bones with Pyrolysis indicate that a unit processing and valorising 10 tons of pig bones per year for the production of hydroxyapatite has an NPV of 1 274 819,00 €, an IRR of 65.43%, and a Payback period of 1,5 years over a timeline of 10 years with a discount rate of 10%. These valorisation routes, circular economy and bio-refinery approach offer significant contributions to sustainable bio-based operations within the agri-food industry.

Keywords

Techno-economic analysis (TEA), Pig Meat Processing Wastes, Circular Economy, Bio-refinery.

ECONOMIC ANALYSIS OF PEACH AND NECTARINES PROCESSING WASTES VALORISATION IN CIRCULAR ECONOMY APPROACH

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ABSTRACT

Peach is the second most produced temperate fruit crop in the world following apple. Up to 30% of peaches and nectarines are discarded or lost on-farm in sorting processes, amounting to hundreds of thousands of tons annually of discarded fruit across the sector. Waste streams are also produced during peaches and nectarines processing including waste in the form of pomace from juicing and stones and skins from juicing, pureeing and canning. Disposing of this fruit waste as animal feed represents limited or no value to the growers and is a loss of important nutrients, including oils, antioxidants, vitamins, pigments that can provide health benefits, and natural colourants.

It was selected the following wastes for valorisation: Pruning wastes, Peach and Nectarines fruits discarded or unsuitable for human consumption, and Peach and Nectarines fruit processing waste. This work includes a comprehensive technical and economic analysis (TEA) for each valorisation route or applied technology. Metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and payback periods were used to evaluate economic feasibility. From this analysis, it can be concluded that the combustion of pruning wastes indicates a high economic feasibility with excellent financial metrics, including an NPV of €1,774,220, an IRR of 199.67%, and a payback period of less than 1 year. This approach efficiently converts waste into energy, providing a sustainable waste management solution. The results of composting of discarded peach and nectarine fruits indicate that the proposed composting process currently has a slight negative cash flow (-583,60 €/year). Although the initial assessment of the composting process's economic viability was negative, optimizing several parameters could make it economically viable in the future. Finally, the TEA results of ultrasound extraction of polyphenols from peach and nectarine processing waste, show that a unit of processing and valorising 10 tons of peach processing waste per year has an NPV of 441 846,00 €, an IRR of 17.00%, and a Payback period of 4,7 years over a timeline of 10 years with a discount rate of 10%. All of these indicators suggest a highly potential project to explore in the future.

These valorisation routes, circular economy and bio-refinery approach offer significant contributions to sustainable bio-based operations within the agri-food industry. This approach transforms waste into valuable resources, enhancing both environmental and economic outcomes and contributing to a more sustainable and circular bio-economy.

Keywords

Techno-economic analysis (TEA), Peach and Nectarine Processing Wastes, Circular Economy, Bio-refinery.

IDENTIFICATION OF COMPANIES AND CHARACTERIZATION OF MARINE PLASTICS RECYCLING TECHNOLOGIES

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ABSTRACT

The issue of marine plastics, characterised by the accumulation of large quantities of plastic waste in the oceans, stands as one of the most critical environmental crises of the 21st century. It is estimated that over 8 million tons of plastics enter the oceans each year, affecting marine life, coastal ecosystems, and even human health. The global problem of ocean plastics has created an urgent need for innovative and sustainable solutions to reduce, recycle, and reuse the plastics already floating in our seas. Among the proposed solutions, ocean plastic recycling stands out as a viable and essential strategy to tackle this challenge. Marine plastics are particularly challenging to recycle. Degradation from sun exposure, salt water, and temperature fluctuations weakens polymer structures, while contamination by organic and inorganic materials, along with pigments and additives, further complicates the recycling process.

The need to remove plastics from the oceans is evident, but the technical, logistical, and economic challenges are considerable. While marine plastic recycling is a promising solution, it still faces various barriers. Plastics recovered from the ocean are often of low-quality, and the recovery process is expensive and complex. However, emerging recycling technologies, coupled with increasing support from global environmental policies and the private sector, are driving the development of innovative solutions. Identifying companies and clusters involved in ocean plastic recycling, therefore, becomes a critical component for the development of a circular economy in the maritime sector.

This paper delves into the recycling technologies and innovations focused on marine plastics, emphasizing the potential of advanced tertiary and quaternary recycling processes. These methods offer the potential to transform degraded plastics by breaking them down into fundamental chemical components or converting them into energy, thus addressing both the removal of impurities and the recovery of valuable resources. By examining and assessing current advancements in these areas, this paper aims to contribute to sustainable strategies for managing marine plastic waste, ultimately aiding in the reduction of oceanic plastic pollution.

This paper also identified the European and global companies currently engaged in the process of ocean plastic recycling with each type of technology or those with the potential to become leaders in this field. Additionally, the possibility of forming industrial clusters that can collaborate to accelerate innovation and effectiveness in ocean recycling operations will be explored. Finally, a matrix of relationships between technologies and companies was created, focusing on the environmental, economic and social benefits, and the possible final destinations of each by-product after recycling.

Keywords

Marine Plastics, Recycling, Blue Circular Economy.

FROM WASTE TO WORTH: HOW WATER MODIFIED THE COMPOSITION OF UNDERVALUED COFFEE SILVER SKIN

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ABSTRACT

Coffea arábica silver skin (CSS), a by-product of coffee processing, is a lignocellulosic biomass with potential for sustainable applications. This study aimed to evaluate the effect of treatment with distilled water at 95ºC on CSS's physical and chemical characteristics. Structural components, ash, ionic demand and mineral compositions by X-ray fluorescence were analysed. The results indicated a 33.46% removal of total extractives, which promoted a structural reorganization of the biomass, including total phenolic compounds decreased by 29.36%. Besides that, reflected in the proportional increase in cellulose (+221.60%) and lignin (+119.56%). The cation demand decreased significantly from 184.67 to 64.33 meq/kg, suggesting lower ionic reactivity. Mineralogical analysis by X-ray fluorescence revealed a reduction in Fe (99.71%), Al (99.54%), and Ca (39.19%), as well as an increase in P (148.86%) and Cl (157.35%). These data show that the physical-chemical treatment significantly modifies the composition of the biomass, contributing to the valorisation of this underused agroindustrial waste, which has the potential to be used in various technological and sustainable applications.

Keywords

Coffea arábica, Physicochemical treatment, lignocellulosic material, sustainable materials, Coffee by-products.

RECOVERY OF FATTY ACIDS, PHENOLIC COMPOUNDS AND PROTEIN FROM BREWERY SPENT GRAIN BY CONVENTIONAL OR SUSTAINABLE PROCEDURES USING GREEN SOLVENTS

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ABSTRACT

This study explores the recovery of three significant fractions of brewery spent grain (BSG), fatty acids, phenolic compounds and protein, by means of sequential extractions. Supercritical CO_2 and ethanol (SCO_2-EtOH) were used to study several parameters of the process (CO_2 rate, particle size and time), measuring their effects in terms of phenolic content, antioxidant capacity, and lipid extraction. A Box Behnken Desing (BBD) was then performed to optimise fat extraction with SCO_2-EtOH, focusing on the parameters of temperature, pressure, and ethanol concentration. Under the selected conditions (45ºC, 200 bar and 100% ethanol) the phenolic and fatty acid profiles of BSG oil were analyzed. The resulting protein extraction was studied using a conventional treatment with diluted NaOH and a sustainable procedure based on the use of deep eutectic solvents (DES). Temperature (110 and 130ºC) and time (30, 60 and 90 min) were considered in the protein extraction using DES. The protein recovered with DES at the best conditions (110ºC and 60 min) was analsed by means of ATR-FTIR, and the secondary structure revealed a well-ordered structure. Finally, the chemical composition joined to the ATR-FTIR spectra of all BSGs following the extractions were assessed, which confirmed the effectiveness of the extractions.

Keywords

brewery spent grain, supercritical CO2, deep eutectic solvents, fatty acids, phenolics, protein.

A SUSTAINABLE PROCESS FOR BREWERY SPENT GRAIN BIOREFINERY BY ACID-BASED DEEP EUTECTIC SOLVENT RECYCLING

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ABSTRACT

Deep Eutectic Solvents (DESs) have been highlighted as the most promising alternative to conventional pretreatments, due to its environmentally benign, biodegradability, and reusable properties. However, the recovery and reuse of DESs in biorefinery processes is necessary for an economically viable bioconversion. In consequence, the present investigation analysed the effect of the pretreatment, recovery and recycling of a DES formulated by choline chloride (ChCl) and lactic acid (LA), in Brewery Spent Grain (BSG) biorefinery. Characterisation techniques, including scanning electron microscopy (SEM), Fourier transformed infrared (FTIR) and X-ray diffraction (XRD) were assayed to determine the physical and chemical properties of polysaccharide rich material (PRM) and lignin rich material (LRM) obtained after DES pretreatment and DES solution in each cycle. The result showed a separation of high-quality of LRM and holocellulose in a single step. Additionally, the yield of polysaccharides content in PRM and the quality of LRM using [ChCl]:LA pretreatment has not significant loss after three cycles, employing a simple recovery process. Furthermore, FTIR and XRD verified uniformity structure and purity from PRM and LRM obtained for each cycle. Therefore, the results generated could demonstrated the effectivity of BSG pretreatment, applying an eco-friendly and sustainable strategy to minimise the utilisation of reagents and the effluents production, promoting a scale-up and simple biorefinery process.

Keywords

Brewery Spent Grain (BSG), Biorefinery, Deep Eutectic Solvents (DESs), recovery and reuse of DESs

SYNTHESIS AND CHARACTERIZATION OF SILICO-ALUMINOPHOSPHATE GEOPOLYMERS PRODUCED FROM COPPER MINE TAILINGS

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ABSTRACT

Mine tailings management poses a major environmental challenge for the mining industry. The production of silico-aluminophosphate geopolymers has been proposed as a potential upcycling strategy, however, the existing literature is still incipient. This study investigates the production of silico-aluminophosphate geopolymers from copper mine tailings via phosphoric acid activation. Copper mine residues have been collected and their particle size distribution, mineralogy (XRD) and oxide composition (XRF) characterized. Copper mine tailings have been activated with phosphoric acid at varying solid-to liquid ratios (0.35, 0.40, and 0.45) and phosphoric acid concentrations (30, 40, and 50 wt%), and cured at different curing regimes (20 and 40 ºC) to investigate the effect of such synthesis factors on the rheological and physico-mechanical properties of silico-aluminophosphate geopolymers. The properties assessed included plastic viscosity, yield stress, and thixotropic behaviour, apparent density, open porosity, water absorption, and compressive strength. SEM and XRD techniques were used to further evaluate the reaction products, morphology and microstructure of geopolymers produced under optimized conditions. The results indicate that copper mine tailings can be effectively upcycled through activation with phosphoric acid, demonstrating their potential as alternative raw materials for the development of innovative and sustainable building materials.

Keywords

Mine tailings; Copper; Acid activation; Sustainable building materials

CARBON NEUTRAL RECYCLED CONCRETE

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ABSTRACT

The construction industry worldwide is heavily dependent on concrete, which is the second most used material in the world after water. Unfortunately, concrete is characterized by a very high CO2 footprint, mostly related to the usage of Portland cement. There are several approaches to improve that situation. Typical include reducing the amount of Portland cement by substituting it partly with secondary cementitious binders (SCMs) and alternative binders. The concrete mix designs and production technologies have been optimized to reduce emissions. Unfortunately, as of today, none of these approaches enabled the production of truly zero-emission neutral sustainable concrete. Test results showed that producing new high-quality structural concrete is possible using only materials recovered from old concrete, including coarse and fine aggregates, fillers, and binders. The recovery method is based on a combination of crushers and ball mills that enable the mechanical activation of fines. The method used old concrete waste from a precast concrete factory yard. The material was crushed and sieved into several fractions, i.e., particle sizes 4-8 mm, 2-4 mm, and a fine powder <2 mm. The fine powder was MCA-treated (Mechanical activation using intensive ball milling). All these materials were mixed, and the produced concrete reached the 28-day compressive strength of 30 MPa. The only new ingredient for that concrete was water with a little superplasticizer to improve the workability. The LCA analysis showed excellent results. The application of this technology in Europe could result in the annual production of 34 million tons of ZERO-emission cementitious binder.

Keywords

Concrete, cement, recycling

DETOXIFICATION OF FERROCHROME SLAG BY REMOVING CR WITH AN ELECTRODIALYTIC METHOD

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ABSTRACT

Industrial by-products and wastes have gained increased interest for use as secondary resources in construction materials. Ferrochrome (FeCr) slag is classified as hazardous material due to a high Cr content, which restricts its use in green construction materials. Here, it was investigated if an electrodialytic treatment method could be applied to detoxify the FeCr slag from a South African smelter, and how the electrodialytic treatment influenced the FeCr slag matrix. By the electrodialytic treatment technique, a direct current is applied to a material suspension, whereafter dissolved ions from the material matrix electromigrate through ion exchange membranes towards the electrode of opposite charge. Thereby, Cr mobilized from the FeCr slag will be separated from the FeCr slag itself and thus the FeCr slag can be detoxified. Seven electrodialytic experiments were done with varying experimental conditions: duration (14, 21 and 28 days), applied current (1mA or 5 mA), and cell set-up (2 or 3-compartment cells). The Cr removal was in the range of 3-19 % in the electrodialytic experiments. The highest Cr removal (19 %) from the FeCr slag was seen when using the longest remediation time combined with a high current in a 2-compartment cell. However, Cr leaching exceeded the regulatory TCLP limits after this experiment. The Cr leaching decreased significantly after all the other electrodialytic experiments and was below the regulatory TCLP limit. This shows the potential for the electrodialytic treatment method to detoxify FeCr slag if the right experimental conditions for electrodialytic treatment are chosen. The FeCr slag was characterized before and after the electrodialytic treatment for chemical content, mineralogy and morphology. The matrix properties did not deteriorate due to the electrodialytic treatment. The relative proportion of Al and Si increased compared to the other elements after the electrodialytic treatment, so the treated FeCr slag would be more suitable for construction materials and should be tested in future studies.

Keywords

FeCr slag; chromium; electrokinetic remediation; hazardous waste; secondary resources

THE INFLUENCE OF PARTICLE SIZE ON MECHANICAL AND THERMAL PROPERTIES OF 100% RECYCLED EVA COMPOSITES

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ABSTRACT

The footwear industry is one of the most relevant sectors of the global industry. More than 23 billion pairs of shoes are produced annually, which represents a footwear consumption of 2.7 kg per person annually in Europe. Many materials used in the manufacture of shoes, such as EVA (ethylene vinyl acetate), plastics, leather, and rubber, are non-biodegradable and can take between 40 and 1000 years to decompose These materials release toxic substances, greatly contributing to environmental pollution and public health risks. Therefore, exploring solutions to prevent landfilling and promoting footwear waste recycling is essential to encourage sustainability and the transition from a linear to a circular economy in this sector. Despite being composed of over 40 distinct components, shoes can be divided into 3 main parts (small items, upper and lower parts). EVA, a suitable material for producing soles and insoles (lower parts) accounts for approximately 14% of a typical shoe. Its lightweight, flexible, and shock-absorbing properties make EVA an essential material in the footwear sector, nonetheless, its extensive use poses recycling issues. Current approaches to improve the mechanical recycling potential of footwear waste include its fragmentation below 6 mm, through processes such as crushing or granulation, which enhance the separation and recovery of mono-materials. This approach not only minimizes particle interconnection but also enables effective separation of EVA from other components, thus improving its potential for recycling into value-added products. This study investigates the influence of particle size on the properties of 100% recycled EVA composites. The EVA waste used in this work is post-industrial, originating from sole cuttings and defective soles. After collection, this EVA waste was ground into four different particle sizes (0.5, 1, 2, and 4 mm) to produce composites through compression molding. To ensure comparison, all composites were made under equal experimental conditions (temperature, pressure, and time) without any binder or matrix. In this study, the samples were analyzed using scanning electron microscopy and energy-dispersive spectroscopy (SEM/EDS) to understand the effects on composite pore size, and the thermal and mechanical properties were investigated to understand the effects of particle size on tensile strength, elongation, air permeability, thermal conductivity, and thermal resistance. The results indicate that decreasing EVA particle size enhances thermal conductivity, tensile strength, and elongation. Thus the composites composed of smaller particles are more suitable for applications requiring high mechanical performance. Conversely, composites produced with larger particles show an enhancement in air permeability and thermal resistance, contributing to improved thermal insulation characteristics. In conclusion, this study demonstrates that particle size affects the properties of recycled EVA composites. Therefore, during the production of 100% recycled EVA composites, the particle size must be determined based on the field of application of the composites.

Keywords

Particle Size; Recycled EVA Composites; Footwear Waste; Circular Economy; Recycling

LIFE CYCLE ASSESSMENT OF WHITE AGGLOMERATED CORK PANELS: ENVIRONMENTAL IMPACTS AND WASTE REDUCTION OPPORTUNITIES

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ABSTRACT

This study presents a Life Cycle Assessment (LCA) of white agglomerated cork panels, produced by a Portuguese manufacturer from cork byproducts generated in cork stopper production. The goal is to assess the environmental impacts at each stage of the product's life cycle, identify critical points, and propose strategies to reduce its ecological footprint. Adopting a "cradle-to-gate" approach, the study covers stages such as transportation, granulation, cooking, drying, adhesive mixing, molding, pressing, cutting, and packaging. It excludes stages like transportation to customers and end-of-life, due to their variability. The functional unit used is 1 m² of cork panel (50 cm × 100 cm × 4 cm) with a density of 300 kg/m³. The study evaluates energy consumption, material inputs, emissions, and waste, using environmental indicators such as global warming potential, resource depletion, and ecotoxicity. For the environmental impacts' assessment, the EN 15804 methods were used, through SimaPro v9.0 software and ecoinvent v3.10 datasets. Results show that energy-intensive production stages, such as hot pressing and drying, along with the use of polyurethane adhesive, are the main contributors to the high Global Warming Potential (GWP) of 10.54 kg CO_2 eq./m². These findings highlight the need to optimize these stages for better sustainability of cork-based insulation materials. One key advantage of the panels is the use of cork byproducts, like cork dust and small pieces, which supports a circular economy by reducing the environmental impact of cork harvesting and adding value to lower-quality materials. Comparing with other insulation materials, such as Expanded Polystyrene (EPS) and Stone Wool (SW), although synthetic materials may have lower GWPs, they lack the renewable, biodegradable, and circular economy benefits of cork. To improve the environmental profile of cork panels, future efforts should focus on optimizing energy efficiency, reducing synthetic adhesives, and refining transportation and other life cycle stages. These improvements will help align cork panels with green construction goals, offering a renewable and competitive option for sustainable insulation applications. This study contributes to a better understanding of cork-based materials' sustainability, supporting the manufacturer in improving production processes and aligning with ISO 14040 and 14044 standards, while promoting circular economy practices, resource efficiency, and renewable energy integration.

Keywords

Agglomerated Cork Panels, Circular Economy, Cork Byproducts, Environmental Impacts, Energy Efficiency, Polyurethane Adhesive.

NATURAL HYDRAULIC MORTARS INCORPORATING CERAMIC WASTE FOR THE REHABILITATION: ENVIRONMENTAL AND HISTORICAL BENEFITS

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ABSTRACT

The present work encompasses a systematic review of literature and discusses the use of natural hydraulic mortars incorporating ceramic waste for the rehabilitation of historical buildings. It highlights the environmental benefits and historical relevance of these mortars, emphasizing the need for sustainable construction practices. The construction industry significantly impacts the environment through its reliance on non-renewable resources and waste generation, accounting for about one-third of total waste in Europe. A shift toward a circular economy is critical, focusing on reusing and recycling materials. Ceramic waste, a major component of construction and demolition waste, possesses pozzolanic properties, making it a viable secondary raw material for producing natural hydraulic mortars. Historically, these mortars were widely used before the development of Portland cement in the late 19th century, as evident in various ancient buildings and archaeological sites. Natural hydraulic mortars with ceramic additives exhibit hydraulic behavior, suitable for applications like brick bonding, wall finishes, and water conduits in historic structures. Ceramic waste contributes to the pozzolanic reaction by interacting with lime, enhancing the mortar's properties. Factors like clay mineralogy and firing temperature influence the efficacy of ceramic particles in these mortars. Despite Portland cement's advantages in modern construction, its incompatibility with historical structures necessitates alternatives like natural mortars for preservation projects. Studies from countries like Italy, Tunisia, and Portugal support the use of natural hydraulic mortars with ceramic waste, yielding results compatible with ancient materials. The research methodology involved a systematic review of literature from 2012 to 2024, using keywords like "ceramic waste" and "mortar" in major databases. The analysis revealed that while most studies address cementitious mortars, those on lime-based mortars confirm their potential for sustainable and effective rehabilitation. Ceramic waste mortars demonstrate favorable chemical and mechanical properties. Chemically, they promote pozzolanic reactions, forming compounds like calcium silicate hydrates, which enhance durability. Mechanically, partial replacement of natural aggregates with ceramic waste improves compressive and flexural strength, elasticity, and pore structure, making these mortars suitable for historical restoration. Challenges include the energy-intensive processes of preparing ceramic waste, such as crushing and sieving, and ensuring their environmental benefits outweigh the energy costs. Nonetheless, incorporating ceramic waste into natural mortars aligns with sustainable construction goals and aids in conserving historical edifices.

Keywords

Ceramic waste, CDW, Historical buildings, Pozzolanic reactions, Natural mortar.

SUSTAINABLE EXTRACTION OF BIOACTIVE PEPTIDES FROM BREWERY SPENT GRAIN

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ABSTRACT

Brewery spent grain (BSG), the main by-product of beer production, constitutes around 85% of total brewing waste. It consists of residual husks, pericarp, and seed coats. Rich in dietary fiber, proteins, and bioactive compounds such as phenolics, BSG holds significant potential for industrial applications. Traditionally used as animal feed, it is now being increasingly explored within sustainable and circular economy practices. Its biochemical composition makes BSG an attractive ingredient in food products. Additionally, BSG has found uses in bioethanol and biogas production and in bioplastics manufacturing. As part of the AGRILOOP EU project, BSG was investigated for the recovery of bioactive proteins and peptide hydrolysates for use in food and bioactive packaging. Protein content in dried and ground BSG samples was analyzed using the Kjeldahl method, revealing 28.0% (w/w) protein. To enhance protein recovery, enzymatic digestion was carried out using Bromelain, Protamex, and Trypsin proteases at a 5% (w/w) enzyme/gDW of BSG ratio. Protein levels in the resulting supernatant fractions were quantified using the Lowry assay, with all three proteases significantly improving protein release compared to undigested controls. Bromelain showed the best results, yielding up to 200 mg BSA equivalents /gDW of BSG. Further analyses evaluated total phenolic content, reducing sugar concentration, and antioxidant activity in the extracted fractions. Protein solubilization experiments were also conducted under alkaline (NaOH, pH 11) and neutral (phosphate buffer, pH 7.2) conditions, followed by precipitation using HCl (pH 3). The results showed low protein precipitation but a high concentration of peptides in the supernatant. These unprecipitated peptides likely originated from beer maltation process. The study highlights enzymatic digestion as an efficient method for recovering proteins and peptides from BSG. It also underscores BSG's value as a source of bioactive compounds with potential applications across several industries. By utilizing these properties, BSG can be transformed into highvalue products, reducing waste and promoting circular economy practices. Such efforts not only will enhance resource efficiency within the brewing industry but also will contribute to sustainable industrial practices and the advancement of a circular bioeconomy.

