Iberoamerican Congress on Biorefineries (5º.2024.Jaén)

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Introduction

The 5th Edition of the Ibero-American Congress on Biorefineries will be held in Jaén, Spain, from 2 to 4 October 2024 at IFEJA, with the aim of continuing to address issues of vital importance for the advancement of biorefinery research. The Congress is organised by the Ibero-American Society for the Development of Biorefineries (SIADEB), the Spanish Network of Excellence in Biorefineries and the University of Jaén.

This 5th edition will showcase the latest advances in the challenges ahead in the development of biorefineries, bringing together scientists, industry professionals and stakeholders from around the world in a collaborative environment to drive the field forward and shape a future where sustainable biorefinery solutions lead the change.

SIADEB, the Ibero-American Society for the Development of Biorefineries, brings together a wide range of researchers from six Ibero-American countries (Brazil, Colombia, Cuba, Chile, Mexico and Venezuela), Spain and Portugal and aims to promote the active participation of companies, Universities and research centres to develop the new generation of biorefineries.

The Spanish Network of Sustainable Biorefineries brings together 15 universities and research centres around the research of biomass conversion processes in a wide range of biofuels.

The University of Jaén, through the Department of Chemical, Environmental and Materials Engineering, and specifically the 'Chemical and Environmental Engineering' research group TEP 223, has been developing over the years an important research work oriented to the use of agro-industrial and forestry agricultural waste (in particular those derived from olive groves) to obtain biofuels, These can be used as substitutes or additives for petrol, as well as other high added value products, such as antioxidants of natural origin, oligosaccharides, renewable chemical compounds or organic fertilisers, applicable to various industries.

In this way, Spain, with its enormous biomass potential, would considerably improve its economic and environmental balance, while reducing its energy dependence on fossil fuels and generating employment.

The aim of the 5th edition of the Ibero-American Congress on Biorefineries is to show, from 2 to 4 October 2024, through the presentation of oral communications and/or posters, the latest advances in the field of biorefinery through the integral use of biomass, in a sustainable way, for the simultaneous production of biofuels, energy, materials and chemical products with added value.

The aim is to demonstrate viable innovative solutions for biorefineries, for which specialists from all relevant areas of knowledge will be involved, from agriculture and agro-industrial economics to process engineering, including key areas such as energy, biotechnology, chemistry, logistics and modelling.

The joint work of researchers, farmers, entrepreneurs and government representatives is essential to achieve the use of a widely available renewable energy source such as biomass, which allows regional development and at the same time represents an environmentally friendly action.

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COMMITTEES

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Opportunities and challenges for the production of advanced biofuels and bio-based chemicals by biomass catalytic pyrolysis and bio-oil upgrading

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Keywords: biomass; lignocellulose; bio-oil; pyrolysis; zeolite catalyst

Abstract

Biomass pyrolysis is a topic of currently high interest since this process allows transforming many types of bio-residues into gaseous, liquid and solid biofuels. Pyrolysis is a relatively simple process involving the thermal decomposition of organic matter in an inert atmosphere (usually at ambient pressure), which can be performed under a wide range of temperatures (350 – 800 ºC) [1]. In particular, lignocellulose pyrolysis has been intensively investigated in the past two decades as a route to directly produce liquid biofuels, i.e. in a single step, with high yields. However, the liquid fraction so obtained (bio-oil) presents a number of undesired properties (high viscosity, acid pH, low calorific value, limited stability) due to its large oxygen content (> 40 wt.%) derived from the presence of a great variety of oxygenated compounds, as well as of water [1].

A number of processes has been proposed for bio-oil upgrading, catalytic pyrolysis, hydrodeoxygenation and aldol condensation being considered the most effective routes as they afford the extensive removal of oxygen. Catalytic pyrolysis presents the advantage of operating under vapour phase conditions at moderate temperatures (400 – 500 ºC) and atmospheric pressure, hence it can be directly and easily coupled with the biomass thermal pyrolysis step [2]. Among the great variety of catalysts tested in lignocellulose catalytic pyrolysis, zeolites (specially ZSM-5) exhibit the best performance due to their singular properties (crystallinity, stability, uniform micropores and tailored acidity), promoting deoxygenation reactions of the bio-oil vapours and the formation of aromatic hydrocarbons that can be used as both raw chemicals and in the formulation of advanced biofuels [2]. On the other hand, catalytic pyrolysis of lignin-rich materials leads to bio-oils with a high concentration of oxygenated aromatics that can be used for the production of different raw chemicals. However, two main issues limit the commercialization of this type of process: i) the low yield of the upgraded bio-oil and ii) the fast deactivation of the catalyst due to the deposition of carbonaceous matter.