Keywords

Brewery spent grain, peptides, protease, phenolics, antioxidant activity.

MULTIFUNCTIONAL TEXTILES DEVELOPED BY AGROINDUSTRIAL WASTES VALORIZATION

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ABSTRACT

Consumer awareness about environmental impacts, the European Commission restrictions and client demands are driving a transformation in the textile industry toward more sustainable materials and processes1. In textile finishing, the exploitation of natural resources, primarily plant-based, as new sources of dyes and pigments for dyeing, coating, and other visual applications is the most well-known example. In this context, a more sustainable approach that can be explored is the valorization of agro-industrial waste by the extraction of functional properties valuable for textile applications. In this study, aqueous process or the combination with enzymes and ultrasound pre-treatment were explored for bioactive agents extraction. Hot trub (HT), extracted olive pomace (OPe) and oregano pruning steams (OPS) were selected for this study aiming to search for antioxidant, antimicrobial, UV protection and water repellence properties and incorporate them into textiles. For that, the functional extracts were applied on 100 % cotton fabric previously cationized via exhaustion and impregnation.

Hydrophobic textiles were developed by the impregnation with HT aqueous extraction supplemented with enzymes, achieving a water contact angle (WCA) of 140.60 ± 6.23 (cellulase and pectinase) and 132 ± 6.81 (cellulase). Also, a hydrophobic (WCA= 134.88 ± 5.25 °) fabric impregnated with OPe pre-treated with ultrasounds followed by enzymatic treatment with pectinase and cellulase was developed. The fabric controls (without enzymes) did not show water repellence properties.

The antioxidant properties of the extracts were first assessed by DPPH radical scavenging activity and Trolox equivalent antioxidant capacity (TEAC). Despite the extraction with pectinase and cellulase presenting a higher antioxidant activity (82.8 ± 2.7 %; 25.5 ± 0.72 TEAC µmol/g waste) compared to the aqueous control (62.8 ± 0.61 %; 5.8 ± 0.06 TEAC µmol/g waste) the same was not noticed when applied on the textiles. The fabrics treated with OPS aqueous extract by impregnation (78,97 ± 4,10 %) and exhaustion (73.22 ± 7.79 %) show higher antioxidant properties compared to enzymatic extract: 66.02 ± 0.24 %-(exhaustion) and 59.29 ± 0.55 %(impregnation).

HT aqueous extracts show antimicrobial activity against *S. aureus* in the disk diffusion method. The HT-functionalized fabrics will be further evaluated for antimicrobial activity (CFU method).

According to AS/NZ standard 4399:2017, excellent UV protection (UPF=50/50^{+}) was achieved on fabrics impregnated with aqueous extract of HT and OPS and good protection (UPF=30) with OPe, extracts following exhaustion method.

In this study, multifunctional fabrics were developed using water-based sustainable methods, without organic solvents, that can be easily implemented in textile finishing processes by the companies.

Keywords

Textile industry, functional properties, agro-industrial wastes, bioeconomy

EXPLORING SUSTAINABLE CEMENT ALTERNATIVES IN 3D CONCRETE PRINTING THROUGH THE INTEGRATION OF BY-PRODUCTS OR WASTE-DERIVED POWDERS

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ABSTRACT

The construction industry faces challenges such as labor shortages, rising costs, and environmental impacts. Digital technologies, particularly 3D Concrete Printing (3DCP), offer solutions by improving efficiency, reducing manual labor dependence, and enhancing working conditions. However, the extensive use of cement in 3DCP materials is a growing concern due to its high energy consumption and significant carbon dioxide emissions, highlighting the urgent need for sustainable alternatives. This study focuses on incorporating alternative powders, some of them derived from waste materials, to partially replace cement in 3DCP materials, aiming to address sustainability and maintain or enhance materials' performance. The alternative powders evaluated in this study include industrial by-products such as fly ash and silica fume, waste materials such as marble powder, granite powder, clay brick powder, sugarcane bagasse ashes, and bottom ash powder from the incineration of municipal solid waste, as well as processed raw materials including limestone filler, quartz powder, and metakaolin. Replacing cement with alternative powders leads to changes in the materials' fresh properties, such as workability, cohesion, setting time, between others, which can positively or negatively impact 3D printing performance. These variations highlight the importance of studying each material individually to fully understand its influence on 3DCP performance, helping to determine optimal mix designs. Cementitious pastes were tested with 20% replacement of two different types of cement (grey and white) by these alternative powders, evaluating fresh properties using a flow table test and printability using a Delta WASP 40100 3D printer to print test samples. Each combination of cement and alternative powder was tested at various w/c ratios, from mixtures that could be successfully extruded to those in which the layers collapsed. This study highlights the potential of integrating alternative powders that promote circular economy into sustainable construction practices.

Keywords

3D Concrete Printing (3DCP), Alternative materials, Waste-derived powders, Sustainable construction, 3D Printing Fresh Properties.

FROM WASTE TO VALUE: VALORIZATION OF PURPLE ONION PEEL AS A TEXTILE BIO-DYE

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ABSTRACT

The textile industry, particularly the dyeing process, is a major contributor to negative environmental impacts due to excessive water consumption and the extensive use of harmful chemicals. These processes not only contribute significantly to pollution but also increase the overall environmental footprint of the entire industry. However, the transition to a circular economy offers a viable and innovative solution by transforming waste into valuable resources, thereby promoting more sustainable industrial practices that can benefit both the environment and society. This study investigates the potential of purple onion peel, a by-product of the agri-food industry, as a sustainable bio-dye for dyeing cotton and wool fabrics. The main objective is to evaluate the effectiveness of this natural dye source as an eco-friendly alternative to chemical dyes, promoting practices in line with the circular economy and the valorization of agricultural waste. In particular, the color fastness of dyed fabrics to the main factors affecting their life cycle (washing and exposure to light) is a crucial part of this work. A solid-liquid extraction process using water as solvent was used to promote the extraction of dyes from purple onion peel. After dyeing textile samples of cotton and wool (in triplicate) with the dyeing solution obtained, the dyed samples were washed with hot and cold water and exposed to natural light for one week with half of the surface covered with a black card and protected from light. After these color fastness tests, the color of the samples was evaluated using the CIELAB color space, a widely recognized system for quantifying color differences. The dyed samples showed visible colorations, ranging from brownish-grey to dark brown. However, the total color difference (quantified by the parameter ΔE^*) between the light-exposed and protected areas of the dyed samples was calculated and it was significant. The ΔE^* parameter was 3.8 for cotton and 3.0 for wool, indicating a clear color difference, according to the classification proposed by Mokrzycki & Tatol. These results show the limitations of the fixation of the dye on the textile fibers, which are very sensitive to fading caused by light. This aspect is one of the main challenges for the use of natural dyes in the textile industry. To address this issue, 1,1'-carbonyldiimidazole (CDI) was used to access its role as a promoter of dye-fiber affinity, enhancing and prolonging its fixation. Different amounts of CDI were tested, ranging from 5 mg to 100 mg, and when amounts close to 30 mg were used, promising results were obtained. Comparing the two halves of the dyed samples (the half exposed to natural light and the half protected from light), the parameter ΔE^* calculated for wool was 1.1, indicating a very small color difference, noticeable only by an experienced observer1. For cotton, the ΔE^* was 2.2, which is a color difference perceptible to an ordinary observer1, but still lower than the value observed for samples dyed without CDI. The results of this study show that dyeing with natural dyes obtained from purple onion peel is a promising alternative for the textile industry, helping to reduce dependence on synthetic dyes that are harmful to the environment.

Keywords

Waste valorization, Bio-dyeing, Circular economy, Purple onion peel, Sustainability

INCREASING ENVIRONMENTAL PERFORMANCE OF BATTERY TECHNOLOGIES: RECYCLING AS KEY FOR MINIMIZING CRITICAL RAW MATERIAL MINING

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ABSTRACT

The transition to electric mobility represents a vital component of global initiatives aimed at decarbonizing the transportation sector, facilitating a shift from fossil fuels to renewable sources. Lithium-ion batteries have, currently, established their position as the most viable solution for energy storage in both electric vehicles and large-scale stationary applications.

Conventional lithium-ion batteries feature a graphite anode on a copper collector, a metal-oxide cathode on an aluminum collector, a liquid electrolyte of carbonate solvents and lithium salts, and a polyolefin separator. Some manufacturers are now developing novel gellified cell concepts that integrates advanced materials, including gellified electrodes and a high voltage-stable gel electrolyte. This innovation aims to exceed the energy density of third-generation batteries, achieving capacities of 350 to 400 Wh/kg and a maximum cathode potential of 4.9 V. Despite this impressive market diffusion, there are growing concerns regarding the sustainability and reliability of raw materials supply, especially critical raw materials such as lithium, nickel, and cobalt. Effective recycling of lithium batteries is crucial for developing a sustainable production cycle, reducing reliance on virgin mineral resources, mitigating environmental harm associated with improper disposal practices and the extraction of virgin material and achieving the European Commission's objectives of recycling about 65%, in weight, of lithium-based batteries by no later than 31 December 2025. The recycling process typically begins with collecting spent batteries, which are then fully discharged before being crushed into smaller fragments. These fragments undergo physical and chemical treatments to recover valuable materials. Traditional recycling methods for lithium-ion batteries are typically categorized into three main approaches: pyrometallurgy, hydrometallurgy, and direct recycling. According to the literature, greenhouse gas emissions associated with producing one pack of lithium-ion batteries can be significantly reduced through different recycling methods. This emphasizes the importance of selecting efficient recycling methods to minimize environmental impacts.

Nevertheless, conventional industrial recycling methods need to be modified for gellified cells. A key step in these processes is removing the toxic and flammable liquid electrolyte. In gellified cells, the active materials and electrolyte are trapped in a PVDF gel, thus, a pretreatment is required to extract the gel and release the electrolyte and active materials before applying any hydrometallurgical processes.

It is essential for recycling technologies to advance with battery cell innovations. Relying on critical material extraction can lead to significant environmental and economic issues. This study explores a new recycling process for 3B battery technology, including an environmental life cycle assessment comparing this method to the extraction of virgin materials. The aim is to emphasize the benefits of new recycling concepts, which can reduce material extraction and demonstrate environmental advantages in battery production. This research is innovative as it addresses currently unavailable recycling options and includes environmental studies for 3B battery cells.

Keywords

Critical Raw Materials, Recycling, Life Cycle Assessment, Lithium-ion Batteries

BOOSTING SUSTAINABLE BIOGAS PRODUCTION FROM SAUCE INDUSTRY NON-CONFORMING PRODUCTS

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ABSTRACT

The EU's reliance on external fossil fuels and its commitment to climate neutrality by 2050 has driven initiatives like the European Green Deal and REPowerEU, which aims to reduce dependence on imported fossil fuels, particularly Russian natural gas. Achieving these goals requires a significant boost in biogas production, with the EU currently producing 4 billion cubic meters (bcm) of biomethane and 15 bcm of biogas. In Portugal, biogas is becoming crucial to the energy and environmental landscape, with the "Biomethane Action Plan 2024-2040" promoting biomethane as a renewable energy source.

Amid the growing need to cut carbon emissions and combat climate change, renewable energy from sustainable resources has become a priority for the EU. Anaerobic digestion will become a vital technology in these efforts, as it reduces landfill waste and provides a viable alternative to fossil fuels such as natural gas. It supports a circular economy and enhances environmental sustainability, especially when integrated into renewable energy strategies. Organic waste from the food industry holds great potential for biogas production, generating methane-rich biogas that can replace natural gas. Many industries, particularly in the food sector, can adopt anaerobic digestion to minimize waste, treat effluents, and lower energy costs.

The present study evaluated the potential for energy recovery through anaerobic digestion of sludge from a biologic wastewater treatment sludge thickener (SW) and two non-conforming products from a sauce industry: a mayonnaise-type sauce (MYO) and a chocolate-based dessert (CHO). The biogas production was determined by the specific biogas production (SBP - the volume of biogas produced per mass of Volatile Solids (VS) fed to the reactor). MYO yielded the highest biogas production among the three substrates, though SW was present in much larger quantities than the non-conforming products (0.951 ± 0.125 NL/g-VS). To enhance biogas production, different ratios of these substrates were tested, including SW:MYO and SW:CHO at 50:50 and SW:MYO:CHO at 50:35:15. The highest biogas yield was achieved when all three substrates were combined (0.834 ± 0.042 NL/g-VS), with SW:MYO yielding the second-highest production (0.804 ± 0.040 NL/g-VS). Thus, this corresponds to a theoretical electrical energy production of 2.27 kWh/kg-VS and 2.19 kWh/kg-VS, respectively. Analyzing the company's waste production, experimental data indicated the potential to generate 40 MWh/year of electricity while reducing greenhouse gas emissions. That demonstrates the dual benefit of anaerobic digestion by promoting the company's sustainable development while simultaneously providing economic gains.

Keywords

Anaerobic Digestion; Biogas; Circular Economy; Clean Energy; Food Waste; Green Energy

SUSTAINABLE PAVEMENT REHABILITATION USING COLD IN-PLANT RECYCLING WITH FOAMED BITUMEN: THE PORTUGUESE ER 243 CASE STUDY

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ABSTRACT

The primary goal of this work was to rehabilitate a distressed road pavement using more sustainable techniques. Cold in-plant recycling with foamed bitumen was chosen as the preferred method, as it allows for the complete reuse of the existing degraded pavement materials while minimising energy consumption. This approach aligns with sustainability principles, offering a cost-effective and environmentally friendly solution for road rehabilitation.

This case study included the design of different pavement structures, always considering a base course constructed with the abovementioned 100% cold in-plant recycled mixtures. Structural solutions were developed as alternatives to conventional pavement reconstruction with hot mix asphalt, considering the known traffic levels.

The development of the mixture to be used in the rehabilitation works began with an extensive laboratory investigation to determine the optimal composition. Key parameters, including binder content, aggregate gradation, moisture levels, and foamed bitumen characteristics, were studied to ensure the mixture design met rigorous mechanical and durability requirements. The optimised mixture incorporated 2.5% foamed bitumen and 2% cement. Although those proportions may be higher than conventional recommendations, they were selected to enhance the mixture's mechanical performance.

Following laboratory validation, the mixture was applied in a full-scale experimental section as part of a road improvement project in Riachos, Portugal. The execution of the trial was closely monitored, with rigorous quality control measures, including field and laboratory testing, to assess the material's characteristics and confirm its suitability for future applications. The results demonstrated that this solution offers excellent performance under actual traffic conditions, making it a viable option for large-scale infrastructure projects.

This study highlights the significant environmental benefits of using 100% reclaimed asphalt in the mixture, contributing to circular economy goals and reducing the environmental impact of road construction. Moreover, it validates the specific proportions of foamed bitumen and cement in the mixture, facilitating its future use in sustainable pavement practices. The findings underline the potential of cold recycling with foamed bitumen to deliver durable, high-performance pavement base courses while prioritising resource efficiency and sustainability.

Keywords

Cold recycling, Foamed bitumen, Sustainable pavements, Reclaimed asphalt, Road rehabilitation, Pavement engineering.

LIFE CYCLE ASSESSMENT AND ENERGY BALANCE OF bioH2 AND BIOGAS PRODUCED FROM FOOD WASTES IN A TWO-STAGE BIOREACTOR

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ABSTRACT

The increasing demand for sustainable energy solutions necessitates the development and evaluation of innovative technologies that transform waste into bioenergy efficiently. This study investigates the energy sustainability and environmental impacts of a two-stage anaerobic bioreactor for producing biohydrogen ($bioH_2$) and biogas from the organic fraction of municipal solid waste (OFMSW). A Life Cycle Assessment (LCA) was performed to analyze the system's energy performance and environmental impact under two scenarios, differentiated by the hydraulic retention time (HRT) in the dark fermentation process: 4 days (scenario S1) and 5 days (scenario S2). The LCA employed openLCA v.1.8.0 software, using CML 2 baseline 2000 and ReCiPe Midpoint (H) methodologies, with 1 kJ of produced gas as the functional unit. The results revealed distinct performance trends for the two processes within the system. $bioH_2$ production in the first bioreactor achieved a positive energy balance, with scenario S1 yielding 67.1 kJ and an energy ratio of 1.74, while scenario S2 achieved an improved energy net of 122 kJ and an energy ratio of 2.64. This indicates that $bioH_2$ production can generate more energy than it consumes, making it a sustainable standalone process. Conversely, the methanogenesis process in the second bioreactor for biogas production demonstrated a negative energy balance, with scenario S1 producing -176 kJ and S2 producing -177 kJ, corresponding to energy ratios of 0.03 and 0.02, respectively. Despite these limitations, the overall energy performance of the two-stage system was better than that of conventional anaerobic digestion (scenario S3), with scenario S2 reducing the net energy deficit to -55.0 kJ compared to -109 kJ in S1. Environmental impact analysis revealed that the biogas production process had higher positive contributions across all analyzed environmental categories. This outcome is attributed to the method of impact calculation based on the functional unit and the higher energy production of the $bioH_2$ system. Additionally, energy-intensive components, such as the foam recirculation and temperature control mechanisms of the methanogenic reactor (second bioreactor), were identified as major contributors to energy consumption. Optimizing these components could significantly enhance the system's energy efficiency and environmental performance. The findings suggest that, while the current laboratory-scale configuration of the two-stage anaerobic bioreactor is not energetically balanced, it holds significant potential for bioenergy production. The $bioH_2$ production process proved particularly promising, capable of achieving energy sustainability independently. In contrast, the methanogenesis stage requires substantial optimization to improve its energy performance. The environmental benefits associated with both production stages underline the potential of the proposed system as a sustainable alternative for waste-to-bioenergy biotechnologies. Future efforts should focus on scaling up the system to the pilot level, where process efficiencies are expected to improve. Additionally, utilizing the organic content in the liquid outflow from the dark fermentation stage for obtaining other products, such as polyhydroxyalkanoates could enhance overall sustainability. In conclusion, while the proposed configuration is not yet fully optimized due to its small scale, it represents a step forward in sustainable bioenergy production, offering environmental and energy advantages over conventional anaerobic digestion processes devoted to biogas production alone.

Keywords

Biogas; $bioH_2$; Two-stage bioreactor; Life Cycle Assessment; Energy balance.

ALKALINE EXTRACTION OF FERULIC ACID FROM WHEAT BRAN – PROCESS OPTIMIZATION AND GENERAL YIELD CONSIDERATIONS

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ABSTRACT

Wheat plays a vital role in the EU economy, primarily as a key resource for food production, while its by-products offer significant potential as feedstocks for biorefinery development. Worldwide wheat production was 800 Mt/year in 2023 (according to FAOSTAT, www.faostat.org) and bran was about 20% of the plant total weight. This by-product is mainly used as a feed supplement, while its applications in the food sector or in biorefineries still play minor roles. However, there is great interest in innovative strategies for its valorization through transformation into added-value biomolecules. Of particular interest is the possibility to recover compounds that can be exploited as building block chemicals or as precursors for high-polymerized substances, such as new bio-materials. Ferulic acid (FA), a hydroxycinnamic acid, seems to be the most promising wheat bran component for such implementations. FA has well known healthy properties, it can be converted into bio-vanillin, and it can be used as a building block for polymerization to obtain bio-plastics or as an additive in polymers to provide biological properties. FA is the major phenolic component of wheat bran, and is present in free and, up to 80–90 %, in bound insoluble form linked to cell wall polysaccharides or to lignin. Several protocols have been assayed for FA recovery including specific enzymatic extraction, but alkaline hydrolysis is generally considered the best method, to the point that it is usually used as a reference to evaluate the yield of other processes. In other words, alkaline extraction is generally considered capable of extracting the FA present in wheat or bran reaching 100% of the yield. The present study demonstrated that even current alkaline hydrolysis of wheat bran can be further optimized and its FA extraction yield increased. Starting from a standard protocol (1:20 solid/liquid ratio, 2M NaOH, 30°C, 2 hours, 150 rpm shaking), the following process parameters were modified in different lab trials: possible pre-treatments, solid/liquid ratio, NaOH concentration, incubation time and temperature. The best protocol was also up-scaled in pilot plant and validated. The resulting FA yields were different depending on the scale. The results of this study can be useful for future valorization of wheat bran and exported to other similar agro-industrial by-products. Moreover, these results open to the reconsideration of how the total content of FA in wheat (or more generally of extractable phytochemicals from plants) is evaluated. Furthermore, they suggest that expressing the yield in % may give rise to overestimates, while it seems to be more correct to express it respect to feedstock weight (for example mgFA/kg bran).

Keywords

Alkaline hydrolysis, Extraction yield, Ferulic acid, Wheat bran.