Different strategies have been assessed to overcome those limitations, like the modification of the zeolite catalysts with metallic phases to attenuate and complement their acid properties or the use of hierarchical zeolites, containing both micro- and mesopores and showing improved mass transport features [1,2]. Likewise, co-processing of lignocellulosic materials with H-rich feedstocks have led to very promising results. Thus, a strong synergistic effect has been realized in the co-pyrolysis of lignocellulosic residues and polyolefinic plastic wastes, with enhanced both deoxygenation activity and aromatic hydrocarbons production. These positive results have been assigned to the interaction, through Diels-Alder reactions, between furans coming from lignocellulose pyrolysis and light olefins formed by polyolefin end-chain cracking, thus offering a very effective route for the formation of aromatic hydrocarbons. Finally, it is worth to highlight a number of interesting recent developments in the field of biomass catalytic pyrolysis, such as stepwise pyrolysis, catalyst combination in cascade processes and low-pressure hydropyrolysis, which should be explored further in the near future.

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Challenges on the extraction and production of biomolecules from residues for the development of biorefineries

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Keywords: biorefineries, extraction, transformation, sustainable

Abstract

The development of biorefineries - sustainable processing of biomass into a spectrum of marketable products and energy - demands that green materials and concepts are applied along the entire production chain, while not forgeting their econonomic and social impact.

Initially the development of biorefineries has been driven by the production of secong generation bioethanol in order to make use of the remaining lignocellulosic material after the extraction of fermentable sugars. Nowadays, it is clear that modern biorefineries will play a key role in the development of biobased economy and will be used for the extraction and production of a large amount of biomolecules. An economy based on innovative and cost efficient use of biomass for the production of both biobased products and bioenergy should be driven by well-developed integrated biorefining systems.

Typically, the lignocellulose-based wastes include agricultural wastes, forestry residues, grasses, and woody materials. For instance, forestry residues (including wastes from wood, pulp and paper industries), dedicated crops, short rotation crops, wastes from agrofood industries, or tertiary wastes were initially used for bioethanol. On the other hand, residues derived from food industry including peels, seeds, shells, hulls provide a high percentage of nonstructural components (phenolic compounds, essential oils) with interesting bioactive activities.

A wide range of products is expected to be obtained in modern biorefineries, the molecules that will be extracted/produced will depend on the starting material and will accordingly require the use of different extraction and transformation technologies. This makes the definition of the main valorization routes to be applied the main challenge in this field, these routes greatly depending on the source of lignocellulosic biomass.

Results on the development of different technologies for the processing of biomass aiming at the development of advanced biorefineries will be presented with a particular enphasis on the application of innovative and sustainable technologies for the extraction and production of biomolecules from residues.

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Novel Biogas Biorefineries

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Keywords: Biogas; Biomethane; gas-phase bioreactors; upgrading

Abstract

The increasing awareness about the need to reduce fossil fuel dependence in order to mitigate climate change, and in particular to decarbonize the transportation sector, has triggered in the past decade the production of biogas and biomethane worldwide. In Europe, this trend has been triggered as a result of the Russian invasion to Ukraine. While membrane separation has gained a major share in the biogas upgrading market over the past 5 years, research in biological methods for CO_2, H_2S and siloxane removal has also attracted significant attention. Thus, hydrogenotrophic biogas upgrading has experienced significant advances, which has resulted in the development of novel process configurations, new insights into process microbiology and significant breakthroughs in technology validation at pilot scale. The expected massive generation of hydrogen from renewable energies will boost this biogas upgrading technology. Similarly, photosynthetic biogas upgrading in algal-bacterial photobioreactors has been optimized and validated at pilot scale and semi-industrial scale, and new photosynthetic biogas upgrading concepts using purple photosynthetic bacteria have been successfully engineered. Electromethanogenesis has also emerged as a promising platform capable of partially removing CO_2 and in-situ generating the required H_2 to fully methanize the remaining CO_2 in biogas. Anoxic biotrickling filtration coupled to digestate nitrification and membrane-assisted microaerobic digestion account for the main innovations in biological methods for biogas desulphurization. In addition, the continuous biodegradation of methyl-siloxanes in biotrickling filters has been validated, with gas-liquid mass transport being identified as the main limiting step. In this context, two-phase partitioning bioreactors constructed with silicone oil can overcome this limitation. Finally, biogas has been also recently evaluated as a feedstock for the biotechnological production of commodities (biopolymers, proteins, etc.) and high-added value products (i.e ectoine), which open-up new opportunities for biogas valorization. The main limitation of this novel biorefining concept relies on the poor aqueous solubility of methane, which requires the validatio of high performance gas-phase bioreactors. The non-energetic valorization of biogas has been validated at lab scale and is currently under validation in the European Projects DEEP PURPLE, CHEERS, CIRCULAR BIOCARBON, and MANUREFINERY.

Acknowledgements – Agencia Estatal de Investigación, Consejería de Educación de Castilla y León, European Commission.

ADVANCEMENTS IN BIOREFINERY TECHNOLOGIES AND FRACTIONATION OF BIOMASS

ADVANCEMENTS IN BIOREFINERY TECHNOLOGIES AND FRACTIONATION OF BIOMASS (Index)

Innovative biomass fractionation and valorization processes using benign solvents: ionic liquids, eutetic solvents and biobased solvents in biorefinery processes

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Keywords: biorefinery, biomass fractionation ionic liquids, eutectic solvents, biobased solvents

Abstract

The development of the so called biobased enconomy, in which biomass is a key source of chemicals, materials, fuels and energy, requires the development of more eco-friendly and sustainable extraction and conversion processes, that would lead to the establishment of biorefineries and also to the circular economy concept.

To achieve those goals innovative biomass fractionation and upgrading processes are essential, and innovative solvents as ionic liquids (ILs), eutectic solvents (ES) and biobased solvents (BS) might play an essential role.

ILs and ES show a tremendous potential in biomass fractionation, not only because of their huge structural diversity, but also because of the potential of their aqueous solutions, whose dissolving potential also enable tuning the solubility of target biomass fractions, as well as on their selective recovery, with impact for example in the recovery of biomass fractions as lignin, hemicelluloses and extractives, as well as in their suitability for further valorisation.

They can also play a key role as reaction catalysts demonstrating an essential role in some biomass components conversion processes. Some highlights of this essential role include:

i) The role of ES components in delignification mechanisms as well as in the suitability of lignin for further valorisation (e.g. lignins for production of nanoparticles).

ii) The isolation of suitable polysaccharides fractions with improved digestibility for biofuels production.

iii) The effective conversion of hemicelluloses into added value chemicals as xylitol and furfural.

Finally, these solvents an also play an important role in the isolation of extracts rich in bioactive compounds.

The present talk will provide an overview of the major acheivments of our group in these domains during the last few years.

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Enhancing Fractionation and Pretreatment of Lignocellulosic Biomass by Steam Explosion in a Biorefinery Context

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Keywords: Fractionation; Pretreatment; Steam explosion; Biorefinery

Abstract

The utilization of lignocellulosic biomass for biofuel and bioproduct production within the biorefinery concept is one of the most promising alternatives for advancing a sustainable bioeconomy. Biomass pretreatment is a critical step to break down its complex and recalcitrant structure, enabling the conversion of polymers like cellulose and hemicellulose into fermentable sugars, as well as recovering other biomass components for conversion into high-value products. In this context, steam explosion (STEX) has gained significant attention due to its efficiency in fractionating biomass and preparing it for subsequent conversion processes [1].

STEX involves the application of high-pressure steam followed by rapid decompression, which disrupts the cell structure and enhances enzyme accessibility to biomass polymers. This process primarily targets the hydrolysis of hemicellulose, facilitating the recovery of xylose and xylooligomers (xylosaccharides), which can be converted into high-value products, while minimizing degradation of cellulose and lignin. STEX can be further optimized by incorporating acidic or alkaline catalysts to promote the selective solubilization of hemicellulose or lignin, depending on the desired outcome. The severity of the process is a key factor that determines the extent of lignocellulosic component solubilization and the formation of undesirable byproducts, such as furfural, 5-hydroxymethylfurfural (5-HMF), or pseudo-lignin [2,3].

Various studies have demonstrated that combining STEX with other pretreatment methods offers significant advantages, particularly in the efficient fractionation of biomass for bioethanol production and other high-value products [4]. However, process optimization remains a challenge, especially in maximizing sugar release while minimizing cellulose degradation and the formation of toxic byproducts.

Both batch and continuous reactors have been employed for STEX [1]. Case studies involving the application of a continuous horizontal pilot-scale reactor for the fractionation and pretreatment of lignocellulosic biomass will be presented, highlighting the key role of STEX in developing more efficient and sustainable biorefineries.