MANAGEMENT OF PERSISTENT ORGANIC POLLUTANTS IN WASTE FROM FUEL STATIONS

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ABSTRACT

Fuel stations are multifaceted facilities that extend beyond the conventional role of providing fuel for vehicles. Over time, they have evolved into complex establishments offering a variety of complementary services aimed at meeting diverse customer needs. It is common practice for these establishments to provide additional facilities such as car washes and vehicle repair and maintenance services. These activities result in the generation of a wide variety of waste types. The proper identification, categorization, and management of such waste are essential not only for operational efficiency but also for ensuring compliance with environmental protection standards. The waste produced at fuel stations encompasses several categories, including used oils and solvents, sludge from oil/water separators, absorbents, filter materials (including oil filters not otherwise specified), cleaning cloths, and protective clothing. Many of these materials may be contaminated with hazardous substances, particularly Persistent Organic Pollutants (POPs). POPs are chemical substances characterized by their long-term persistence in the environment, their potential to bioaccumulate in living organisms, and their ability to cause adverse effects on human health and ecosystems. Due to their chemical stability, these substances can remain in the environment for extended periods and may be transported across international boundaries through air currents, water flow, and the migration of species, far from their original source of release. The primary objective of the present research is to identify and quantify the concentration of POPs in the waste generated by fuel stations and compare the results with the legal limits established by European regulations. Specifically, the research focuses on Regulation (EU) 2019/1021, as amended by Regulation (EU) 2022/2400, which provides detailed guidelines for the management of waste contaminated with POPs. Adhering to these regulations is critical to ensuring legal compliance and fostering environmental sustainability. In addition to quantifying POPs concentration, this study also emphasizes the importance of implementing good management practices for waste contaminated with these hazardous chemicals. Such practices are designed to ensure that POP content in waste is either destroyed or irreversibly transformed. The identification, separation, and proper disposal of waste containing POPs at its source are of paramount importance. This proactive approach not only reduces the likelihood of environmental contamination but also helps limit the dispersal of hazardous substances into water, air, and soil. By prioritizing these measures, fuel stations can play a significant role in protecting public health and contributing to global efforts aimed at reducing the environmental and health impacts of POPs. Effective waste management practices not only ensure regulatory compliance but also reinforce the commitment of such establishments to environmental stewardship and sustainability.

Keywords

Persistent Organic Pollutants, waste management, sustainability, fuel stations, environmental legislation.

IDENTIFICATION AND ASSESSMENT OF THE ECOTOXICOLOGICAL RISK OF MICROPLASTICS ACCUMULATED IN THE BOTTOM SEDIMENTS OF A WATER RESERVOIR

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ABSTRACT

Small dam reservoirs perform a variety of functions ranging from flood control to water supply for drinking or agricultural purposes. Unfortunately, experience shows that in addition to water retention, such facilities also determine the processes of retention as well as deposition not only of sediments suspended in their water, but also of other co-occurring pollutants (ncluding plastic waste, i.e. microplastics (MP)). Moreover, it has been shown so far that MPs can have harmful (and even carcinogenic) effects on organisms. Once introduced into the environment, MP remain in it for tens or even thousands of years. As a consequence, this MP is constantly creating new global challenges for sustainable water resources management. At present, there is a gap in knowledge about the occurrence and threat of MP in terrestrial ecosystems, and this paper may provide a missing link in this regard to some extent. This paper presents the results of a study on the identification of microplastics (MPs) and the assessment of the ecotoxicological risk resulting from their presence in the studied environmental component. For this purpose, bottom sediment samples were collected from a small water reservoir located on the Crișul Repede River in Bihor County (Romania). Bottom sediment samples were taken from two research stations located in the littoral zone of the reservoir (in the inflow zone and in the near-dam zone), and a third station located just downstream of the dam. A novel (author's) method based on density separation of MP was used to extract MP from the bottom sediment matrix. The MPs thus extracted were then identified (both quantitatively and qualitatively) using the Laser Direct Infrared (LDIR) method. The LDIR method makes it possible to precisely determine the type as well as the size of MP, based mainly on the characteristic infrared absorption properties of polymeric microparticles. Generally, the occurrence of commonly used plastics in industry as well as in households was identified in the studied material. It was observed, the occurrence of spatial variability in MP abundance, polymer diversity as well as particle size. In general, these observations indicate that MPs not only have the ability to accumulate in bottom sediments, but also that a certain portion of them can be transported onward with the river current. Moreover, the calculated PHI (Polymer Hazard Index) suggests that the identified MPs contained in the bottom sediments of the studied reservoir have a high ecotoxicological potential.

Keywords

microplastics waste, polymer accumulation, water reservoirs, ecotoxicological risk, LDIR spectroscopy.

HYDROTHERMAL CARBONIZATION OF PINEAPPLE STUBBLE WASTE: EFFECT OF INITIAL BIOMASS PROPERTIES ON THE HEATING VALUE AND ENERGY YIELD OF THE RESULTING HYDROCHAR

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ABSTRACT

The growing global demand for energy, particularly in the form of fuels, highlights the urgent need to explore alternative sustainable energy sources that can reduce our dependence on fossil resources and mitigate environmental impacts. One promising alternative is to produce valuable energy materials from the large volumes of biomass waste generated by agroindustries worldwide; however, poor waste management practices present a significant environmental challenge. In Costa Rica, as in many other tropical countries, circular economy strategies actively promote the utilization of biomass waste to enhance economic competitiveness and environmental sustainability. One of the most promising biomass sources is pineapple waste (stubble), which, despite its abundance, is often underutilized. The conversion of these stubble wastes—mainly leaves and stems—into solid fuels through hydrothermal carbonization offers an innovative solution for waste management and energy production. This process can efficiently transform wet biomass into high-energy hydrochar, contributing to further diversifying the country's renewable energy matrix and optimizing the use of local resources. Despite the growing interest in hydrothermal carbonization in recent years, particularly for its ability to work with wet biomass, the application of this process to pineapple stubble wastes remains underexplored. Moreover, little research has addressed the impact of the initial conditions (properties) of biomass waste on the quality and quantity of the final hydrochar. Factors such as the initial moisture content, particle size, and particularly the "freshness" of the biomass—whether it has been recently cut or has rested for several days— are variables that, due to the nature of the crop, can easily vary and significantly impact the characteristics of the resulting hydrochar. For this reason, this research aims to assess the effect of the initial condition of the pineapple stubble waste on the solid-fuel properties of the hydrochar obtained by the hydrothermal carbonization process. For this, a randomized complete block design was used to evaluate experimental variables at different levels. The experimental variables included: (1) the initial moisture content of the biomass at three levels: original moisture, 50% of its initial moisture, and completely dried biomass; (2) the state of the biomass at two levels: freshly collected and cut several days before; and (3) the particle size obtained using different types of mills at four levels: small-size knife mill (GM 200, Retsch), medium-size knife mill (GM 300, Retsch), cutting mill (SM 400 XL, Retsch) and chipper (GTS 1300c, GTM Professional). Pineapple stubble wastes were washed with deionized water to remove debris. Then, hydrothermal carbonization was carried out in a high-pressure reactor (BR-200, Berghof) using ground biomass mixed with deionized water in a 1:20 ratio. The reactor temperature was increased at a rate of 5 °C/min until reaching the reaction temperature of 200 °C, which was maintained for 1 hour. Subsequently, the solid product was subjected to vacuum filtration. The resulting hydrochar was dried in an oven at 85 °C for 12 hours. The characterization of the hydrochar included determining its higher heating value (HHV) using a bomb calorimeter (6772 Calorimetric Thermometer, Parr Instrument Company), as well as analyzing the ash content, volatile matter, and elemental composition (carbon, hydrogen, oxygen, nitrogen, and sulfur). The hydrochar production and energy yields were calculated. It was found that there are no significant differences in the hydrochar production or energy yields with respect to any of the three analyzed variables. However, significantly higher combustion heat values were observed for fresh pineapple residues, as well as for the wet and dry samples, with values ranging from 19.6 MJ/kg to 24.0 MJ/kg. In conclusion, hydrochars obtained from pineapple stubble wastes show high potential as solid fuels, as the obtained heats of combustion allow them to be classified as high calorific value biomass. Also, it was concluded that the initial condition of the pineapple stubble wastes does not significantly affect the energy yield of the obtained hydrochar. All these results support the viability of hydrochar to contribute to the diversification of the renewable energy matrix, which is in line with national strategies for waste utilization and sustainability.

Keywords

Sustainable energy, Biomass waste management, Pineapple stubble waste, Hydrothermal carbonization, Hydrochar production, Solid fuels

ENERGY OPTIMISATION OF ELECTROCHEMICAL TREATMENT OF TEXTILE WASTEWATER

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ABSTRACT

The textile industry is one of the most water-intensive sectors worldwide, with nearly all the water used during production processes discharged as wastewater. This intensive water usage poses a significant challenge, as water scarcity is an increasingly critical issue. The reuse of treated wastewater has been highlighted as an important measure to a more efficient resource economy. Aiming to achieve the quality required for wastewater reuse, innovative and sustainable treatment technologies have been developed, with electrochemical oxidation (EO) emerging as a promising solution, especially when boron-doped diamond (BDD) anodes are used. EO with BDD anode is very effective in removing organic pollutants from wastewater, enabling the production of highly reactive hydroxyl radicals, which unselectively promote the mineralization of a wide range of organic pollutants. Nonetheless, because the electron is the main reagent in EO, the energy consumption involved in the process can be an obstacle to its large-scale application, thus being required the optimisation of the current efficiency to reduce the operational costs. The present study focused on the energy optimisation of EO treatment of textile wastewater for reuse purposes. As textile wastewater is a mixture of streams resulting from different processes, streams separation was considered to increase their treatability and reuse options. Wastewaters originated from the dyeing process (dyeing wastewater, with an initial chemical oxygen demand (COD) of 0.9 ± 0.1 g L^{-1}), and from the washing process (washing wastewater, with an initial COD of 0.5 ± 0.1 g L^{-1}) were evaluated. The treatment was performed in a laboratory-scale electrochemical cell, comprised of a BDD anode and a stainless-steel cathode with 225 cm^2 area each, working in batch mode with recirculation, using 3 L of wastewater. The influence of the applied current density on the performance of the electrochemical oxidation was investigated, being the current density decreased by steps along the experiments, through several current profiles, aiming to optimize the efficiency of the process. For the EO treatments performed at constant applied current density along the experiments, a decrease in the current efficiency was observed, reflected by an increase in the specific energy consumption (SEC) with treatment time. The decrease in the applied current density during the experiments led to a significant decrease in SEC. For the dyeing wastewater, a reduction in SEC from 66 to 18 kWh kg^{-1} COD was achieved by decreasing the applied current density during the treatment, without affecting the treatment time (24 h) or the COD removal (97%, final COD below 30 mg L^{-1}). Regarding the washing wastewater, the reduction in SEC was from 340 to 106 kWh kg^{-1}_{COD}. These higher SEC values compared to those from dyeing wastewater are mainly due to the lower electrical conductivity and COD of the washing wastewater. Besides the decrease in SEC, the decrease in the applied current density during the experiments led to a reduction in the concentration of perchlorate ions formed. Alongside high COD removal, high mineralisation degree of the organic compounds and complete colour removal were attained for both wastewaters evaluated. These findings disclose the potential of electrochemical oxidation for textile wastewater treatment and reuse.

Keywords

Electrooxidation; Boron-doped diamond anode; Dyeing effluents; Specific energy consumption.

SLATE WASTE INCORPORTION IN PASTE FORMULATIONS FOR 3D PRINTING BY EXTRUSION

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ABSTRACT

Incorrect waste disposal is a common occurrence in the slate extraction and processing sector. This leads to a series of negative environmental impacts, including soil degradation, water pollution and an increase in the number of landfill sites. Slate production in Portugal has seen a remarkable increase, from 52 million tons (2020) to 80 million tons (2021), demonstrating the significant growth of the extractive practice and its subsequent generation of waste. The analysis of the scenario reveals an opportunity for design intervention, with the aim of using this industrial waste, contributing to the mitigation of its environmental impacts. The aim of this work is to implement a practical strategy that outlines the process of developing the reuse of slate waste into 3D extrusion. It was found that up to 70% of this waste can be incorporated into the composition of a commercial white earthenware without a significant increase in its water content. The feasibility of adding other types of industrial waste, such as marble or granite dust, was also demonstrated. Different formulations were developed and tested to achieve a standard printable mixture composed by 30% slate powder and 70% white earthenware. Up to 30% of marble powder was incorporated in this mixture and the extrudability, buildability and printability, both in a manual extruder and in a 3D printer (Delta WASP 40100 clay), was evaluated. After extrusion, the samples obtained were fired at temperatures ranging from 950ºC to 1050ºC in cycles of 16h, revealing the same 6.4% shrinkage of the white earthenware. This result demonstrates that the incorporation of this waste does not affect the thermal cycle of this material. Material Driven Design (MDD) method was adopted to develop a new product: ceramic modules for vertical panels. The product design sought to explore the potential of slate, from its traditional applications to its use in contemporary contexts, such as 3D printing technology. This work not only reinvents slate as a sustainable material, but also demonstrates the potential of 3D printing as a tool for design and environmental preservation.

Keywords

Design, Slate dust, 3D printing, Ceramic, Extrusion

LEACHING BEHAVIOR AND CHEMICAL COMPATIBILITY OF INDUSTRIAL BY-PRODUCTS: SUSTAINABLE LINERS FOR WASTE CONTAINMENT SYSTEMS

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ABSTRACT

The valorization of industrial by-products as geomaterials presents a transformative pathway for sustainable waste management and environmental protection. This study investigates the leaching potential of industrial by-products—water treatment sludge (WTS), vegetal biomass ash (VBA), granitic mining waste (GMW), and blast furnace slag (BFS)—when used as components in engineered liner systems for waste containment facilities. With global waste generation expected to surge by 70% by 2050, recycling industrial by-products into functional materials aligns with the principles of the circular economy and supports the United Nations' Sustainable Development Goals Through comprehensive laboratory testing, the study evaluates the leaching behavior of these byproducts under various environmental conditions to ensure compliance with environmental standards. Key assessments include chemical composition, heavy metal mobility, pH stability, and interaction with surrounding soils. Results reveal that, when mixed with sandy soil in optimized ratios, these materials exhibit low leaching potential while maintaining critical hydraulic and mechanical properties. Specifically, the mixtures demonstrated hydraulic conductivity values suitable for liners (10^{-9} m/s) and effective chemical compatibility, ensuring long-term environmental protection. This research underscores the dual benefits of reducing industrial waste disposal and advancing the development of sustainable geomaterials for geotechnical engineering applications. By converting industrial by-products into reliable, low-leaching liners, this work contributes to sustainable waste recycling practices and supports resilient infrastructure development. The findings highlight an innovative approach to addressing global environmental challenges while promoting sustainable development through waste valorization.

Keywords

Sustainable Development; Waste Recycling; Circular Economy; Geoengineering; Environmental Protection; Industrial By-products.

BIO-BASED TEXTILE COATINGS DEVELOPED BY VALORIZATION OF TEXTILE WASTE AND INCORPORATION OF BACTERIAL CELLULOSE

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ABSTRACT

The Waste Framework Directive requires EU Member States to implement separate collection systems for textiles by January 2025. This directive aims to promote re-use, repair, and recycling as primary circular solutions for managing TW. Therefore, new solutions for TW valorisation are needed. Additionally, the use of fossil-based products in textile finishing processes, including coating, poses another environmental challenge. In this work, innovative bio-based coatings were developed by incorporating textile waste (TW) to confer colour and aesthetic properties, and bacterial cellulose (BC) as a sustainable alternative to fossil-based commercial polymers. A green and black fabrics were ground to 0.25 mm particle size. BC was produced by Kombucha strain under static culture, washed, bleached, and freeze-dried. The coating formulation was prepared by mixing 32 % (w/w) of a bio-based commercial polymer, 2 % (w/w) of a synthetic crosslinker and 1.6 % (w/w) of BC, varying the amount of TW incorporated. The coating formulations were applied on a cotton fabric by knife over roll coating process. The coated textiles were characterized by the colour coordinates (CIELAB) and evaluated regarding light fastness and durability during use. The developed coatings presented a soft touch, no breaks and excellent flexibility. The variation in the number of layers enabled the creation of coatings with different thicknesses and colour shades. For the coatings incorporating green TW, an increase in the negative value of the a* coordinate was detected with increasing thickness. For coatings containing black TW and mixture of green (3 g) and black TW (1.0 g), a significant decrease in the L* coordinate and an increase in K/S (colour strength) were observed as the number of applied layers increased, indicating the production of darker and more intense colour coatings. As expected, reducing the black TW incorporation from 1.0 g to 0.5 g, while keeping the green TW quantity constant, resulted in a less pronounced decrease in the L* coordinate and greater increase in the negative values of a* coordinate. This effect occurred because, with increasing thickness, the green TW progressively overshadowed the black TW. In the light stability test, despite the higher colour difference (ΔE) values and lower grey scale ratings, no visible differences were noted between the exposed and unexposed areas, and no significant changes in K/S values were detected. Regarding durability during use, good results were achieved for all coatings, with grey-scale values exceeding 3-4 and a ΔE below 3, except in some coatings with a thickness of 0.4 mm. The best results were reached with the mixture of 3 g green TW and 1 g black TW at a thickness of 0.4 mm, attaining a grey-scale rating of 4–5 in both light stability and durability during use. Mechanical tests for abrasion resistance and tensile strength are being performed. The developed work demonstrates an innovative approach in which the addiction of BC and TW allowed reduce the synthetic components of a conventional coating. A new approach to add colour to coatings without adding synthetic pigments was also validated.

Keywords

Textile circular economy, textile waste, bacterial cellulose, coatings

ALMOND AND WALNUT SHELLS AS SUSTAINABLE SOIL AMENDMENTS: PHYSICAL INSIGHTS FOR GEOTECHNICAL APPLICATIONS

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ABSTRACT

The use of agricultural waste as soil amendments aligns with global efforts to promote sustainable development and circular economy principles. This study investigates the potential of almond and walnut shells as eco-friendly soil amendments, focusing on their physical and mechanical characteristics, including density, plasticity, compaction, and consolidation behavior. By incorporating these biodegradable by-products into soil systems, the research seeks to evaluate their chemical compatibility with natural soils and their suitability for enhancing geotechnical performance. Laboratory analyses were conducted to determine the shells' specific gravity, Atterberg limits, Proctor compaction parameters (optimum moisture content and maximum dry density), and oedometric consolidation properties under various stress conditions. Results indicate that almond and walnut shells exhibit very low density, making them suitable for reducing soil weight in specific applications. Additionally, their favorable compaction and plasticity characteristics contribute to improved soil workability. Consolidation tests reveal that these amendments enhance the compressibility and permeability of treated soils, suggesting potential applications in agricultural and environmental engineering contexts. The findings highlight the dual benefits of reducing agricultural waste disposal and improving soil properties, contributing to the United Nations' Sustainable Development Goals. By showcasing the viability of almond and walnut shells as sustainable soil amendments, this study provides a novel approach to integrating agricultural by-products into geotechnical engineering practices, supporting both environmental protection and infrastructure resilience.

Keywords

Sustainable Development; Waste Recycling; Circular Economy; Geoengineering; Environmental Protection; Agriculture By-products.

RECYCLING PRACTISES IN COLOMBIAN BANANA INDUSTRIES: THE ECOLÓGICA RECONECTANDO CASE STUDY

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ABSTRACT

Waste management is still a challenging issue in Latin American countries. Recycling practices are not structured at national level, and they are mostly run by private initiatives; waste collection generally relied in street pickers, whose work is not properly regulated. *Ecológica Reconectan*do is a waste management social enterprise located in the territory of Carepa (Apartadò, Colombia). The recycling scheme of *Ecólogica* is innovative. The activities of *Ecológica* are many: to create a system of local selective collection of waste, to educate the population to conscious consumption and recycling, to provide environmental and language education to the young generations of the communities, and to give stable and dignified employment to street pickers. The background is the North Colombian tropical territory, strictly linked to the banana industry, in a complex and deep-rooted mechanism. For this reason, *Ecólogica* collaborates with banana companies, which participate in the collection and invest part of the funds allocated by Fair Trade for projects with communities. At the moment there are no examples in literature of banana farm waste composition analysis. In this work, the on-going project of *Ecólogica* is described and the results of the on-site analysis on waste composition of banana farms are presented. The objective was to identify the material waste streams and the repartition according to the recycling equipment supplied by *Ecólogica*. The information derived from the work will improve the quality of the collection scheme and will set a basis for future development.

Keywords

Waste management, Recycling scheme, Waste composition analysis, Banana industry, Latin American countries

TERNARY BLENDS OF WHITE CEMENT, LIMESTONE AND WASTE GLASS POWDER FOR 3D CONCRETE PRINTING

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ABSTRACT

The development of cementitious materials for 3D printing (3DPC) still presents many material and structural challenges, as well as ecological fragilities. 3DPC formulations require a high amount of cement and SCM to achieve rheological properties that meet printing requirements. Therefore, it is imperative to study alternative materials, (partial) substitutes for Portland cement, to reduce the carbon footprint of 3DPC, particularly in the long-term vision. The use of locally available SCM reduces the costs and carbon dioxide (CO2) emissions associated with the production of 3DPC, while at the same time adding value to local and abundant industrial waste or by-products.

As part of the DigiCrete Project, this study aimed to study potential ternary mixtures for 3D printing using national materials, including waste glass powder. At the first stage, paste, fresh state, hardening, mechanical properties, and carbon efficiency were studied. Using a centred factorial plan, the influence of the main variables of the mixture on the properties of 3DPC was evaluated, and the main effects of the mixture factors on the responses and possible interactions were identified. This knowledge can facilitate protocols for optimizing 3DPC compositions. The potential and optimized mixtures at the paste level went on to be studied at the mortar level. The results showed that it is possible to correlate results from traditional tests (spreading, slumping) in the study of mortars and rheological parameters from the study of pastes and establish a printable mortar. Finally, it was possible to conclude that using local materials, including the industrial waste studied, is viable for 3D printing of cementitious materials.

Keywords

3D concrete printing, waste valorization, glass powder, mix design, response surface.

PALLADIUM RECYCLING FROM SPENT CATALYSTS BY SOLVENT EXTRACTION

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ABSTRACT

The implementation of circular economy is a fundamental approach to guarantee the sustainable survival of living species on Earth in the coming years. Therefore, recycling actions developed to recover critical materials – those that are decisive for the preservation of our living standards – should always be considered, for the health of all living organisms and safeguarding of Earth resources.

Since 2011, platinum-group metals (PGMs) have been considered by the European Union as critical materials, due to their high economic value, difficult replacement in most technological applications, and their scarcity in mineral resources. Palladium, together with platinum, is the most demanded of the PGMs, being the inclusion in automotive catalysts (an essential device for minimizing the emission of toxic exhaust gases from combustion engines) its most relevant application.

The objective of this communication is to illustrate the main contributions of the author's research group, in activity in this area for almost twenty years, to find viable and technologically interesting approaches to efficiently and selectively recover palladium from leachates coming from the hydrometallurgical treatment of spent automotive and petrochemical catalysts by solvent extraction (SX). With this purpose, Pd(II) recovery has been investigated, through the implementation of SX schemes involving the most promising organic compounds developed, namely a thiodiglycolamide and, more recently, a thiodipropanamide derivative. The overall results obtained point out to excellent Pd(II) extraction performances shown by all derivatives from HCl solutions up to 6 mol L-1, the metal ion being quantitatively stripped from the loaded organic phases by acidic thiourea aqueous solutions. All compounds exhibit very good Pd(II) loading profiles and promising behaviors for a suitable reutilization in successive extraction-stripping cycles. The data achieved concerning the selective Pd(II) recovery from model and real leaching solutions of spent catalysts are similarly encouraging.

The main drawback is the successive accumulation of aluminum in all solvents; although Pd(II) recovery is not affected when a small number of extraction-stripping stages are carried out, it can be anticipated that aluminum poisoning will disturb the performance and compromise the technological interest of the developed SX systems. A promising commercial extractant has also been tested under similar conditions [5], but it showed comparable disadvantages.

Keywords

Palladium; solvent extraction; hydrometallurgy; recycling; spent catalysts.

ELECTRODIALYTIC TREATMENT OF INCINERATED SEWAGE SLUDGE ASH (ISSA) FOR HEAVY METAL RECOVERY: A SUSTAINABLE APPROACH TO RESOURCE RECOVERY

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ABSTRACT

The treatment of incinerated sewage sludge ash (ISSA) is significant for the removal of heavy metals and pathogen material from the ash, protecting the exposed environment when disposal occurs. This research aimed at recovering heavy metals from ISSA by investigating the effects of pH, recovery time and current intensity as an effective and sustainable approach to resource recovery. The pH of the catholyte kept rising due to the migration of the positive ions hence it was adjusted to the required pH of between 1 and 2 because a lower pH improves the solubility of metal ions available in the dissolved sewage sludge ash located in the middle chamber, thereby encouraging their migration from the ash. Conductivity at the catholyte was found to reach values between 11.76 and 12.55 mS after day 4, which is higher, indicating a drop in the flow of electrons. Raw ISSA sample and treated sample collected after the experiment were characterized to outline changes in elemental composition and chemical structures of both samples. Key elements such as Fe3+, Zn2+, Cr3+, Ni2+ and Cu2+ which are expected to migrate to the cathode were found to be present in the X-ray Fluorescence analysis. Solutions from the cell were collected and taken for analysis using the Inductively coupled plasma optical emission spectroscopy (ICP-OES). Sulfuric acid (H2SO4) interactions released metal ions such as Zn2+, Cu2+, Fe3+ and Cr3+ from ISSA more significantly and higher than nitric acid (HNO3) where the percentage recovery of Fe, Zn, Cr, and Cu when sulfuric acid was used increased from 3.87, 0.84, 5.53 and 0.27% to 9.25, 27.12, 0.86 and 11.03% in the catholyte solutions respectively. Maintaining current intensity between 75 and 100 mA improves recovery of metals by increasing the flow of ions within the cell. It is recommended that further tests be conducted over an extended period of days.

Keywords

Electrodialytic Treatment; Electrolysis; Heavy Metals; Resource Recovery; Sewage Sludge Incineration; Sewage Sludge Ash

ELECTRODIALYTIC TREATMENT OF INCINERATED MUNICIPALITY SOLID WASTE (IMSW) FOR RESOURCE RECOVERY

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ABSTRACT

The production of municipal solid waste (MSW) is increasing rapidly as a result of population growth and the disposal of solid products creates serious environmental and health issues as it consists of leachable heavy metals. Incineration has emerged as a common method for waste management, resulting in the generation of fly ash (FA) as a by-product. This study aimed to investigate the application of electrodialysis (ED) to remove heavy metals from incinerated municipal solid waste fly ash (IMSW-FA) thus addressing its environmental hazards. The electrodialysis treatment effect on IMSW-FA was evaluated through a 7-day run. Parameters such as pH, conductivity, and current were monitored and recorded daily with the pH being adjusted to values between 1 and 2. The study also compared the efficiency of using nitric acid (HNO_3) and sulfuric acid (H_2SO_4) in adjusting the pH of the electrolytes during the treatment process on the recovery of heavy metals. The elemental composition of untreated and treated IMSW-FA was analyzed using X-Ray Fluorescence Spectrometer (Rigaku Primus II) (XRF). High concentrations of nickel (Ni), copper (Cu) and Zinc (Zn) were detected in the untreated IMSW-FA and a further reduction in concentrations of these metals was noted in the treated IMSW-FA. Moreover, the concentrations of heavy metals in the treated wastewater were determined by the Inductively coupled plasma optical emission spectroscopy (ICP-OES). The results showed that ED treatment significantly reduced the concentration of heavy metals mainly Zinc (Zn) and copper (Cu). The results further revealed that the use of nitric acid (HNO_3) to adjust the pH of electrolyte solutions was more effective than sulfuric acid (H_2SO_4) on the recovery of heavy metals. Removing heavy metals from IMSW-FA using ED treatment was successful indicating high potential of ED treatment to reduce heavy metals from IMSW-FA thus promoting sustainable waste management practices.

Keywords

Electrodialysis; Environment; Heavy metals; Incineration; Municipal Solid Waste

SUSTAINABLE REMOVAL OF BORON FROM AQUEOUS MEDIA USING CAROB KIBBLE WASTE MODIFIED BY CALCIUM CHLORIDE

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ABSTRACT

Boron contamination in wastewater poses a significant environmental concern due to its toxicity at high concentrations, adversely impacting aquatic ecosystems, agriculture, and human health. Industries such as glass and ceramics manufacturing, detergents, fertilizers, and pharmaceuticals contribute to boron contamination of water sources, necessitating effective remediation strategies. Recent advancements in adsorbent materials, including modified biosorbents, may offer environmentally friendly and efficient solutions for boron removal. This study evaluates the adsorption efficiency of modified carob kibble, a low-cost, waste-derived biosorbent characterized by surface functional groups such as carboxyl (-COOH) and hydroxyl (-OH), which enable interactions with positively charged ions. To enhance its adsorption properties, the carob kibble was modified using calcium chloride ($CaCl_2$) at concentrations of 1M and 2M. Calcium (Ca^{2+}), a positively charged ion abundant in industrial residues from quarries, limestone mining, cement production, flue gas desulfurization, and soda ash production, serves as a sustainable and readily available resource for biosorbent modification. Experimental conditions involved exposing 50 mg/L of modified and non-modified carob kibble biomass (particle size: 0.025–0.106 mm) to boric acid (H_3BO_3) solutions at an alkaline pH of 11.5. At this pH, H_3BO_3 undergoes deprotonation, forming negatively charged borate ions ($B(OH)_4^-$), which dominate above pH 9. Adsorption assays were conducted using an initial boron concentration of 25 mg/L, simulating concentrations within the typical range found in industrial wastewater. The experiments were carried out for 5 h at 130 rpm at room temperature, with boron analysis performed using Microwave Plasma-Atomic Emission Spectroscopy (MP-AES). The results demonstrated a significant improvement in boron removal with 2M $CaCl_2$-modified carob kibble, achieving a removal efficiency of 92.2 ± 0.72% and an equilibrium adsorption capacity (qe) of 0.457 ± 0.004 mg/g. In contrast, non-modified carob kibble achieved a lower removal efficiency of 64.03 ± 0.57% and a qe of 0.317 ± 0.003 mg/g. Kinetic studies revealed that the adsorption process follows a pseudo-second-order reaction model, while equilibrium data are best described by the Sips isotherm. These findings highlight the potential of carob kibble, modified with environmentally abundant and low-cost materials like $CaCl_2$, as a promising biosorbent for boron removal from wastewater. This approach highlights its scalability and relevance for industrial-scale applications, contributing to sustainable water treatment solutions that align with circular economy principles.

Keywords

Sustainable Remediation, Adsorption, Boron, Modified carob kibbles waste, Calcium chloride

STRATEGIC PATHWAYS FOR DEVELOPING ECO-EFFICIENT GYPSUM PLASTERS FROM RECYCLED MATERIALS

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ABSTRACT

The G2E project addresses the critical challenge of integrating circular economy principles into the construction sector by proposing a strategic framework for developing eco-efficient gypsum plasters using recycled plasterboard waste. This initiative aligns with the European Green Deal's decarbonisation and resource efficiency goals. The project's innovative approach focuses on valorising gypsum and paper resulting from gypsum board waste through their incorporation into sustainable building materials, thereby reducing landfill dependency and the consumption of natural resources. Key objectives include optimising recycling processes for gypsum and cellulose fibres, adapting industrial equipment to integrate recycled materials efficiently, and designing formulations that meet performance and sustainability criteria. This work presents a methodological and strategic approach derived from the G2E project. A comprehensive framework was developed to guide the incorporation of recycled gypsum and paper waste into new plaster formulations, emphasising eco-design and lifecycle thinking from the early stages of product development. The methodology includes defining technical specifications for waste valorisation, adapting industrial processes to accommodate circular practices, and conducting preliminary assessments of environmental impacts through Life Cycle Assessment. The discussion on the main challenges to enforcing the methodology and how to tackle them is presented. The establishment of new value chains by fostering collaboration between the construction and waste management sectors and the development of eco-innovative materials for building envelopes, implementing production models that embrace circularity principles, are two relevant paths of the developed framework. This includes valorising by-products, reducing energy consumption by lowering calcination needs, and improving the durability of new coatings. These new materials and by-products will add significant value to final products, aligning with the pursuit of high-value solutions and creating new value chains and product lines. Compared to other binders, gypsum's lower embedded carbon positions it as an ideal material for achieving Europe's 2050 climate neutrality goals and contributes to the Renovation Wave for buildings. This work highlights the transformative potential of eco-efficient gypsum plasters in achieving more sustainable and resilient built environments. Focusing on methodology and long-term impacts contributes to advancing sustainable waste valorisation technologies and supports the transition towards a low-carbon construction industry.

Keywords

Circular Economy, Waste Valorisation, Sustainable Construction, Recycled Gypsum, Eco-Efficient Materials.

INTEGRATED CHARACTERIZATION OF A HIGH-PERFORMANCE CONCRETE WITH GLASS POWDER INCORPORATION

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ABSTRACT

The construction industry faces increasing pressure to develop sustainable materials that minimize environmental impact while maintaining high performance. High-performance concrete (HPC) is a technologically advanced material with recognized mechanical and durability benefits but raises sustainability concerns. These materials not only offer a more sustainable alternative but also provide potential improvements in durability, making them suitable for applications in building façades. This study presents a multi-level characterization of an HPC developed at FEUP, incorporating a massive partial replacement of Portland cement with limestone filler and waste glass powder (GP) as supplementary cementitious materials (SCMs). As such, several engineering properties of the HPC were assessed, including compressive strength, electrical resistivity, reflectance, colour, thermal conductivity, emissivity, water permeability, moisture content, and resistance to hard body impact. The results showed that HPC achieved a compressive strength exceeding 90 MPa after 28 days. The electrical resistivity increased over time, reaching 116 Ω.m at 28 days, indicating a very compact matrix with a refined pore structure due to the combined effect of hydraulic and pozzolanic reactions. Surface reflectance values corroborate with light-coloured materials, while thermal conductivity was slightly higher than conventional dry concrete due to moisture content. The material demonstrated high emissivity, possibly attributed to GP's presence in the mix design, indicating the capacity to emit solar radiation. Moisture content variations between saturation and 80% humidity were minimal, further suggesting a dense microstructure. Water absorption tests confirmed the material's near-impermeability, indicating stability under distinct environmental conditions. Using locally sourced SCMs in this HPC improves sustainability by avoiding landfill use and reducing embodied CO2 emissions through lower cement consumption. Transforming waste into value-added by-products benefits local concrete producers and contributes to building decarbonization. This research highlights the viability of producing sustainable HPC with ternary blends of limestone filler and glass powder, providing a promising pathway for achieving high performance while addressing environmental challenges in the construction industry.

Keywords

Eco-efficient concrete, High-performance concrete (HPC), Mechanical strength, Hygrothermal performance.

PUBLIC PERCEPTION AND PARTICIPATION IN THE SELECTIVE COLLECTION OF BIOWASTE: A CASE STUDY IN GUARDA, PORTUGAL

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ABSTRACT

The Waste Framework Directive (Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018, amending Directive 2008/98/EC on waste), established January 1, 2024, as the starting date for mandatory biowaste collection, which accelerated the development of public policies for biowaste management. Based on this framework, Portugal, through Decree-Law No. 102- D/2020 of December 10, advanced and implemented a biowaste collection, treatment and management system at the municipal level. In this context, after a year of operation, it is interesting to analyze the sensitivity, adherence, motivation and limitations that the residents felt throughout this period. Therefore, the present study aims to evaluate the selective collection system for biowaste implemented in the parish of Guarda, Portugal, thus contributing to the improvement of sustainable waste management and promoting the adhesion of more citizens to the system. An observational, crosssectional, and analytical study was conducted, and a survey was developed and used as the data collection instrument about the target population. The survey was distributed through digital platforms between February 2024 and January 2025. The assessment included questions about the community's understanding of the biowaste concept, their awareness of the system implemented, levels of participation, satisfaction, and perceptions of its positive and negative aspects after one year of its implementation. The study uses statistical analysis of survey responses from the population of the parish of Guarda. The preliminary results of the ongoing survey indicate that the majority of the 173 respondents understand the meaning of biowaste, and everyone agrees that the selective collection of biowaste is important for the environment and, therefore, believes they should participate. Most participants (72.3%) pointed to the environmental and economic advantages of separating and recovering biowaste. However, gaps exist given that many participants (43.9%) remain unaware that the municipality has already implemented and is actively establishing a biowaste collection network, so they are not adequately segregating biowaste. Moreover, the majority (57.8%) believe that the infrastructure for selective biowaste collection in their area of residence or work is inadequate. As public awareness is critical for the success of these initiatives, enhancing communication with the population is crucial; the participants gave their opinions about the dissemination of information regarding the separation, collection, and recycling of biowaste, of which the dissemination on social networks stood out (92.5%) followed by the municipality's website (88.4%), information leaflets in the letterbox (72.8%) and information boards on public roads (72.3%).
Therefore, this study underscores the potential for improvement in selective biowaste collection systems through comprehensive public education and consistent communication. The municipality of Guarda can significantly enhance its recycling and sustainability practices by addressing the identified barriers, leveraging the observed strengths, and fostering greater acceptance and efficiency, which offers a hopeful and motivating prospect for the global environmental protection and waste reduction agenda.

Keywords
Biowaste, selective collection, recycling, sustainability, public participation, statistical analysis.

VALORIZATION OF *Carapa guianensis* FRUIT WASTE AS A SUSTAINABLE SOURCE OF NATURAL TEXTILE DYES

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ABSTRACT

Carapa guianensis Aubl., known as andiroba, is a native tropical forest tree, widely distributed throughout the Amazon and other regions of South and Central America. This species is of great ecological and economic importance and plays a crucial role in the livelihoods of Amazonian communities. While the oil extracted from andiroba seeds is known for its medicinal, and cosmetic properties, the fruit husks, which constitute a significant portion of biomass, are typically discarded as waste during processing. This underutilization represents a missed opportunity for sustainable biomass valorization.

The aim of this study was to evaluate the potential of andiroba fruit husk extract as a natural dye for textile dyeing and to promote its value as a sustainable alternative to synthetic dyes. To obtain the dye, the powder from the husks was subjected to a traditional solid-liquid extraction with water at 70°C. The resulting solution, after filtration, was used to dye textile samples of cotton (both, organic and with a pretreatment of cationization), wool, linen, and silk, in triplicate. After dyeing, the samples were washed in cold and hot water and exposed to natural light for one week, with half of the samples protected from light. The final evaluation of color fastness and stability was performed using the CIELAB color space, using the parameter ΔE^* to quantify the difference between sample colors. Values of ΔE^* greater than 2 indicate color differences noticeable to the human eye1. The dyed fabrics presented beige tones, with variations depending on the material. Exposure to natural light had a negligible effect on the color stability of all fabrics. Only cotton showed a slight perceptible change, while variations in other fabrics were virtually imperceptible. Compared to the control (undyed fabric), all fabrics exhibited different colors ($\Delta E^* > 7$). The cationized cotton samples showed the highest color difference ($\Delta E^* = 21.8 \pm 0.5$), significantly outperforming untreated cotton, wool, linen, and silk, which exhibited ΔE^* values ranging from 7.8 ± 0.8 to 11.7 ± 0.2. These results were obtained without the use of mordants, relying solely on the aqueous extract of andiroba husks as a natural dyeing agent.

The findings of this study demonstrate the potential of *C. guianensis* fruit husk, a widely available residue in the Amazon, as a source of durable and stable natural dye. By transforming plant residues into valuable resources, this research not only enhances the economic utility of andiroba by-products but also proposes a sustainable alternative to synthetic dyes. Such an approach contributes to reducing environmental impact and promoting the ecological and economic importance of this species within the Amazon region.

Keywords

Waste valorization; Andiroba; Textile dyeing; Sustainability

INCLINED PLANE SHEAR BEHAVIOUR OF AGGREGATE-GEOTEXTILE INTERFACES: INCINERATOR BOTTOM ASH *VS.* NATURAL AGGREGATE

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ABSTRACT

The high volume of waste generated globally poses significant environmental challenges. Incineration is a process normally used for the treatment of municipal solid waste, resulting in the formation of large quantities of incinerator bottom ash (IBA). IBA is mainly composed of non-combustible materials, such as mineral residues, glass, ceramics and metals, and is commonly deposited in landfills. Over the years, some recovery solutions have been studied for IBA. Examples include its use in cementitious materials, in the manufacture of concrete or in road construction. These uses of IBA mitigate the volume of waste sent to landfill and contribute to the preservation of natural resources by reducing the demand for natural materials. In some applications (for example, in road construction), IBA may come into contact with geosynthetics (polymeric materials used in civil engineering applications), such as geotextiles.

This work studies the shear behaviour at the interface between IBA and nonwoven geotextiles. For that purpose, inclined plane shear tests were conducted. The tests were carried out in a prototype equipment developed at the Faculty of Engineering of the University of Porto and followed the main guidelines of EN ISO 12957-2. The procedure adopted provided a controlled and reproducible environment to assess the shear characteristics of the IBA-geotextile interface. Two different nonwoven geotextiles (materials with different physical and mechanical properties) were tested. For comparison purposes, inclined plane shear tests with a natural aggregate (*tout-venant*, a well-graded untreated mixed aggregate) were carried out (natural aggregate-geotextile interface). The shear characteristics of the interfaces (IBA-geotextile and natural aggregate-geotextile) were evaluated under constant vertical stress (10 kPa) and for identical

aggregate conditions (degree of compaction and water content). The sliding mechanism of aggregates (IBA and *tout-venant*) over the geotextiles were examined and the friction angles at the interfaces were estimated. The results obtained for the IBA-geotextile interface were compared with the results found for the natural aggregate-geotextile interface.

Keywords

Incinerator bottom ash; geotextiles; shear behaviour; alternative aggregates; sustainable construction.

SEPARATION OF PLASTIC WASTE BY DISSOLUTION/PRECIPITATION PROCESS WITH GREEN SOLVENTS

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ABSTRACT

Plastic pollution is one of the biggest environmental challenges of the 21st century, causing potential damage to ecosystems and human health, with the increasing need to find solutions to minimize these impacts. According to the OECD, only 33 million tonnes (Mt), 9% of the 353 Mt of plastic waste, were recycled in 2019. Thus, international policies enhance research, innovation, and the development of plastic recycling processes. Given the EU's target of achieving a 55% recycling rate for plastic packaging by 2030, this study was conducted to identify suitable solvents for a dissolution/precipitation process aimed at recycling a mixture of plastic waste, including polyethylene (PE), polypropylene (PP) and polyethylene (PE) plastic waste. (PP), polyvinyl chloride (PVC), polyethylene terephthalate (PET), and polystyrene (PS). The selection of solvents must consider dissolution properties, low environmental impact, and the absence of harmful effects on health. In the first interaction 119 solvents were analysed for their ability to dissolve PE, PP, PVC, PET, and PS plastics based on Hansen method, which determines the three types of intermolecular interactions involved in solubility, which are polar solubility parameter (δP), dispersion solubility parameter (δD) and hydrogen bonded solubility parameter (δH). As a result of this analysis, 30 solvents suitable for dissolving the plastics under study were identified, and solvents from biorenewable sources were selected for laboratory testing in order to validate the dissolution conditions, namely temperatures and dissolution/precipitation time. The solvents tested in the laboratory were: Cyrene™ for PVC; Dimethyl isosorbide (DMI) for PET and PVC; Anisole for PET; d-Limonene for PE and PS; 2-Methyltetrahydrofuran for PS; Eucalyptol for PE and PS; Cumene (Isopropyl Benzene) for PE, PS and PP; 1,2,3,4-Tetrahydronaphthalene for PS; and p-cymene for PE and PS. To carry out the laboratory tests, plastics used in everyday life were used, which were heated with agitation in the selected solvents, until their dissolution was verified. In tests where sample dissolution was verified, the next procedure includes the recovery of the plastic, by cooling or adding an anti-solvent (such as water or alcohol). This work aims to i) validate the solvent selection methodology based on the Hansen method. In cases of dissolution, establish the optimal dissolution conditions (temperature and dissolution time) and the precipitation process for recovering the dissolved plastic; ii) identify the most suitable solvent, taking into account the optimal dissolution conditions and the lowest impact on the environment and human health; and iii) and propose a treatment sequence for effectively separating a mixture of plastics.

Keywords

Plastics wastes. Green solvents. Plastic recycling. Selective dissolution-precipitation.

LCA AND LCC OF TETRAHEDRITE-BASED THERMOELECTRIC DEVICES DEVELOPED WITHIN THE START PROJECT

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ABSTRACT

The START (Sustainable energy harvesting systems based on innovative mine waste recycling) project intends to use secondary raw materials (i.e. tetrahedrite) to develop thermoelectric generators (TEGs).
By capturing waste heat, which can be over 60% of the primary energy in manufacturing or heating processes, TEGs can directly convert temperature gradients into electricity, enabling green energy harvesting and thus clean energy sources. However, rare and toxic raw minerals (e.g. tellurium), geographically concentrated outside Europe, are generally used in TEGs production. These critical raw materials can be potentially substituted by waste sulphides of the tetrahedrite series ((Cu,Fe)12Sb4S13), extracted from deactivated mine dumps in Europe (with abundancy of deposits in the Iberian Peninsula). In fact, high-purity tetrahedrite has thermoelectric operational temperature similar to lead telluride (<550° C), with far lower toxicity and thus higher environmental sustainability.
In order to deliver TE devices with an optimized and sustainable system efficiency, life cycle assessment (LCA) and life cycle cost (LCC) analysis of this innovative tetrahedrite-based TEGs were also carried out and compared to traditionally (tellurite-based) TEGs. In this paper, we present the data associated to raw material extraction, mineral processing and TEGs production and assembly. Materials use (e.g. sulphite tetrahedrite, bismuth or lead tellurite, reagents, TEGs components, consumables, water, etc.) and energy consumption (in the mining, production or assembly phases) were adopted as input of the model. Furthermore, the effective and/or potential costs of the considered life cycle stages of the TEGs were determined in the LCC analysis.
Although some assumptions were introduced in the LCA-LCC models, inserting a certain degree of uncertainty, results showed that the adoption of tetrahedrite-based TEGs can reduce energy consumption, wastes and air emissions, when compared to tellurium-based TEGs. Energy harvesting through tetrahedrite-based thermoelectrics can thus have considerable potential for a) reducing the consumption of fossil fuels, b) preventing valuable resources ending up in mine tailings, c) reducing contamination and issues for human health and the environment (i.e. mining environmental liabilities), and d) delivering tellurium-free thermoelectric devices.
It is worth noting that mineral concentration and preparation (e.g. delamination, density separation, magnetic separation, drying), as well as leg production (e.g. powder technology, solidification, layer deposition, etc.) are necessary to obtain high-purity tetrahedrite, efficient legs and suitable TEGs, significantly increasing energy consumption and the use of chemical compounds. Potential costs for such processes show also that additional optimization steps will be necessary to improve the economic efficiency and circular economy of the produced tetrahedrite-based TE devices.
Further developments are ongoing to fully implement the LCA-LCC model, by considering also aspects related to use, repair and maintenance, and end-of-life (disposal or recycling).

Keywords

Tetrahedrite, Tailings, TEGs, Sustainability, LCA, LCC

LIFE CYCLE ASSESSMENT IN PROCESS DESIGN USING LASER-BASED MANUFACTURING TECHNOLOGIES

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ABSTRACT

The FLASH project (Flexible Laser-based manufacturing through precision photon distribution) aims to develop a multi-process laser system to shift the existing manufacturing paradigm (including cutting, drilling, welding, cladding and micro-machining, among others) by exploiting the benefits of laser processing and enabling flexible and customizable production. Among other benefits, the project intends to reduce energy consumption in comparison with traditional laser processes and allow for the replacement of traditional mechanical and chemical processes, requiring fewer consumables and generating less waste. In order to quantify these benefits in terms of environmental indicators, a tool will be developed to perform LCAs of the multiple individual processes that will be accessible using the FLASH machine. This tool will deliver a meaningful LCA of a processing strategy that combines multiple laser-based steps.

Five industrial use-cases were selected to demonstrate the FLASH machine in an operational environment, i.e. the manufacturing of the acetabular cup in orthopaedic hip implant systems, manufacturing of polycrystalline diamond micro drills and Cubic Boron Nitride (CBN) grinding wheels, manufacturing and assembly of the automotive cross car beam, and stripping and welding of copper hairpins. In these use cases, the FLASH laser processing replaces multiple resource and energy intensive process steps.

This paper presents the environmental data that was collected for the proposed FLASH laser technologies, and data for the current standard manufacturing technologies of each industrial use-case, to serve as benchmark for the new processes. The LCA approach is cradle-to-grave and includes all relevant processes and life cycle stages such as raw material extraction, manufacturing, use and end-of-life. Environmental indicators such as energy use, CO_2 emissions, water and resource consumption, and environmental ecotoxicity are used to quantify the changes introduced by the new laser processes, namely by reducing energy consumption, replacing consumables and chemical associated with conventional processes, and reducing the amount of waste that needs to be collected and safely treated.

The preliminary LCAs allow the definition of parameters for the development of the digital decision-making tool, which can be directly integrable with existing CAD programmes. Ultimately, this tool will assist industry operators in selecting optimal process chains and thus achieve the necessary product quality and minimize environmental impacts of manufacturing along the life cycle stages of the products.

Keywords

Life Cycle Assessment, Laser-based manufacturing, Mechanical process, Chemical process, Digital decision-making tool

STUDY OF IRC EXEMPTION IN THE SCOPE OF WASTE MANAGEMENT IN PORTUGAL

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ABSTRACT

This study examines the Corporate Income Tax (Portuguese acronym: IRC) exemption provided in Article 53 of the Tax Benefits Code (Portuguese acronym: EBF). It is aimed exclusively at entities managing integrated systems for managing specific waste flows, such as packaging, tyres, used oils and electronic equipment, batteries and accumulators, and end-of-life vehicles. Duly licensed under the General Waste Management Regime (Portuguese acronym: RGGR), these entities benefit from exempting results reinvested or intended for legally assigned purposes, promoting environmental sustainability and alignment with the Sustainable Development Goals (SDGs). The analysis is based on a normative approach, complemented by financial and operational data from the beneficiary entities between 2011 and 2022. Of the 542 tax benefits analyzed, 36 are classified as "CF.05" (environmental protection) within the scope of the classification used to identify the allocation of tax expenditure to the different functions of Public Administrations. Of these, 23 are intended to encourage the use of more sustainable vehicles (CF.05.3), 12 are aimed at forest management (CF.05.4), and only one is addressed to waste management (CF.05.1). In the total of 12 years analyzed, of 797,964 million euros in tax revenue collected, only 8% comes from the collection of IRC and only 0.02% of this percentage represents the amount granted by the exemption. Despite its limited financial impact, the measure was a strategic instrument to encourage sound environmental practices, including a significant increase in waste collection, sorting and recovery. The results demonstrate that the exemption enabled infrastructure development and innovative waste management practices, strengthening beneficiary entities' role in promoting the circular economy. A positive relationship was observed between the evolution of tax expenditure and environmental gains, reflected in the expansion of selective collection networks, the reduction of waste sent to landfills and the reuse of secondary materials. Furthermore, the measure contributed to the economic competitiveness of the sector, ensuring reinvestment in technology and more efficient processes. Within the scope of the SDGs, the exemption from IRC had a direct impact on several objectives:

- SDG 11 (Sustainable Cities and Communities) promotes the mitigation of urban environmental impact and encourages sustainable management practices in urban areas.
- SDG 12 (Sustainable Consumption and Production): encourages consumption and production patterns based on recycling and reuse of materials.
- SDG 13 (Climate Action): reduces emissions associated with inadequate waste disposal, reinforcing the transition to a low-carbon economy.
- SDG 17 (Partnerships for Goals): strengthens collaborations between the public and private sectors, promoting innovation and efficiency in managing specific waste streams.

The IRC exemption also played an important role in implementing European Union directives related to waste management, demonstrating the Portuguese tax system's ability to integrate environmental objectives into public policies. This synergy was essential to consolidating the national commitment to the circular economy while enhancing the creation of economic value from waste. It is concluded that the tax benefit, although modest in direct financial impact, is an effective tool to promote sustainability practices and integrate fiscal and environmental policies. Its application reinforces the importance of extra-fiscal instruments for the green transition and highlights the strategic role of waste management entities in achieving global sustainable development goals.

Keywords

Waste Management, Tax Benefits, Sustainable Development Goals, Circular Economy

ELECTROGENERATION OF HYPOCHLORITE FROM REVERSE OSMOSIS RETENTATE FOR REUSE AS ANTIFOULING AGENT

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ABSTRACT

Recent concerns about water scarcity are closely related to the sharp increase in the world's population and industrial production, which has raised the water demand and wastewater discharges. The textile industry is a water-intensive consumer, due to its requirements throughout the industrial process. The large volumes of water used result in intensive wastewater generation, which must be properly treated. Among the several treatment technologies available, reverse osmosis (RO) is known for its efficiency in purifying wastewater, being one of the few capable of achieving the quality required for wastewater reuse in textile industrial processes. There are two main challenges when applying RO to treat textile wastewater: (1) the retentate left behind after the process, a highly concentrated solution that has to be discharged or further treated; (2) the loss of effectiveness of the process due to the increased fouling of the membranes. This study aims to provide an effective solution to both challenges through the use of electrooxidation (EO) to treat and reuse RO retentate. The experiments were performed in a laboratory-scale electrochemical cell comprised of Ti/IrO_2-RuO_2 anode and cathode with 182.25 cm^2 area each, working in batch mode with recirculation. The mixed-metal oxide (MMO) anodes are well known for their ability to generate reactive chlorine species (RCS) from chloride oxidation, enabling the treated RO retentate, rich in RCS, to be reused as an antifouling agent in the membrane process. Since textile wastewater has a highly variable composition, originating retentates with dissimilar characteristics, different RO retentate samples were used in the experiments (chemical oxygen demand (COD) ranging from 305 to 1045 mg L^{-1} and chloride concentration between 659 – 3029 mg L^{-1}). The influence of applied current intensity (0.5 – 1.0 A) and sample volume (5.0 – 15.0 L) were evaluated. The obtained results showed that, at the experimental conditions studied, the rate of chloride oxidation was only dependent on the applied electrical charge, being unaffected by the retentate characteristics, sample volume, or applied current intensity. This finding favors the application of this technology on an industrial scale, where wastewater characteristics may vary in short periods. Thus, an adjustment of the applied current is enough to keep the efficiency of the process, which is compatible with an automation system. The energy consumption (kWh m^{-3}) decreased with the increase of the initial amount of chloride in the retentate. Still, the higher the initial chloride amount, the lower the efficiency of the process to generate hypochlorite, evaluated by the difference between the expected (i.e., theoretical) and experimentally generated hypochlorite. This difference is related to the production of RCS other than hypochlorite and can be explained by the Nernst equation. Alongside the effective generation of hypochlorite, EO promoted COD and color removal. Also, the final pH values ranged from 8.5 to 9.0, acceptable for reuse in membrane processes. The treated samples were tested as antifouling agents in a membrane plant treating textile wastewater, reducing the COD and the color of the entry wastewater. EO with MMO anode is an effective strategy to treat RO retentates and allow their reuse as antifouling agents, improving the sustainability of the textile industry through a circular economy approach.

Keywords

Textile wastewater; membrane concentrates; electrooxidation; mixed-metal oxide electrodes; reactive

ECO-EFFICIENT SCC FOR BUCKLING-RESTRAINED BRACES: DESIGN, MODELLING AND OPTIMISATION

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ABSTRACT

Concrete has the potential to incorporate significant amounts of waste and industrial by-products, aligning with the principles of the Circular Economy. By reducing the need for landfilling and promoting resource reuse, the concrete industry plays a crucial role in creating sustainable materials for construction. This is particularly relevant in structural applications like Buckling-Restrained Braces (BRBs), where concrete strength is not the primary factor, allowing for the exploration of environmentally friendly and economically attractive mixtures. Glass powder (GP), derived from recycled glass waste, offers significant environmental and economic benefits when used as a partial replacement for Portland cement. Recycling glass waste prevents environmental harm caused by landfilling and reduces greenhouse gas emissions associated with traditional cement production, making it an attractive option for creating greener concrete solutions.

This study investigates the properties of eco-efficient self-compacting concrete (SCC) as an infill material for BRBs. Binder formulations incorporating GP with varying replacement percentages are explored to determine the optimal ratio for achieving desired engineering properties. A factorial design approach is employed at the mortar level to model the material behavior and optimize mixtures for SCC-filled steel tubes, focusing on partial Portland cement replacement (targeting 50% replacement) using both conventional and unconventional supplementary cementitious materials (SCMs). This approach enables mathematical modeling of the influence of key mixture parameters, including the water-to-powder ratio (Vw/Vp), GP/cement ratio, and superplasticizer-to-binder ratio, on critical engineering outputs such as mechanical strength, and shrinkage. The desirability function is applied to the statistical model to identify the optimal combination of materials, water, and admixtures, achieving a balance between engineering properties and carbon efficiency. The results so far indicate the successful development of a concrete formulation with properties well-suited for application in BRBs, demonstrating the potential of this approach for sustainable construction practices.

Keywords

carbon-efficient concrete, self-compacting concrete, alternative SCM, glass powder, buckling restrained braces

INOVCIRCOLIVE PROJECT: INNOVATING SUSTAINABLE MANAGEMENT OF OLIVE OIL PRODUCTION SURPLUSES

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ABSTRACT

The olive oil production industry in Portugal has experienced significant growth in recent years, with a remarkable 119.5% increase during the 2021/2022 campaign, reaching a record production of 215,260 tons. This surge has positioned Portugal as the fifth-largest exporter of olive oil globally, with business volume increasing by over 250% since 2017. However, alongside this economic success, concerns over the sustainability of the industry have emerged, particularly regarding the waste and by-products generated during the extraction process. These by-products, now referred to as "surpluses" within the framework of the circular economy, include a variety of materials such as wet olive pomace, pruning residues, leaves, wastewater and olive pits.

In the Alentejo region, which produces the majority of the country's olive oil using two-phase extraction systems, wet olive pomace is the most prevalent surplus. This by-product is produced in quantities four times greater than the olive oil itself, posing a significant challenge in terms of waste management. Typically, wet pomace is processed through drying units; however, these facilities have limited capacity to cope with the continuous rise in olive oil production. Consequently, this surplus often contributes to environmental issues, including waste accumulation and resource inefficiency.

Recognizing the need for sustainable solutions, the INOVCIRCOLIVE Project was established to address the challenge of giving new life to these olive oil production surpluses. The project is rooted in the principles of circular economy, where the goal is to minimize waste and transform by-products into valuable resources. One of the key strategies employed by the project is the integrated valorisation of olive oil surpluses through innovative methods such as composting. An experimental protocol has been developed to create compost piles primarily using olive oil surpluses, with the aim of reducing environmental pressure and fostering more sustainable agricultural practices.

The project envisions that the valorisation of these surpluses will contribute to a near-zero-waste economy within the olive oil sector, reducing the reliance on natural resources and mitigating the environmental impact of extractive activities. In addition, the project seeks to introduce new business models and foster industrial symbiosis practices, where the by-products of one industry can be used as inputs for another, thus promoting a more sustainable and circular agricultural ecosystem.

By transforming olive oil production surpluses into valuable products, the INOVCIRCOLIVE Project not only aims to enhance the environmental sustainability of the olive oil industry but also to support the development of new economic opportunities in rural areas, contributing to the long-term viability of the sector. The outcomes of this project are expected to offer valuable insights into alternative methods for surplus treatment and valorisation, opening new perspectives for the olive oil industry and other sectors in the agri-food chain.

Keywords

Olive sector; sustainability; Circular Economy; composting; wet olive pomace.

SUSTAINABLE SOLUTION FOR SOFT SOIL STABILIZATION

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ABSTRACT

The increase in urban development has been demanding infrastructure construction on weak soils. One of the techniques that has been used to improve the soil's behavior is the chemical stabilization. Through methods like mass stabilization and deep soil mixing, it provides a cost-effective and sustainable alternative when compared with traditional stabilization techniques. While the addition of Portland cement, even in small amounts, can significantly enhance soil strength, its production carries a substantial environmental burden, contributing 5% to 7% of the total CO2 emissions. Moreover, the resulting cement-based stabilized soil exhibits a brittle behavior. Incorporating fibers into this composite material offers a promising approach to mitigate this brittleness. In this paper it is explored an alternative, environmentally friendly cementitious material with a lower carbon footprint than Portland cement making use of an industrial by-product, granulated blast furnace slag (GGBS), activated with sodium hydroxide, and combined with natural fibers, specifically sisal fibers. Laboratory samples were prepared with and without fibers, cured for 28 days under controlled humidity and temperature conditions, and subjected to unconfined compressive strength (UCS) tests to characterize the strength and stiffness of the composite material under compression. The results demonstrate that the geopolymer (GGBS + activator) exhibits higher unconfined compressive strength than Portland cement. While the inclusion of sisal fibers led to a decrease in UCS for Portland cement-stabilized soil, a beneficial effect was observed when fibers were incorporated into the geopolymer-stabilized soil. Regarding brittle behavior, the addition of sisal fibers to Portland cement-stabilized soil effectively mitigated brittleness, an effect not observed in the geopolymer samples.

Keywords

stabilized soil, fiber reinforcement, geopolymer, GGBS, UCS, sisal fiber.

INCORPORATION OF GLASS FRIT ON GEOPOLYMER FABRICATED USING ADDITIVE MANUFACTURING FOR COAL-MINING WATER REMEDIATION

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ABSTRACT

This study investigates the synthesis, characterization, and potential environmental applications of a geopolymer material, synthesized from metakaolin activated with a NaOH and Na_2SiO_3 alkaline solution. The preparation involved a mechanical stirring system to form a homogeneous paste, followed by the addition of bentonite (10 %) for improved workability and glass frit (25 %) as a volumetric filler. Glass frit, a recycled material, was selected due to its effectiveness in achieving the required viscosity for 3D printing and its eco-friendly nature compared to other materials such as pure alumina and SiO_2. After homogenization, the paste was extruded through a Delta-type 3D printer using Direct Ink Writing (DIW) at air pressures ranging from 1 to 5 bars, and the printed structures were cured at room temperature for seven days.

Characterization of the geopolymer included mechanical testing, nitrogen adsorption for specific surface area (SSA), and scanning electron microscopy (SEM) for surface morphology. The compressive strength of the geopolymer, GP_25F, was found to be satisfactory for practical applications, achieving 4.2 MPa, with a total porosity (TP) of 67.04 % and open porosity (OP) of 66.08 %. X-ray diffraction (XRD) confirmed an amorphous structure typical for geopolymers, with some crystalline peaks attributed to kaolinite and anatase impurities. The material demonstrated mesoporous characteristics, contributing to its potential use in adsorption processes.

Environmental applications were explored through adsorption tests on real water samples contaminated by mining activities. Samples were collected from two sites in Siderópolis, SC, Brazil: an acid mine drainage (DAM) lake and a nearby river impacted by mining (AIM). Parameters including pH, temperature, and dissolved oxygen were measured during sample collection, and the concentrations of heavy metals and anions were analyzed. The adsorption tests evaluated the material's ability to remove these contaminants. The results showed variable performance depending on the contaminant and the type of water. For Cu^{2+}, no significant removal was observed. Fe^{2+} removal was more effective in AIM, achieving 19.53 % removal. Mn^{2+} demonstrated the highest removal efficiency, with a 100% removal in AIM. The geopolymer also achieved significant removal of Zn^{2+} in AIM (61.62 %) and Cl^- in DAM (94.70 %). However, the removal of other anions, such as SO_4^{2-} and PO_4^{2-}, was minimal.

These findings suggest that the GP_25F geopolymer is more effective at adsorbing certain cations, particularly manganese and zinc, in water impacted by mining activities. However, the performance in DAM was less effective due to high concentrations and competition for active sites. To enhance its applicability, modifications to the geopolymer formulation are recommended, focusing on improving the specific surface area and porosity. This study highlights the potential of recycled materials, such as glass frit, in the development of sustainable geopolymers for environmental remediation applications, particularly in the treatment of mining-contaminated waters.

Keywords

Glass residue, Aluminosilicate, Direct ink writing, Adsorbent, Heavy metals, Separation process

INCORPORATION OF INDUSTRIAL SECONDARY RAW MATERIALS IN PORCELAIN STONEWARE PRODUCTION: PRELIMINARY TESTING AND EVALUATION

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ABSTRACT

In 2020, manufacturing activities in the European Union generated more than 226 million tonnes of waste, with only 13 wt.% being recycled. In Portugal, the recycling rate is even lower, reaching just 2.6 wt.% (*Eurostat, 2024*). In recent years, the ceramics industry has been investing in the implementation of a circular economy, aiming to incorporate both endogenous and exogenous waste and by-products into its production process. In this context, applying the principles of industrial symbiosis can serve as an effective means for transitioning toward a more sustainable industrial system. However, the challenges of implementing circular economy and industrial symbiosis strategies, as well as developing eco-innovative solutions at an industrial level, are significant. Overcoming these challenges requires targeted actions to acquire the necessary knowledge, covering all the technical aspects essential for developing suitable solutions.

In this study, the incorporation of four industrial secondary raw materials into porcelain stoneware bodies was evaluated. Specifically, powder from the dry grinding process of porcelain stoneware, biomass fly ash, and casting sand and foundry fines generated in the production of cast iron were the studied residues. They were firstly characterized in terms of chemical and mineralogical composition, particle size distribution, and thermal behaviour. Next, tiles (5 x 10 cm²) were produced using pastes containing 2 and 5 wt.% of each residue. These tiles were fired in a laboratory furnace at a maximum temperature of 1100 ºC. The specimens were then characterized in terms of colour, firing shrinkage, loss on ignition, flexural strength, water absorption, and apparent density.

With the exception of the foundry fines, no significant differences were observed between the properties of the specimens produced with 5 wt.% waste and the standard sample, with the obtained values accomplishing with technological requirements. In the case of the foundry fines, the maximum incorporation percentage should be limited to 2 wt.%. For future work, industrial trials will be conducted, and the products will be characterized following the company's procedures. The results obtained highlight the potential of integrating industrial waste into porcelain stoneware materials, enhancing circularity and contributing to a more sustainable ceramic production.

Keywords

Ceramic Industry; Porcelain stoneware; Waste valorization; Circular economy; Industrial symbiosis; Sustainability.

BIOGAS PRODUCTION FROM WINERY BY-PRODUCTS: AN EVALUATION OF BIOCHEMICAL METHANE POTENTIAL AND KINETICS

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ABSTRACT

Grapes are among the most widely cultivated fruit crops worldwide, with Portugal ranking as the world's tenth-largest wine producer, producing 7.5 million hectoliters annually. The northern regions of Minho, Trás-os-Montes, and Douro account for 40% of the country's vineyard area. Because of their extensive activity, the wine industry is linked to the generation of a considerable amount of by-products, including grape pomace (GP) and wine lees (WL) during the harvest season, as well as wastewater (WW) and waste-activated sludge (WAS) produced year-round. Anaerobic digestion (AD) is a well-established technology for converting organic biomass into biogas. Biochemical Methane Potential (BMP) assesses the substrates' suitability for AD by evaluating their biodegradability and determining their maximum methane yield under anaerobic conditions. This work assesses the BMP of direct and indirect by-products resulting from the wine industry activities. Direct by-products include White and Red GP and WL which are produced seasonally during the harvest season and wine production, while indirect by-products stand for Winery WW and WAS which are generated throughout the year. White and Red GP and WL were collected during the 2024 harvest season, with physical and chemical characterization of by-products showing a similar composition and an acid matrix. White and Red Pomace exhibited a higher VS%/TS% ratio (*ca*. 0,9) than Wine Lees (*ca*. 0,8), suggesting a greater proportion of biodegradable VS. COD measurements showed different matrix profiles. GP had COD_t = 380 g/kg reflecting the organic matter concentrated in the solid fraction, while Wine Lees showed values of total COD (White lees' COD_t = 226.5 g/L; Red Lees' COD_t = 214.5 g/L) indicating a soluble organic matrix. The BMP tests conducted with by-products without pre-treatment identified Pomace as the most suitable substrate for anaerobic digestion, with a value of 188.3 NLCH4/kgVS for Red Pomace and 111.9 NLCH4/kgVS for White Pomace. During BMP experiments of both WLs (i.e., Red and White), a significant amount of gas was released initially, followed by an inhibition period without gas production. The high CO2 concentration in the gas produced (*ca. 75* %(v/v)) suggests that alcoholic fermentation predominated over anaerobic fermentation. Such an undesired outcome could be attributed to the active yeast fermentation of the lees at the time of collection. Indirect by-products were gathered throughout the year (i.e., May, June, September, and November 2024) to reflect the different industrial activity periods. The wastewater sample collected in September (i.e., during the wine campaign) presented the highest total COD value (CODt=10,25 gO_2/L), as expected, followed by the samples from May and June. Still, despite the highest COD value, it showed the lowest BMP. The following BMP values were obtained for September, May, and June, respectively: 203.8 NL_{CH4}/kg_{COD}, 240.5 NL_{CH4}/kg_{COD}, and 252.6 NL_{CH4}/kg_{COD}. WAS showed a VS%/TS% ratio of 0.78. However, due to its composition rich in microbial cells (activated sludge), WAS presented a low BMP value ($BMP_{40\ days}$ = 48.25 NL_{CH4}/kg_{VS}). An even lower BMP value was obtained by increasing the S/I from 0.5 to 1. A preliminary alkali pre-treatment screening using different concentrations of KOH (i.e., 0.04 and 0.08 g/gTS) showed that combining WAS with 0.04g/gTS KOH for 24h could slightly improve the BMP. Kinetic evaluations were also performed to understand each substrate's biodegradability, hydrolysis rate, and maximum methane potential. Current results pointed out that Red GP and wastewater are the most promising substrates for AD, while co-digestion and pre-treatments may be considered to improve wine lees and WAS degradation through AD.

Keywords

Anaerobic digestion, Biogas production, Biochemical methane potential, Winery by-products, Kinetic evaluation

KINETIC ANALYSIS OF THE ANAEROBIC DIGESTION OF HORSE MANURE WITH EFFLUENTS FROM PIG FARMS AND WASTEWATER TREATMENT PLANTS

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ABSTRACT

The agricultural sector, particularly intensive livestock systems, significantly contributes to environmental issues such as greenhouse gas (GHG) emissions and groundwater pollution.

In this work effluents from pig farms and wastewater treatment plants (WWTPs) were used as a substrate and collected from a wastewater treatment plant in Alto Alentejo and a pig farm located in Baixo Alentejo, Portugal. Fresh horse manure was used as an inoculum in this study and was collected at a riding school in Alto Alentejo. The effluents and manure were stored at 4 °C in an airtight plastic container to prevent any degradation until its next use.

Anaerobic digestion tests were conducted in 1000 mL Schott-Duran glass bottles with a working volume of 700 mL. The reactors were placed in a laboratory incubator (POL-EKO APARATURA) maintained at 38 ± 1 °C under mesophilic conditions and held at a constant temperature for 28 days. At the start of the process, each reactor was supplied with appropriate amounts of effluent (substrate) and inoculum, maintaining an inoculum-to-substrate (Ino/S) ratio of 1:9 on a mass basis. The biogas, collected once per week, was immediately analyzed using a portable gas analyzer (GasData GFM406), which measured the volumetric percentages of CO_2, CH_4, O_2, H_2S, and CO in the gas mixture. The bottles were manually shaken at regular intervals, and gas production values were reported under standard temperature and pressure conditions. The maximum biogas yield achieved was 360 mL and 1730 mL, respectively, for pig effluent without and with horse manure inoculum. In the case of effluent from the WWTPs without and with the inoculum, the maximum biogas achieved was 980 mL and 1220 mL, respectively.

The biogas production was optimizing, predicting, simulating, and monitoring performance under various conditions using mathematical kinetic models. These models are essential for estimating kinetic parameters and gaining a deeper understanding of the digestion process. This study aims to evaluate the kinetic enhancement of biogas production by horse manure with effluents from pig farms and WWTPs. Two mathematical kinetic models – the first-order kinetic model and the modified Gompertz model –were applied to estimate key parameters, including biogas production potential, maximum production rate, and lag time, by fitting the observed biogas yields. The modified Gompertz model is widely regarded as a reliable empirical non-linear regression model for predicting methane accumulation. It provides crucial information on the lag phase and the maximum specific methane production rate, characterizing microbial growth in terms of exponential growth rates and lag phase duration. In this study, the modified Gompertz model demonstrated a better fit to the experimental data compared to the first-order kinetic model. The modified Gompertz model predicted a production of 980 mL and 1276 mL for WWTP effluent without and with inoculum, respectively, and for pig effluent with inoculum it predicted a production of 1743 mL.

Keywords

Anaerobic Digestion, Horse Manure, Effluents, Pig Farms, WWTPs.

METAL RECOVERY FROM E-WASTE BY CLAYS AND ACTIVATED CARBON

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ABSTRACT

The growing global population and industrialization are driving an increasing demand for essential resources, particularly in key sectors such as the transition to climate neutrality and the development of innovative technologies. In this context, waste from electrical and electronic equipment (WEEE) represents a significant source of valuable materials.

E-waste comprises various types of materials, including critical raw materials, plastics, and precious metals, each with different composition and recovery potential. The strategic raw materials are of particular interest, infact they play a vital role in the development of technologies for climate neutrality, aerospace, and safety sectors. These materials can be recovered and refined from e-waste, providing an alternative to environmentally damaging conventional mining practices. However, a large percentage of e-waste materials are currently discarded or lost, resulting in the waste of valuable metals and resources.

To mitigate the environmental impact of traditional mining, several innovative techniques for material recovery are being explored, including pyrometallurgical, hydrometallurgical, and biotechnological methods. Among these, hydrometallurgy offers several promising technologies for metal separation, with solid-liquid adsorption standing out due to its high recovery efficiency, rapid extraction time, and the large quantities of adsorbents that can be utilized.

This study investigates the adsorption of metal ions from a complex leachate solution derived from the leaching of milled mobile phone printed circuit boards (PCBs). The solution was analysed via ICP-OES (Inductively Coupled Plasma – Optical Emission Spectroscopy) to determine its composition. The multi-ions leachate was then exposed to two different sorbents, clay and activated carbon, both in their pristine and modified forms, while maintaining a fixed sorbent/solution ratio. ICP-OES analysis of the post-treatment solution allowed for the calculation of uptake efficiency for the different metals contained in the waste. The findings indicate the different behaviour of the sorbents towards the various ions. All the sorbents show the same uptake efficiency (of 100 wt.%) towards tin, while a different affinity is shown towards the uptake of copper: the clay reaches 1 wt.% of efficiency, while the other sorbents exceed 50 wt.%.

Additionally, a release experiment was conducted under acidic conditions (pH = 1) to assess the release efficiency of each sorbent. Given that the leachate solution exhibited an extremely high concentration of copper (90 wt.%), a modified experimental setup was proposed, incorporating an electrodeposition step prior to adsorption. This new step significantly reduced the copper concentration from 21.5 g/L down to 1.58 g/L, reducing the amount of metal ions present in the solution.

Keywords

e-waste, critical raw materials, clays, activated carbon, adsorption, release

LIFE CYCLE ASSESSMENT AND TECHNO-ECONOMIC ANALYSIS OF WASTE STREAM REINCORPORATION IN INDUSTRIAL SCALE TOMATO-BASED SAUCE PRODUCTION

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ABSTRACT

The food processing industry generates significant amounts of waste, creating environmental and economic challenges associated with waste treatment and management. This study focuses on the environmental and economic implications of waste stream reincorporation in the production of tomato-based sauces, specifically targeting the purge stream generated during batch production. Using an integrated approach combining Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA), this study evaluates the potential reduction in environmental emissions and economic impact of the waste management strategy. The study highlights the importance of the adoption of a circular economy strategy in the food processing industry, demonstrating how waste streams can be effectively reused in the production system without affecting product quality.

The research was conducted using primary data collected from a tomato-based sauces production facility that operates with a batch production of 1300kg. 5.5% of the total production that goes as a waste stream, generated primarily during the recollection of product from tubes and processing stage, was considered for reincorporation into the mixing unit at varying levels (40% and 100%) to evaluate its impact on greenhouse gas (GHG) emissions. Preliminary LCA results indicate approximately a 2.3% reduction in GHG emissions when reincorporating 40% of product from the waste stream while 100% reincorporation achieves a 6% reduction. These results were calculated based on a cradle-to-gate system boundary, including raw material sourcing, production of sauce, and filling into the plastic bottles. The life cycle inventory (LCI) was made using primary data collected from the sauce production facility, supplemented with secondary data from LCA databases like Ecoinvent v3.10 and Agribalyse v3.1.1. In addition to environmental performance, the study includes a TEA to assess the economic sustainability of waste stream incorporation. Factors considered involve capital expenditure, operational cost, and potential cost savings from reduced waste disposal and raw material cost savings from using the waste stream. The findings aim to identify the balance between environmental performance gains and economic feasibility, providing a practical way for industry adoption. The results of this study offer valuable insights for food industry stakeholders seeking to align their operations and production with sustainability goals.

Keywords

-Sustainability management -Circular economy -Life cycle assessment -Techno-economic analysis -Waste management

LITHIUM-ION BATTERY RECYCLING BY PHYSICAL PROCESSING: EVALUATION OF RECOVERY AND METAL CONTENT IN SHREDDING AND SIEVING OPERATIONS

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ABSTRACT

In the contemporary context, the recycling of Li-ion batteries (LIBs) has emerged as a pivotal aspect of sustainable resource management, particularly regarding the recovery of critical metals present in the electrodes. In the treatment of spent LIBs, the electrode materials rich fraction, designated as black mass, contains the valuable metals from the cathode as Li, Ni, Co and Mn. This fraction is obtained in a physical processing step where the cells are shredded (usually in more than one stage) and processed by physical separation operations. During the first shredding stage, the cells are comminuted, the electrode materials are disaggregated, and a fine fraction is separated by sieving. This paper presents an in-depth laboratory study of the shredding process of pouch-type LIB cells to assess the efficiency of the electrode materials liberation and its recovery in the fines. The cells were previously subjected to cryogenic treatment for safety reasons. After shredding, the materials were sieved resulting in the identification of several granulometric classes, which were chemically characterized to determine the metals content and their distribution. The recovery yields were assessed from the cathode composition, while contamination with copper and aluminum (from the supporting and conductive foils of anode and cathode, respectively) allowed to evaluate the selectivity and purity of the obtained black mass. By using a shredding discharge grid of 4 mm, an average particle size of 0.9 mm was obtained. Visual inspection showed most of the casing material (aluminum laminate) in the coarse fractions without visible contamination with electrode powders, which can be separated and sent to further valorization. The 2 mm sieve retains the highest mass fraction (26% of the total mass). The chemical showed that most of the cathode material was present in the intermediate fractions (between 0.15 and 2 mm), while copper clearly prevailed in the 2 mm sieve size. Regarding aluminum, its content increases with the sieve size, yet the Al mass distribution was higher at 2 mm. The assessment of the black-mass recovery and content to be attained in a sieving process (in the fines, e.g. in the infra-sieve), after shredding, was carried out based on the cumulative distribution curves (for each metal or compound). Several scenarios have been considered but, concerning the goal of attaining high purity, sieving at 0.5 mm provided the recovery of 44% of the cathode in the black-mass with a content of 56wt% cathode, 0.59wt% Al and 3.7wt% Cu. Copper is the most relevant impurity in the process, which it will contaminate the leach liquors of the subsequent hydrometallurgical processing of the black-mass. The results obtained can be considered a good approach for the first step of grinding. The coarse material should undergo further treatment by a second grinding step and additional physical operations to attain higher recovery yields.

Keywords

Li-ion batteries; Recycling; Physical processing; Shredding.

MADEIRA COASTAL INSIGHT SERVICE (MCIS) IN SUPPORT OF THE IMPLEMENTATION OF EU POLICIES AND DIRECTIVES IN AN OUTERMOST REGION

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ABSTRACT

The European Union (EU) recognizes its nine outermost regions as valuable hubs for research and innovation. Ocean islands, including those in the EU's outermost regions, are renowned for their biodiversity and are crucial for understanding oceanic phenomena. The outermost region of Madeira, a mountainous island in the Northeast Atlantic Ocean, exemplifies the environmental complexity of these regions. Large land-based material inputs into its coastal areas often lead to frequent phytoplankton blooms, while the limited capacity of local Wastewater Treatment Plants (WWTPs) exacerbates water quality challenges. Monitoring the island's coastal waters is crucial due to its distinct environmental, economic, and social characteristics, but existing global oceanic forecast models lack sufficient resolution to represent small-island processes, especially in coastal areas. Therefore, developing local operational services is essential for improving coastal monitoring and supporting EU policies and directives. The Madeira Coastal Insight Service (MCIS), a new project funded as a National Collaboration Program by the MERCATOR OCEAN, aims to create a comprehensive coastal monitoring service that integrates cutting-edge technologies and methodologies for real-time and accurate data collection, aligning with EU policies and directives. The service's objectives are to ensure the sustainable management and protection of Madeira's coastal waters, guarantee compliance with EU environmental policies, and enhance local environmental management capacity. The service will utilize in-situ observations and remote sensing data combined with high-resolution numerical models to generate blue (physical) and green (biogeochemical) datasets. Two primary Use Cases will drive this initiative. Use Case 1 focuses on using Lagrangian models to assess water quality, particularly sanitary risks in areas critical for tourism and aquaculture. By incorporating data from WWTP discharges and in-situ water quality measurements, this case aims to enhance pollution patch predictions, produce real-time water quality reports, and generate interactive maps to track contamination sources and distributions. Use Case 2 targets the assessment of nutrient budgets and their impact on marine ecosystems. This approach integrates biogeochemical models, remote sensing, and in-situ data to study nutrient sources, sinks, and cycling. The service will offer high-resolution daily forecasts of physical and biogeochemical variables, with reports and tools for visualizing nutrient impacts on ecosystems. The expected outcomes of the MCIS include: i) enhanced real-time monitoring to support informed decision-making; ii) improved policy compliance through documentation and reporting on environmental conditions in line with EU Directives (i.e. Water Framework Directive, Marine Strategy Framework Directive, Nitrate Directive, Urban Waste Water Treatment Directive, Bathing Water Directive); iii) provision of insights and recommendations for effective pollution mitigation and coastal management; and iv) strengthening local expertise and capacity, fostering better management practices and stakeholder engagement in environmental protection. In the scope of the WASTES 2025 conference, we propose to present the progress of the implementation of the MCIS's Use Cases that will be part of the Copernicus Marine Services.

Keywords

Water quality monitoring; In-situ observations; Remote sensing; Lagrangian models; Biogeochemical models; EU environmental policies and directives

EFFECT OF HOUSEHOLD SOURCE SEPARATION REGULATIONS TO PACKAKING WASTE AND BIOWASTE CONTENT OF THE MIXED WASTE

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ABSTRACT

Helsinki Region Environmental Services Authority (HSY) is the largest environmental services provider in Finland, serving the Helsinki metropolitan area and one-fifth of the country's population. Annually, we collect 45,000 tons of biowaste from households and process it at the Ämmässuo Eco Industrial Center. The efficiency of the collection system in the Helsinki region relies on a good coverage of door-to-door-collection.

The waste management regulations of Helsinki Metropolitan area were given first time in 1984. These regulations did not include source separation regulations but only for example regulations for wastebin types, emptying frequency and how to handle waste on the property. In 1998 source separation regulation for biowaste was added to the regulations. From 1998 on, residents in apartment buildings having 10 or more dwelling units were regulated to source separate their biowaste. The next step took place in 2006 when regulation for cardboard source separation for residents of apartments buildings having 20 or more dwelling units. The source separation regulations for glass and metal packages were added in May 2012 and at the same time regulation for cardboard was expanded to cover also apartment buildings of 10 of more dwelling units. The collection service for plastic packages started in 2016. No source separation regulations were given for plastic packages at that time, but households were encouraged to source separate plastic packages on voluntary basis. The next noticeable change in household waste source separation regulations took place in 2021 when source separation of packaging waste and biowaste was expanded to cover all households living in apartment buildings of equal or more than 5 dwelling units. From July 2023 on the source separation of biowaste became obligatory also for one family houses and apartment buildings of dwelling units between 2-4.

HSY has investigated the amount and content of the household mixed waste from 1996 on to find out what is the effect of source separation regulations to content and amount of the mixed waste generated in households at Helsinki metropolitan area. In the latest study executed in 2024, the average amount of mixed waste per capita was 126 kilos while for example in 2007 the amount was 165 kilos. How ever even if the mixed waste generation has increased, the amount of biowaste in mixed waste is still quite high, 41,6 kilos that corresponds to 33,1 %. The results and analyze of these investigations in detail are presented in this paper.

Keywords

Source separation, biowaste, packaging waste, mixed waste

MAPPING BIOWASTE GENERATION: A SPATIAL DECISION-MAKING FRAMEWORK FOR IMPLEMENTATION OF EU DIRECTIVE 2018/851

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ABSTRACT

In the European Union (EU), biowaste represents 34% of the municipal waste generated. Managing this waste stream is crucial to achieve a circular economy, as it can provide valuable soil amendments and fertilizers, as well as biogas, through recycling. Despite this, a high proportion of biowaste is still sent to landfills or incinerated. To address this, EU Directive 2018/851 established a mandatory separate collection of biowaste by the end of 2023. However, in pursuit of a circular economy and sustainable waste management, the directive recognizes that separate collection may not be feasible at a technical, economical, or environmental level, thus allowing for well-founded territory derogations. In response to the requirement of territorial coverage and considering the importance of a sustainable biowaste collection system, this study proposes a decision-making method, in waste management planning, to assess the feasibility of separate biowaste collection, within a territory. More specifically, the aim of this study is to find, within a region, the most precise geographical distribution of biowaste generation. In this talk, we will present a new indicator, the "Artificial Urban Area" indicator, which assesses the size of the built-up area within a territory where biowaste is generated. This indicator is defined as the ratio between the built-up area within a given geographical region and its total area. With well-defined thresholds, the suitability of areas for separate biowaste collection was effectively determined. A national case study in mainland Portugal will be presented to demonstrate its applicability. The results show that selective biowaste collection is viable in 52% of national parishes, representing 87% of the total biowaste generation. This spatial understanding of the built-up areas where biowaste generation is concentrated will support a more efficient allocation of waste management resources within territories.

Keywords

biowaste, decision making support, indicators, waste collection, waste management

TECHNO-ECONOMIC ANALYSIS OF BIOGAS-TO-BIOMETHANE AND ELECTRICITY PRODUCTION FROM AGRO-INDUSTRIAL WASTE

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ABSTRACT

This study presents a comprehensive techno-economic analysis of a biogas-to-biomethane and electricity production system using pig manure effluents and agro-industrial waste (ESRA). The proposed system integrates anaerobic digestion, biogas upgrading, and electricity generation from syngas, demonstrating the feasibility of producing renewable energy from agricultural residues. The process begins with anaerobic digestion of ESRA, which produces biogas. This biogas undergoes upgrading to biomethane, which is then pressurized and injected into a nearby natural gas pipeline. The residual waste from digestion is dried and gasified to generate syngas, which is used to generate electricity in internal combustion engines. The plant is designed to use approximately 25% of the generated electricity for its own consumption, with the remaining 75% available for injection into the electrical grid. Furthermore, the byproducts—ash from gasification and liquid effluent—are utilized as fertilizers.

The financial analysis of the system includes the calculation of the Levelized Cost of Energy (LCO) and the specific cost of biomethane (SC_Bio-CH4). The LCO for biomethane was calculated to be 42.97 €/MWh, consistent with industry benchmarks ranging from 25 to 50 €/MWh. The cost of producing biomethane is 0.36 €/Nm³, aligning with reported costs in the literature (0.25–0.55 €/Nm³). The capital expenditure (CAPEX) required for the plant was estimated at 3.33 million euros, with specific CAPEX calculated at 3428.38 €/kW. The digestor and gasifier contribute significantly to the total CAPEX, representing 74.5% of the investment.

The financial viability of the project was further evaluated through key financial indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). The NPV, using an 8.5% discount rate, was found to be 5.22 million euros, indicating a positive return on investment. The IRR was calculated at 22.71%, which exceeds the required discount rate, confirming the financial attractiveness of the project. Additionally, the PBP is 6.47 years, well within the plant's 25-year operational lifespan, further supporting the economic feasibility of the project.

Overall, the study demonstrates that the proposed biogas-to-biomethane and electricity production system is economically viable, making it a promising solution for renewable energy production from agro-industrial waste. The combination of biogas upgrading and syngas-driven electricity generation provides a sustainable, cost-effective model for energy recovery, while the use of byproducts as fertilizers adds environmental and economic benefits.

Keywords

Biogas, Biomethane, CAPEX, Economics

ASSESSING THE INFLUENCE OF REFUSE-DERIVED FUELS ON THE PHYSICAL AND COMBUSTION PROPERTIES OF BIOMASS PELLETS

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ABSTRACT

Global energy transition, marked by replacing energy matrices based on fossil fuels, has promoted research and development of technologies that utilize waste as an alternative energy source. It is essential to deepen technical and empirical knowledge on the use of waste on a large scale to identify and mitigate the challenges associated with this practice. This study investigated the impact of adding refuse-derived fuel (RDF) composed mainly of plastics (32 %), textiles (16 %), and paper (11 %) on the quality of end-of-life lignocellulosic biomass pellets. The pellets were formulated in different proportions by weight: 100 % RDF, 50 % RDF+50 % Biomass, 25 % RDF+75 % Biomass, 15 % RDF+85 % Biomass, and 100 % Biomass, using a semi-industrial pelletizer of 350 kg/h capacity (Andritz, Germany) and with a 6 mm die. Through a detailed analysis of the physical and combustion properties of the produced pellets, parameters such as density, mechanical durability, amount of fines, moisture, carbon and hydrogen content, heating value, and ash were evaluated. The content and composition of the ash are crucial parameters in the energy valorization of waste and biomass since they relate to slagging, fouling, and corrosion phenomena associated with combustion. Thus, this study also considered ash characterization to determine the slagging and fouling indices of these pellets.

The results demonstrated that the addition of RDF had a positive impact on the physical characteristics of the pellets. Despite the lower apparent density in the pellets containing RDF, there was an increase in mechanical durability from 97.7 % to 99.5 % and a decrease in the fines content from 2.3 % to 0.5 % of samples 100% Biomass and 100 % RDF, respectively. This may be due to light plastics in the RDF that confer resistance to the pellets. As for the combustion properties, the addition of RDF also favored the quality of the pellets, the higher heating value (HHV) increased by 16 %, from 17.46 MJ/Kg for 100 % Biomass pellets to 20.85 MJ/Kg for 100 % RDF pellets. All the pellets produced presented and energy density value above 10.5 GJ/m³, and for pellets 100 % RDF, the energy density was the highest (11.5 GJ/m³). Regarding the slagging and fouling indices, the addition of RDF led to an increase in the concentrations of alkali metal oxides, and chlorine, both strong indicators of potential slagging and fouling problems. All RDF-containing pellets complied with the EN ISO 21640:2021 recovered solid fuel standard for energy recovery in incineration and co-incineration plants. Overall, this work demonstrated that mixing RDF with biomass can provide high-quality pellets with a high load of waste material under the same operating conditions necessary for biomass pelletization.

Keywords

Pellets, refuse-derived fuel, biomass, energy source, combustion, biofuel

BIOLPG PRODUCTION AND MARKET DYNAMICS

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ABSTRACT

BioLPG (biogenic liquefied petroleum gas) is a renewable fuel with growing potential as a sustainable alternative to fossil-based LPG. In 2020, BioLPG accounted for only 0.06% of the global LPG market, primarily derived as a byproduct of hydrotreated vegetable oil (HVO) and sustainable aviation fuel (SAF) production. This process, utilizing waste and vegetable-based oils as feedstocks, yields BioLPG at approximately 10 wt.% of the total output, with the EU and the USA leading production. Market expansion is supported by leading energy companies, such as Neste and Total Energies, operating facilities with annual BioLPG capacity exceeding 50,000 tons.

The market for BioLPG is driven by global policy shifts, including the EU's ambitious 2030 renewable fuel targets and incentives favoring waste-derived biofuels. Despite limited direct policy measures for BioLPG, its eligibility for double-counting schemes and decarbonization benefits position it favorably for growth. Key demand drivers include increasing environmental awareness, policy incentives, and consumer preferences for sustainable products. On the supply side, technological innovations, government support, and cost-effective production methods play critical roles. Challenges remain, particularly in establishing a robust pricing framework and scaling production. However, the deployment of advanced technologies and partnerships between technology providers and market leaders are fostering industry growth.

BioLPG production largely relies on hydrotreating, a well-established process in petroleum refining, adapted for biofuel generation. The current global landscape features numerous operational and planned HVO plants, with select facilities extracting BioLPG for commercial use. As technological maturity progresses and legislative frameworks align with sustainability goals, BioLPG has the potential to emerge as a pivotal player in the renewable energy sector.

Keywords

BioLPG, Hydrotreatment, Renewable fuels, Market drivers

STUDY OF PHENOL ADSORPTION ON TO ADSORVENTS FROM THERMOCHEMICAL PROCESSES

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ABSTRACT

The promotion of systems for production of green and low-carbon energy is becoming increasingly critical for the development of countries. Biomass and waste materials are increasingly being utilized as abundant, zero-carbon renewable resources for the production of various by-products. Among these, the conversion of waste into adsorvents and its subsequent use as a low-cost, efficient adsorbent is a topic of growing research, due to its proven ability to effectively remove both organic and inorganic pollutants. Adsorption is one of the most commonly employed techniques for pollutant removal, with phenolic compounds, particularly phenol, serving as widely studied probe molecule over the years. In this context, by-products obtained from gasification and carbonization processes—derived from mixtures of biomass and refuse-derived fuel—were tested for their efficacy in liquid phase adsorption of phenol. Various activation methods were employed to produce the samples used in this study. The adsorption experiments were conducted using UV-Visible spectroscopy, and the results were analyzed through adsorption isotherms. The experimental data were then fitted to the Langmuir and Freundlich isotherm models to evaluate the adsorption capacity and mechanism of the adsorvent material.

Keywords

Phenol; Adsorvents; Liquid phase adsorption; Residues; Thermochemical processes

CARBON FOOTPRINT IN URBAN SOLID WASTE COLLECTION: A COMPARISON BETWEEN DIESEL AND ELECTRIC TRUCKS

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ABSTRACT

Transportation associated with waste collection is a significant source of greenhouse gas (GHG) emissions in urban solid waste management. Understanding the environmental impact of different collection methods is crucial for developing more sustainable waste management strategies. This study, based on a case study methodology, analyzes the carbon footprint of waste collection in Fornos de Algodres municipality (Portugal), comparing diesel and electric trucks to determine which option results in a lower carbon equivalent emissions.
The analysis focuses on energy consumption, a key factor in the sustainability of waste collection and transportation. Diesel trucks rely on fossil fuels, a primary source of carbon emissions, while electric trucks use grid electricity, with carbon emissions dependent on the national energy matrix. This study quantifies energy consumption regarding fuel volume and electricity use to compare vehicle efficiency. Additionally, it considers the potential benefits of integrating renewable energy sources into the electricity grid to reduce electric trucks' carbon footprint further.
The carbon footprint is estimated based on factors such as distance travelled, energy consumption, and the technological characteristics of the vehicles. The study evaluates battery efficiency in electric trucks and fuel combustion efficiency in diesel trucks to provide a more comprehensive assessment. Furthermore, operational efficiency is evaluated through route design, collection frequency, and load capacity, as these factors influence each option's feasibility and environmental impact. In addition, this study also considers economic and social implications, including the long-term cost associated with the initial investment, operational expenses, and potential government incentives.
The findings will address the core question: Is waste collection in Fornos de Algodres municipality (Portugal) more sustainable with electric or diesel trucks? This research aims to guide decision-making in both the public and private sectors, encouraging solutions that minimize GHG emissions and promote sustainable urban mobility. By providing a detailed comparison, the study supports policymakers in implementing more effective waste collection strategies aligned with broader environmental goals. Moreover, the results will be relevant not only to the municipality analysed but also to other municipalities and waste management companies, considering a transition to greener collection methods.

Keywords

Carbon footprint, Solid waste collection, Electric and combustion transportation, Sustainable mobility.

VALIDATION OF A GIS MODEL TO IDENTIFY MARGINAL SOILS IN MAINLAND PORTUGAL

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ABSTRACT

As energy is fundamental for the development of human life, an increasingly latent and growing need to seek alternative energy sources exists. Bioenergy is a renewable and alternative energy, which is produced from the conversion of organic material, namely, biomass (including energy crops and wastes) through biological, chemical, thermochemical, and biochemical processes. Energy crops are industrial species (perennial, woody and annual species, algae, among others) that can generate energy, biofuels and bioproducts. The soils that should be most adequate for the production of energy crops in mainland Portugal are marginal soils (e.g. salinity soils), degraded soils (lands eroded by natural factors such as climate change that cause a physical, chemical and biological change in its nature, generating soil desertification), and contaminated soils (polluted with toxic elements and polymetallic agents) avoiding Indirect Land Use Change (ILUC) burdens. Based on a previous study that mapped the marginal areas of mainland Portugal, using tools and baseline documents and ArcGIS software as a GIS tool, three specific areas were subsequently selected to implement energy crops. This work aims to present the soil characterization of the chosen areas (pH, electrical conductivity, total organic carbon, etc), in order to identify additional constraints to the cultivation of the energy crops not foreseen in the modeling and also to validate the model used. Among the different marginal areas identified by the model, the three soils chosen correspond to three regions with different edaphoclimatic conditions of mainland Portugal, namely, Braga in the north (region with high precipitation), Loures in the Metropolitan area of Lisbon and Mértola, further south, specifically at São Domingos Mine. Based on the marginal map obtained, the Braga soil is acidic, with a pH of 4.87 and slopes between 16% and 25%, the Loures soil has a topsoil containing 30% or more of clay (52%) and the São Domingos soil is very acidic (pH ≈ 3.95). In each of the three selected areas, the soil was collected and then characterized. Results obtained on the analysis of the collected soils show that the model used to map the marginal soils can be validated. Furthermore, the global soil characterization allows to identify additional physicochemical information important to classify the soil in terms of characteristics for the growth of selected energy crops, i.e. N and P content, heavy metal content, cation exchange capacity (CEC), among others.

Keywords

Low ILUC, energy crops, marginal soil, degraded land, contaminated soil, soil properties.

A SUSTSAINABLE MANAGEMENT OF VOLCANIC ASH: A FOCUS ON ETNA VOLCANO

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ABSTRACT

The fallout of volcanic ash (VA), in addition to being dangerous for human health, constitutes a significant economic damage for agricultural activities and causes imaginable difficulties for vehicle circulation, so much so as to induce the authorities to limit their speed and often even prohibit their use, at least until a sufficient level of safety can be guaranteed. The presence of such particles in the atmosphere, up to heights of several kilometers, also represents a very great danger for air navigation and often leads to closures of the airports involved and deviations of air traffic.

Therefore, the fall of volcanic ash causes problems not only to the population living in that area, but also weighs on the municipal administrations, which must deal with getting rid of the volcanic ash, collecting it and dispose it in the safest way as soon as possible. This inconvenience found in all those areas where there are active volcanoes, has pushed the scientific community, in the perspective of the circular economy, to consider volcanic ash not as a problem but as a resource by reusing it as a replacement for raw materials used in various fields The present work aims to propose environmentally and economically sustainable management solutions for the valorization of volcanic ashes to solve the issues - deeply felt in the cities around the ETNA volcano - of managing sudden and tremendous quantities of ash produced by unpredictable eruptive events.

Starting from a critical review of the literature in which the performance of VA applications has been analyzed, sustainable reuse solutions have been identified, with particular reference to use in agriculture.

The volcanic ash collected during the eruptive events of ETNA Volcano in 2021 was characterized from a physical-chemical point of view with a specific focus on the leaching behaviour to verify their possible recovery. Moreover, a protocol for sustainable management and regulations compliance was devised for different reuse strategies. The different samples were characterized by analyzing the presence of light and heavy hydrocarbons, PCBs (polychlorinated biphenyls) and PCTs (polychlorinated triphenyls) and PAHs (polycyclic aromatic hydrocarbons), the Acid Neutralization Capacity (ANC) and the Total Organic Carbon (TOC). Furthermore, elemental analysis was performed by studying the pH, the residue at 105°C and the residue at 600°C. Subsequently, the analysis of metals and the leaching test to analyzing anions were performed.

The characterization results were compared with the limits imposed by Italian legislation on recovery (Ministerial Decree 05-02-98) and by the discipline on fertilizers (D.Lgs 29-04-2010, n.75) demonstrating the feasibility of an alternative and sustainable use of volcanic ash in agriculture. The activities were conducted in collaboration between the University of Catania, National Institute of Geophysics and Volcanology, Cisma Ambiente S.p.A. and ENEA.

Keywords

volcanic ash, waste valorisation, sustainable recovery, fertilise

RE-FEED: RENEWABLE ENERGY PRODUCTION AT FARM LEVEL FOR ENERGY EFFICIENCY AND DEFOSSILIZATION

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ABSTRACT

Agricultural activities generate considerable organic waste, including crop remains, animal manure, and food processing by-products. Research on converting these materials into bioenergy is of utmost importance, as it will help reduce waste while providing new renewable energy sources. Using biomass to recover energy, decreases reliance on non-renewable sources, lowers operational costs, and reduces carbon footprint. Moreover, defossilization is essential towards achieving national and international climate objectives. Given the urgency to mitigate climate change and reduce greenhouse gas emissions, integrating bioenergy solutions using residual biomass into the agricultural sector emerges as a critical strategy. The pig sector has high economic importance and is strategic for food self-sufficiency. Portugal's mainland has 4,000 industrial pig farms, distributed mainly along the coastline between Coimbra and Santiago do Cacém. Furthermore, the pig sector has relevant energy needs for feed production, heating animals, etc. Therefore, the RE-FEED project aims to act at two levels: (i) promote energy efficiency by conducting energy audits at pig farms and defining energy efficiency measures; (ii) assess a strategy to valorize waste by converting slurry into a valuable energy source and a safe organic fertilizer. The project will implement a proof-of-concept of renewable energy mix production at a pig farm: (i) an anaerobic co-digestion pilot, processing a feeding mixture of pig slurry and agri-food biomass, (ii) a photovoltaic system, and (iii) a solar thermal system. Several possible scenarios of biogas use will be assessed. The digestate produced will undergo solar thermal hygienization, ensuring its safety and adding value to the circular economy model. RE-FEED also aims to empower farmers by facilitating the establishment of energy communities and offering alternative methods for energy generation. Adopting various renewable energy technologies applicable to agriculture, such as biogas systems and solar panels, is of paramount importance. These solutions provide farms with sustainable energy and create energy savings and carbon credit sale opportunities. Innovation and research in biomass conversion, energy storage, and economic feasibility are key areas for advancing renewable energy integration in agriculture. Despite these benefits, challenges such as high initial investment costs, technical complexities, and regulatory barriers remain. The RE-FEED project highlights the importance of government support, financial incentives, and technical assistance programs in facilitating the adoption of renewable energy practices, since without that, the change cannot happen. Community engagement and collaboration among farmers, researchers, and policymakers are crucial for successfully implementing sustainable energy solutions. The expected results from creating an integrated renewable energy community at the farm level include increased energy efficiency, reduced greenhouse gas emissions, sustainable waste management through waste-to-value conversion, and potential carbon offset transactions. The energy efficiency measures, proposed based on the results from energy audits, will allow farms to enhance operational efficiency and reduce costs. Additionally, creating energy communities brings economic benefits for farmers, energy cost savings, joint revenue streams, job creation, and collaborative efforts between the agricultural and energy sectors. Collectively, these outcomes underline the environmental, economic, and social advantages of adopting renewable energy practices in farming.

Keywords

Anaerobic co-digestion, Agro-food waste, Energy Community, Energy Efficiency, Renewable Energy Mix.

VALORIZATION OF AGRO-INDUSTRIAL WINE RESIDUES THROUGH EXTRACTION WITH GREEN SOLVENTS

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ABSTRACT

Residues generated by agro-industries are an important source of global waste, representing a significant percentage of the total residue produced worldwide as well as on a national and regional scale. Therefore, the valorization of this class of residues must be one of the aims regarding the principles of circular economy. Additionally, the use of green (environmentally friendly) processes and solvents must be another objective to have in mind, due to the growing environmental concerns. This study was then focused on the wine industry wastes and their valorization through the extraction with green solvents, envisaging the recovering of polyphenols. This class of compounds is present in significant amounts in several types of wine residues and is well known for its antioxidant properties and for the positive effects on health: anti-cancer, anti-age, among other advantages. In previous research works, the residues generated by wine production were characterized and quantified in terms of organic and inorganic matter, moisture, total Kjeldal nitrogen, phosphorus, starch, and crude fiber. Residues from regional wine industry production of two subsequent years (2023 and 2024) were selected and then compared. The preparation of the wine-industry residues before the extraction involved distinct methods: drying overnight (at 50ºC) only; drying overnight (at 50ºC) followed by crushing in a mill; lyophilization for approximately 13h and crushing in a mill. Further, the extraction of polyphenols from wine-industry residues was carried out using green solvents (namely water and ethanol) and several extraction methods were then compared: "classical" extraction using Soxhlet devices; extraction overnight with agitation; extraction overnight with agitation followed by ultrasound treatment (for 40 min- 2 sets of 20 minutes each); extraction overnight with agitation ended with pH adjustment (neutralization);water with ultrasound at 50ºC during 30 min. Polyphenol quantification was developed using the traditional method with Folin-Ciocalteu reagent, sodium carbonate and standard solutions of gallic acid. Gallic acid solutions with 25, 50, 75, 100, 200, 300, 400 and 500 mg/l were prepared from the dilution of the standard solution. Absorbances of the treated samples were read in a spectrophotometer at 765 nm. In what concerns the classical Soxhlet extractions, a mixture of 50% water and 50% ethanol proved to be the most promising solvent to carry out this type of extractions. However, high times of extraction (over 2h30min) and high energy consumption were required. Therefore, some alternative extraction techniques envisaged were the extraction overnight, ultrasound treatment and pH adjustment. Regarding these alternative techniques, it was possible to obtain concentrations of polyphenols ranging from 0,2151 g/L to 0,8519 g/L. Lyophilization did not seem to favour the extraction efficiency and the more recent/fresh residues from 2024 had quite higher polyphenol content comparing to those collected in 2023. The antioxidant activity of these extracts was evaluated showing promising results.

Keywords
Wine Industry, Grape Pomace, Grape Seeds, Polyphenols, Valorization, Green Solvents.

GREEN CHITIN: SUSTAINABILITY AND GREEN METRICS IN CHITIN RECOVERY FROM VARIOUS WASTE SOURCES WITH A FOCUS ON INSECTS

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ABSTRACT

Chitin, a biopolymer with versatile applications in biomedicine, packaging, and sustainable materials, has conventionally been sourced from crustacean waste, such as shrimp and crabs. However, with the increasing need for environmentally responsible material recovery, alternative sources such as insects and fungi are also explored and getting attention. Despite this shift, a systematic comparison of waste utilization strategies for chitin recovery from these sources remains underexplored. Furthermore, there is a lack on sustainability assessments, particularly those involving Life Cycle Assessment (LCA) and other green metrics. Thus, this study aims to bridge these gaps by (a) systematically reviewing waste utilization approaches in chitin recovery from crustaceans, insects, fungi, and other biomaterials, (b) critically assessing the sustainability profile of insect-based chitin, considering environmental impact, processing challenges, and circular bioeconomy potential, and (c) providing an experimental proof-of-concept study evaluating the sustainability of demineralization techniques for chitin extraction from insect wastes.

A systematic literature review analyses the extent of waste valorization across different biological waste resources. Crustacean-derived chitin continues to dominate industrial and academic fields, whereas fungal and insect-based chitin sources remain relatively underrepresented. Additionally, the review highlights that Life Cycle Assessments (LCA) and other "green" metrics are inconsistently implemented. Thus, a direct comparison of environmental impacts based on the different resources is challenged. However, insect-derived chitin offers promising advantages in terms of waste stream utilization, rapid biomass regeneration, and reduced ecological footprint. Nevertheless, concerns persist regarding the standardization of extraction processes and scalability of production. To supplement the review, an experimental evaluation of demineralization strategies for insect-derived chitin was conducted. Various acid-based extraction approaches (HCl, HNO_3, H_2SO_4, H_3PO_4, citric acid, and formic acid, all 1M) were tested to determine their efficiency and environmental viability. Hydrochloric and nitric acid demonstrated the highest demineralization efficiency, resulting in ash contents of 0.1% (HCl) and 0.2% (HNO3), respectively. However, these methods were associated with lower chitin yields (HCl: 55.8% and HNO3 56.4%), potentially limiting their practical sustainability. Conversely, formic (FA) and citric acids (CA) exhibited slightly lower demineralization rates (ash content of FA: 0.5% and CA: 0.4%) but preserved higher overall chitin yields (66.2% and 65.4%), highlighting a preferable balance between efficiency and environmental considerations. This study underscores the necessity of integrating systematic sustainability assessments in chitin recovery processes. By combining a critical review of waste utilization, a sustainability-focused assessment of insect-derived chitin, and experimental validation of sustainable extraction techniques, this work contributes to the development of eco-friendly, efficient chitin recovery methodologies. Future research should prioritize the optimization of extraction techniques, adaption of sustainability evaluations, and broader industrial implementation of insect-derived chitin for a circular bioeconomy.

Keywords

Circular Bioeconomy, Green Extraction, Waste Valorization, Sustainability, Chitin, Insects

ASSESSMENT OF WASTE DERIVED AMENDMENTS FOR THE *IN SITU* STABILIZATION OF ACID SOILS FROM A PYRITE MINE

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ABSTRACT

Soils from abandoned mines located in the Iberian Pyrite Belt (*e.g.*, Aljustrel, Lousal, Sao Domingos), present significant environmental challenges for their rehabilitation, due to soils extreme acidity and high total metals and metalloids concentrations. These conditions inhibit plant growth, even in areas subjected to constructive remedial actions, due to the remaining potential for acid mine drainage. Despite these challenges, there is potential for the revegetation of these soils, primarily through the cultivation of species adapted to climatic adverse conditions, or even to the production of a benefit crop (e.g., bioenergy crops). However, these solutions demand for the previous *in situ* stabilization of soils, to mitigate the effects of acidity and contamination, further providing the essential nutrients for crop development. In this context, a laboratory incubation experiment was conducted, to understand how waste-derived amendments can be used to improve the properties of a soil sampled in the Aljustrel's mine area. Biochar (B) from forestry residuals was chosen for its ability to improve soil structure, increase water holding capacity, nutrient retention and counteract soil acidity; municipal solid waste compost (MSWC) was selected for its high organic matter (OM) and nutrients content; and oyster shell powder (O) was used as liming agent, given its high calcium carbonate content ($CaCO_3$ ~ 96%). Biochar and MSWC (64 g/kg application dose for both, the equivalent to 100 t/ha), and oyster shell powder (11.5 g/kg), were applied to the mine soil (S; 250 g soil samples), individually (SB, SC, and SO) and in combination (SBC, SBO, SCO, and SBCO). To evaluate the effects of increasing the application dose of biochar, additional treatments with 2-times (128 g/kg) and 5-times (320 g/kg) of the standard dose were also prepared. All treatments were prepared in triplicate, incubated for one-month at 70% of its water-holding capacity (WHC), room temperature of ~20^{o}C, monitored weekly for soil pH modifications. After the incubation period, all samples were analysed for their: pH, electrical conductivity, OM content, N Kjeldalh, extractable P and K, cation exchange capacity, and bioavailable fractions of As, Cu, Pb and Zn, extracted by $CaCl_2$ 0.01 M solution (1:10 w/v). The mine soil was very acid (pH = 3.5), and the biochar application, even at 5-times the selected application dose, was only able to increase soil pH to 4.6. Oyster shell powder was much more effective to counteract soil acidity, able to replace conventional liming materials, increasing soil pH to circa neutral values. MSWC was also able to, individually, increase soil pH above 5.0, while also increasing soil OM content, as well as nutrients content (total N, available P and K). The reduction on bioavailable Cu, Pb and Zn fractions was accomplished by the application of MSWC and oyster shell powder, alone or in combination, while biochar application was very effective to increase soil OM content. Given the results, a combination of the three waste-derived amendments would be recommended for the *in situ* stabilization of this type of mine affected soil.

Keywords

Biochar; municipal solid waste compost (MSWC); oyster shells wastes; soil amendments; pyrite mine soils; soil remediation.

BLACK SOLDIER FLY EXUVIAE: EXPLORING THIS RESOURCE FOR CHITIN PRODUCTION

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ABSTRACT

Insects, such as black soldier fly, have gained increasing attention as sustainable source of biomaterials, as well as an alternative for food and feed, mainly due to their ability to convert biowaste into compounds of increased interest such as proteins, lipids, and amino acids. This growing interest has also led to a rise in residual substrate, also known as frass, which comprises, among other residues, larval feces, undigested food, and the pupal exuviae, the latter being an abundant and unexploited source of chitin. Chitin is a precursor of chitosan, a valuable polysaccharide with applications across multiple fields, from biomedical uses to food packaging. Demineralizing and deproteinizing the substrate are the first steps to obtain chitin from exuviae. In the demineralization step, minerals, primarily calcium carbonate, are removed through acidic treatment, while deproteinization involves the removal of proteins via an alkaline treatment. The remaining material is then converted into chitosan through further processing with sodium hydroxide. This conventional methodology employs in the demineralization process strong inorganic acids, e.g. hydrochloric acid, given its efficiency in removing calcium carbonate from the substrate. Yet, the process generates acidic waste that poses an environmental concern. This encourages research towards greener methodologies for chitin extraction. In this regard, this study aims at the evaluation of the effectiveness of milder and greener acids at removing minerals from black soldier fly exuviae. Tests were conducted for 3 hours at room temperature to reduce energy consumption and minimize potential degradation of chitin. Preliminary results suggest that greener acids, namely citric and formic acids at 1 M, are as effective at removing minerals as the conventional hydrochloric acid at the same concentration, with a demineralization efficiency of 97.02 ± 1.37% and 97.82 ± 1.38%, respectively, compared to 98.20 ± 0.65% for hydrochloric acid (n = 3). These findings contribute to the ongoing search for more sustainable extraction methods, highlighting the potential of organic acids as environmentally friendly alternatives in chitin extraction. By optimizing these approaches, we can enhance the viability of insect-derived chitin and chitosan production while reducing the environmental issues related to the extraction process. Additional work is being conducted to obtain chitin from exuviae and to process it into chitosan.

Keywords

Chitin, Chitosan, Insects, Exuviae, Subproducts

CYNARA CARDUNCULUS L. BY-PRODUCTS AS A SUSTAINABLE SOURCE OF BIOACTIVE COMPOUNDS FOR INDUSTRIAL APPLICATIONS

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ABSTRACT

Cynara cardunculus L. (cardoon) is a versatile perennial crop that thrives in challenging environments with high productivity. Its flowers are valued for their coagulating properties in cheesemaking, while its leaves, rich in bioactive compounds, are normally discarded. This study aimed to assess the antioxidant and antimicrobial potential of ethanolic and methanolic extracts from fresh and dried cultivated cardoon var. *altilis* DC leaves (FCC and DCC, respectively) to evaluate the impact of oven-drying with forced air circulation on the bioactive profile of the leaves.

Dried cultivated cardoon leaf extracts exhibited stronger antioxidant activity than fresh leaf extracts, although fresh leaves contained a greater variety of polyphenolic compounds. Among the 16 identified compounds, chlorogenic acid, apigenin, and luteolin were the most abundant. The best antioxidant activity was observed in dried leaf extracts for both methanolic (EC50 = 0.8 mg/mL, AAC = 279.67) and ethanolic (EC50 = 2.1 mg/mL, AAC = 448.06) solvents.

Regarding antimicrobial properties, Gram-positive bacteria showed higher sensitivity to both ethanolic and methanolic extracts compared to Gram-negative bacteria. The dried leaf ethanolic extract demonstrated stronger antimicrobial activity, with lower minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values (125–2000 µg/mL) across most tested microorganisms. Dried leaf extracts exhibited better antimicrobial efficacy than fresh leaf extracts, although only mild inhibition was observed against *Aspergillus fumigatus*. In conclusion, the findings suggest that dried cardoon leaves are a valuable by-product as a source of bioactive compounds for various industrial applications, particularly in the food industry, as well as in cosmetic and pharmaceutical industries. In this sense, the use of active compounds obtained from cardoon leaves is aligned with the concepts of circular economy and sustainability. More specifically, it is aligned with the United Nations Sustainable Development Goal 12, Ensure sustainable consumption and production patterns. This approach promotes both environmental and economic sustainability by transforming high-value by-products into innovative applications.

Keywords

Cardoon; Antimicrobial properties; Antioxidant properties; Circular economy; Chlorogenic acid

DECISION-SUPPORT FRAMEWORKS FOR INDUSTRIAL SYMBIOSIS PRACTICES IN PHOTOVOLTAIC WASTE MANAGEMENT

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ABSTRACT

Transitioning to a circular economy necessitates not only the promotion of renewable energy but also the sustainable management of resources, particularly in the face of escalating waste challenges. The rapid expansion of photovoltaic installations underscores the urgent need to effectively manage waste electrical and electronic equipment streams, especially decommissioned photovoltaic panels. If not properly managed, these panels could undermine the environmental benefits of clean energy and impede the recovery of critical raw materials.

With this review, we aim to critically examine existing decision support frameworks that integrate Lifecycle Assessment and Multi-Criteria Decision Analysis within the contexts of industrial symbiosis and decommissioned photovoltaic panels management. By focusing on the circular economy (CE), the review highlights how waste, once considered a by-product, is now being re-envisioned as a valuable resource for recovering critical raw materials. In this paradigm, industrial symbiosis is a promising strategy for reducing resource consumption and waste generation. However, CE implementation has been challenged by the diverse and dynamic environmental, economic, and social impacts over time.

A systematic process was employed to select the most relevant literature, ensuring that the frameworks analysed, comprehensively, assess sustainability metrics. This study synthesizes current methodologies, identifies prevailing trends, and highlights critical gaps in the holistic evaluation of industrial symbiosis strategies. We emphasise the role of digital tools in waste management, which enhance data integration, streamline analytical processes, and support more informed decision-making. These digital innovations are crucial for managing the complexity of waste streams and ensuring that environmental, economic, and social considerations are balanced during the transition to a just and equitable industrial framework.

The results of this exploratory research not only advance the theoretical understanding of sustainability assessments but also offer practical guidance for policymakers, industry leaders, and researchers. The paper lays the groundwork for future research into digital waste management tools and integrated decision support systems by articulating best practices and methodological innovations. Ultimately, the findings underscore the importance of harnessing waste as a resource, mitigating environmental impacts, and fostering social and economic equity in pursuing a resilient circular economy.

Keywords

Circular economy; Industrial symbiosis; Photovoltaic waste; Lifecycle assessment; Multi-criteria decision analysis.

VALORIZATION OF PARAFFIN WAX WASTE IN CEMENT MORTARS: PHYSICAL AND MECHANICAL BEHAVIOR

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ABSTRACT

The foundry industry is an essential part of the modern economy, manufacturing vast quantities of castings annually. However, this extensive production generates significant amounts of wastes, with the majority ending up in landfills. Efforts to repurpose these wastes are necessary not only to reduce landfill accumulation but also to preserve natural resources. One of the primary residues generated by foundries is paraffin wax waste, a byproduct of the investment casting industry. This technique, which has ancient origins, allows the creation of precise castings with important applications in the automotive, aircraft, and aerospace industries. Unlike waste foundry sand, which has been widely studied for reuse, the potential applications of paraffin wax waste remain unexplored. The paraffin wax waste functions as an organic phase change material (PCM). When incorporated into construction elements, PCMs help regulate the temperature in buildings due to their capacity of store and release thermal energy in response to environmental temperature fluctuations. These properties offer social, environmental, and economic advantages, such as enhanced thermal comfort, lower reliance on nonrenewable energy sources, and reduced air conditioning usage and costs. This characteristic make PCM valuable for enhancing energy efficiency and sustainability in the construction sector. Additionally, the construction sector significantly contributes to raw material consumption. Providing solutions to repurpose industrial wastes, such as paraffin wax, can improve resource efficiency and support the principles of a circular economy. The main objective of this study was to evaluate the physical and mechanical behavior of cement mortars with incorporation of paraffin wax wastes as a replacement for natural aggregates. The replacement content used were 20%, 40%, 60%, 80%, and 100%. The results indicated that the modified mortars exhibited satisfactory physical and mechanical performance, indicating possible future construction applications for this innovative material. By utilizing paraffin wax waste in cement mortars, this study presents a sustainable alternative for waste management in the foundry industry while contributing to the development of energy-efficient building materials.

Keywords

Paraffin wax wastes, phase change material, cement mortars, physical and mechanical behavior

MULTISTAGE VALORIZATION OF FISH BY-PRODUCTS IN SUSTAINABLE BIOPROCESSING FRAMEWORKS: ADVANCING TOWARDS A ZERO-WASTE PARADIGM

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ABSTRACT

With the exponential growth of the global human population and the corresponding rise in food demand, the seafood sector has experienced a significant expansion over recent decades. This growth has been accompanied by a marked increase in the volume of fish waste generated globally, particularly as a result of industrial fish processing activities. It is estimated that up to 60% of the total fish biomass processed can result in by-products, including heads, viscera, skins, bones, and scales, which are often treated as low-value waste or disposed of without adequate treatment. This represents not only a serious environmental concern but also a missed economic opportunity. The current linear model of production and disposal is increasingly being challenged by sustainability-oriented approaches that advocate for the transition towards circular economy frameworks. Within this context, the valorization of fish processing by-products has emerged as a promising strategy to reduce environmental impact while creating additional revenue streams. Valorization refers to the biotechnological or chemical transformation of low-value biological materials into high-value products, thereby aligning environmental protection goals with industrial competitiveness. The implementation of cascade valorization strategies, in which biomass is sequentially processed to extract multiple valuable compounds, offers a particularly efficient use of resources. These strategies not only allow for the full utilization of biological material but also diversify the product portfolio derived from fish by-products. Key compounds of interest include omega-3-rich fish oil, bioactive protein hydrolysates, antimicrobial peptides (e.g., bacteriocins), natural pigments (e.g., astaxanthin), vitamins (such as A and D), collagen, gelatin, and calcium-rich mineral powders. These bioresources have applications across diverse sectors, including human and animal nutrition, pharmaceuticals, cosmetics, agriculture, and biomedicine. Moreover, advances in biorefinery technologies and green extraction methods have enhanced the efficiency and scalability of these valorization processes, making them increasingly attractive from both an economic and environmental perspective. At the same time, the integration of life cycle assessment (LCA) and techno-economic analysis into valorization planning has enabled a more holistic evaluation of sustainability outcomes. From a socio-economic standpoint, valorizing fish by-products can reduce operational costs for processing companies by lowering waste management expenditures, while simultaneously contributing to food security, bioeconomy development, and sustainable blue growth. In addition, it aligns with the objectives of global sustainability frameworks, including the United Nations Sustainable Development Goals (particularly SDG 12 – Responsible Consumption and Production, and SDG 14 – Life Below Water). This work aims to provide a comprehensive overview of the current state of knowledge regarding the valorization of fish processing by-products. It explores the main technological approaches, the range of value-added compounds that can be obtained, and the potential industrial applications of these derivatives. By critically analyzing existing practices and emerging trends, this review highlights the central role that fish by-product valorization can play in reshaping the seafood industry into a more sustainable, circular, and innovation-driven sector. The findings are expected to inform future research directions, policy-making, and industrial strategies that collectively contribute to a zero-waste future.

Keywords

Fish process industry; fish wastes, by-products; circular economy, sustainability.

OPTIMIZATION OF MULTIENZYME PRODUCTION BY *SCOPULARIOPSIS ALBOFLAVESCENS* USING COFFEE SILVER SKIN IN SOLID-STATE FERMENTATION

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ABSTRACT

The valorization of coffee by-products as sources of energy and chemical compounds through biorefinery or biotechnological approaches contributes significantly to the circular bioeconomy. Considering the pressing need for sustainable development and efficient resource use, this study aimed to optimize the production of total cellulases (Fpase), CMCase, pectinase, xylanase, manganese peroxidase, lignin peroxidase, and laccase via solid-state fermentation, using a central composite rotational design (CCRD) and coffee silver skin (CSS) as a lignocellulosic substrate. The independent variables included fermentation time (7–21 days), moisture content (65–75%), and peptone concentration (0.05–0.15%). A total of 18 experimental runs were performed, including four central points. *Scopulariopsis alboflavescen*s UFLA24, isolated from decaying wood, was obtained from the Microorganism Bioprospecting Laboratory culture collection at the Federal University of Lavras, Minas Gerais, Brazil. The strain was cultivated on YEPG agar medium (yeast extract: 10 $g \cdot L^{-1}$; glucose: 20 $g \cdot L^{-1}$; bacteriological peptone: 20 $g \cdot L^{-1}$; agar: 15 $g \cdot L^{-1}$) and incubated at 28 °C for 14 days. The inoculum was prepared by adding 15 mL of modified Mandel's solution ($(NH_4)_2SO_4$: 1.4 $mg \cdot L^{-1}$; KH_2PO_4: 2.0 $mg \cdot L^{-1}$; $CaCl_2 \cdot H_2O$: 300 $mg \cdot L^{-1}$; $MgSO_4 \cdot 7H_2O$: 300 $mg \cdot L^{-1}$; $FeSO_4 \cdot 7H_2O$: 5.0 $mg \cdot L^{-1}$; $ZnSO_4 \cdot 7H_2O$: 1.4 $mg \cdot L^{-1}$; $MnSO_4 \cdot H_2O$: 1.6 $mg \cdot L^{-1}$; bacteriological peptone: 100 $mg \cdot L^{-1}$; Tween 80: 100 $mg \cdot L^{-1}$) to the fungal colony and spreading it with a platinum loop. Spore concentration was adjusted to 6 log $CFU \cdot mL^{-1}$ using a Neubauer chamber. Fermentation was carried out in 250 mL Erlenmeyer flasks containing 15 g of sterilized CSS. The flasks were incubated at 28 °C in a shaker incubator with static temperature-controlled conditions. Homogenization was performed with a sterile glass rod. A negative control was included, consisting of 15 g of CSS without inoculum. After fermentation, the crude multienzyme extract was obtained by adding 100 mL of distilled water to each flask and shaking at 180 rpm at 25 ± 2 °C for 1 hour. The mixture was then filtered and centrifuged at 8000 rpm for 20 minutes at 4 °C. The supernatant was collected and stored at −80 °C for enzymatic activity analysis. In both linear and quadratic models, fermentation time and peptone concentration significantly affected the production of enzymes. Among the enzymes evaluated, only CMCase ($R^2 > 0.80$), pectinase ($R^2 > 0.90$), and lignin peroxidase ($R^2 > 0.70$) showed a statistically significant model fit, indicating good predictive accuracy. Optimal enzyme production was achieved after 25 days of fermentation, with moisture levels above 65% and a peptone concentration of 0.18 g, yielding 169.18, 33.00, and 4833.20 U/g for CMCase, pectinase, and lignin peroxidase, respectively. These findings demonstrate that coffee by-products can be effectively utilized for the sustainable production of crude multienzyme extracts, with potential applications in plant cell wall degradation.

Keywords

Agro-industrial waste valorization, circular bioeconomy, Lignocellulosic enzymes, coffee by-products, Response surface methodology.

SUSTAINABLE PACKAGING MATERIALS: REINFORCEMENT OF RECYCLED HDPE WITH SLATE WASTE FOR IMPROVED MECHANICAL AND BARRIER PROPERTIES

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ABSTRACT

The growing demand for sustainable materials has led to the development of reinforced polymer composites aimed at enhancing the performance of recycled polymers, enabling the wider use of bio-based plastics and the valorization of industrial waste, such as slate residues. In this way, the present work consists in the development and characterization of composite materials based on recycled high-density polyethylene (HDPE), reinforced with slate particles smaller than 250 µm. The main goal was to develop a bio-based composite with improved mechanical and barrier performance, compared with the base polymer, for use in rigid packaging designed for the petrochemical, agrochemical, and detergent industries, where high performance and durability are required. Twin-screw extrusion was used to produce the biocomposites, which contained 5, 10, 20, and 30% w/w, of slate. Mechanical specimens were created by compression molding into 3 mm-thick plates. To evaluate barrier properties, films with thicknesses ranging from 0.6 to 1 mm were compression molded to mimic the normal wall thickness of industrial packaging. Tensile tests demonstrated that the addition of slate had no appreciable effect on the Young's modulus or maximum tensile strength of the recycled polymer, even at the highest loading level. This shows that the mechanical integrity of the base material is preserved even with higher slate content. In contrast, when slate content increased, the flexural modulus also increased, indicating a significant improvement in material stiffness. This increase in stiffness is especially useful in packaging applications requiring dimensional stability. Barrier properties evaluation yielded very promising results. Air permeability decreases to undetectable levels in all formulations using slate, demonstrating the biocomposite materials' more effective sealing capabilities. The addition of slate reduced water vapor permeability significantly. Adding 5% slate reduces water vapor permeability by 38.54 g/m²/day compared to the base polymer, with the lowest value at 20% slate content (10.50 g/m²/day). These findings emphasize mineral reinforcement's potential for use as a diffusion barrier, which improves material performance in humid or moisture-sensitive conditions. Furthermore, UV radiation transmittance evaluation demonstrated that slate is highly effective at blocking ultraviolet light. At only 5% slate content, transmittance values across the UV spectrum were decreased nearly to zero, providing excellent protection against radiation-induced degradation, which is critical for packaging exposed to sunlight or UV-rich conditions. In conclusion, incorporating slate into recycled HDPE improves flexural stiffness and barrier properties to air, water vapor, and UV radiation while maintaining tensile strength. These improvements, combined with the underlying polymer's sustainability, make these materials suitable for durable, protective, and ecologically responsible packaging solutions in demanding industrial fields.

Keywords

Biocomposites, Packaging, Recycled HDPE, Slate

SUSTAINABLE SCHOOL FURNITURE: MANUFACTURING NEW COMPONENTS USING PP, WOOD AND SLATE WASTE

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ABSTRACT

The inadequate management of end-of-life school furniture waste, mainly composed of polypropylene (PP), particleboard and high-pressure laminate, represents a significant environmental challenge. This study explores the reuse of these heterogeneous waste materials, previously ground into smaller particles, as reinforcement and filler in new composite materials produced by compression and injection molding.

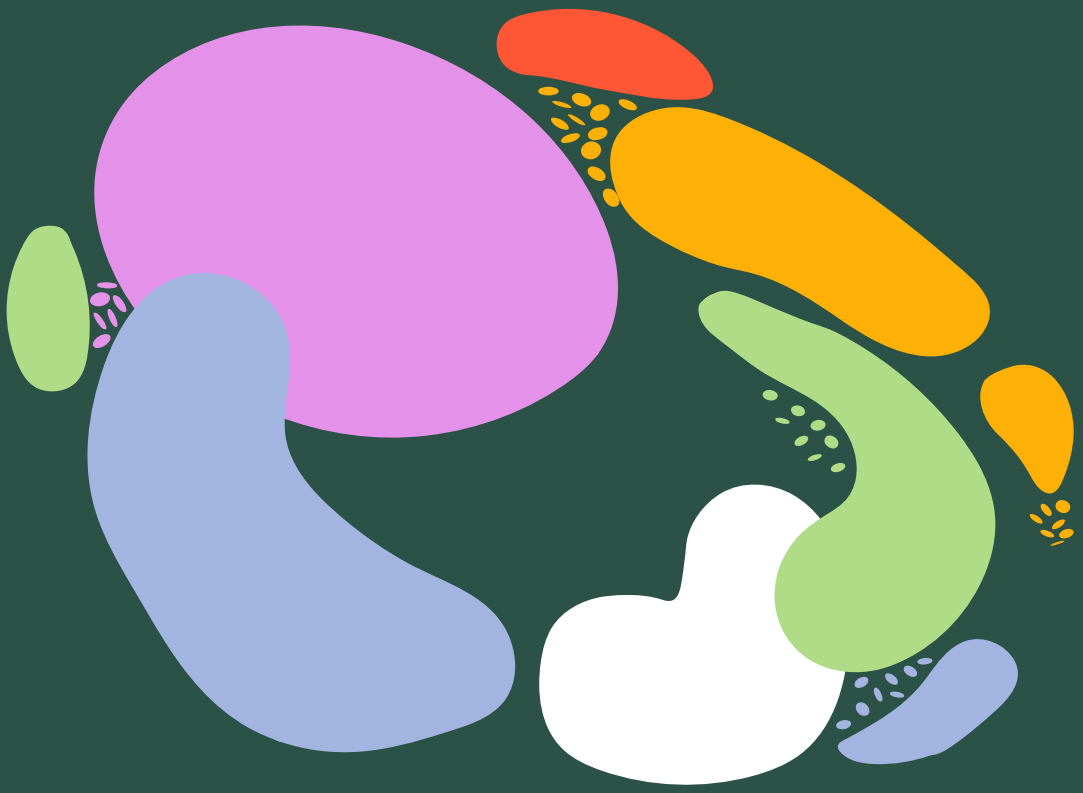
The main objective of this work is to evaluate the reintegration capacity of waste generated during the production process itself, as well as defective or end-of-life furniture components, thereby closing the material loop in a circular economy approach. After collecting, the different residues undergo an initial treatment that includes shredding and careful particle size control. Coarser fractions are used in compression molding processes, while finer particles are blended with recycled polypropylene (rPP) by extrusion and subsequently shaped by injection moulding. Before processing, the materials are dried to reduce moisture content and then mixed to ensure homogeneous distribution of the waste within the matrix.

Focusing on compression moulding, two matrix systems were investigated: a thermosetting epoxy resin and rPP. For the thermosetting matrix, waste was added in high proportions of 60, 70, and 80 wt%, while for the rPP matrix, lower addition levels of 30, 40, and 50 wt% were tested, alongside a reference sample consisting of 100 wt% rPP. Flexural tests showed a decrease in mechanical strength of up to 60% with increasing waste content, but also an increase in flexural modulus of up to 40%, which suggests a stiffer composite material. The epoxy-based samples achieved the highest strength, while thermoplastic matrix composites exhibited lower surface roughness and a more uniform finish, which may be advantageous in aesthetic applications.

Although this is an ongoing study, the initial prototypes have already been produced, demonstrating the feasibility of transforming pre- and post-consumer waste into new products, suitable for school furniture. These results reinforce the potential of combining thermoplastic and thermosetting processing routes to maximize waste valorization and contribute to a more sustainable product lifecycle.

Keywords

Recycled polypropylene, wood-based waste, compression molding, composite, school furniture



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