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Biorefinery electrification and recycling of post-consumer bio-based packaging for sustainable production of platform chemicals and biopolymers

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Keywords: Biorefinery electrification, circular economy, biopolymers, bioprocess development, platform chemicals

Abstract

Conventional biorefineries and bioprocesses converting biomass resources into bio-based platform chemicals, biopolymers and other value-added products cannot compete with petrochemical processes considering techno-economic aspects. The lower energy and carbon density of biomass resources than fossil ones, the heterogeneity of the biomass, the presence of oxygen in the renewable feedstocks and the utilization of water during processing are some of the reasons that impede the cost-competitiveness of biorefineries and bioprocesses. Thus, novel technologies should be introduced to facilitate the transition to the circular economy era. Conventional biorefineries and bioprocesses could be restructured by novel technologies using renewable electricity and by introducing new feedstocks via recycling of post-consumer bio-based plastics and CO_2 conversion technologies. For instance, non-thermal plasma for pretreatment of lignocellulosic biomass, electrochemical membrane extraction of carboxylic acids during fermentation and chemical or biotechnological recycling of post-consumer bioplastics could improve the sustainability of conventional value chains and conversion technologies.

The replacement of steam, bases, acids and chemicals by renewable electricity could reduce the environmental impact of conventional bioprocesses and biorefineries. The *in-situ* extraction of carboxylic acids produced during fermentation could minimize the inhibition of microbial growth, reduce the utilization of bases for pH control and enhance the production efficiency of carboxylic acids. Furthermore, biorefinery electrification could lead to improved resource and energy efficiency. Downstream separation and purification processes could be simplified by replacing energy-intensive unit operations. The chemical or biotechnological recycling of post-consumer bioplastics as well as the conversion of CO_2 into acetic acid or formic acid could generate carbon sources for fermentation processes leading to circular reproduction of biopolymers minimizing virgin feedstock requirements. Specific case studies will be presented to demonstrate the sustainability potential of the proposed concepts. For instance, non-thermal plasma technologies could be employed for both pretreatment of food industry waste and by-product streams (e.g. brewers' spent grains) and post-consumer bioplastic pretreatment to facilitate enzymatic hydrolysis. Electrochemical extraction of succinic acid produced during fermentation will be presented to demonstrate the significant improvement of environmental impact.

Acidogenic fermentation of process water from hydrothermal carbonization of sewage sludge: volatile fatty acids production

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Keywords: waste valorisation, hydrothermal carbonization, chain elongation, acidogenic fermentation

Abstract

Sewage-sludge valorisation using hydrothermal carbonization (HTC) results in the production of a solid product called hydrochar, with many application as a soil amendment or energy resource, and a liquid phase subproduct, process water (PW). The main aim of this work is to evaluate the production of volatile fatty acids (VFAs) from process water of secondary sewage sludge using acidogenic fermentation process. The HTC process was carried out at 230 ºC during 45 min. As inoculum a sludge from an anaerobic digester was used, with a previous thermally pretreatment for the inhibition of methanogenic microorganisms. The AF process was carried out in batch mode and in mesophilic range (35 (1) ºC) using as substrate the PW obtained from a first filtration of HTC product with a 0.5 mm filtration pore size and with an extra filtration by 0.45 µm. The effect of the pH on VFA production was also analyzed, working with the original pH of the mixtures (7.2-7.3) and adjusting it at 5.5 (with HCl 2N) and 9.0 (with KOH 2N), respectively. Process evolution was studied by making sacrificies of samples during 30 days of experiment, analyzing TS, VS, pH, VFA, total and soluble DQO, glucose, lactic acid and ethanol concentrations, as well as gas volume production and its composition.

The highest production of VFA was obtained for PW filtered by 0.45 µm and working with the original pH, achieving concentrations of 9.0 g DQO/L, followed by both experiments that worked with pH = 9.0 with a VFA production of 8.5 g DQO/L. In the case of the experiment that used PW without an extra filtration and without pH modification there was a VFA production of 7.7 g DQO/L. The experiments carried out with pH = 5.5 did not produce any VFA. Biogas production was almost insignificant and no methane was detected.

Regarding the results obtained, another experiment was carried out to study VFA chain elongation into medium chain carboxylic acids (MCCAs) with the addition of different doses of ethanol and lactic acid (from 5 to 15 g/L), respectively. The best condition (PW filtered by 0.45 µm and original pH) was used and also working in batch mode and mesophilic range, studying process evolution during 30 days. A higher production of VFA was obtained when the dose of ethanol was increased until 15 g/L in the reaction medium, achieving a production of 21.2 g DQO/L of which acetic acid (C2) and caproic acid (C6) represented the 16.3% and 45.6%, respectively, comparing to control where C2 and C6 represented the 41.5% and 0.1%. In the case of the experiments with 15 g/L of lactic acid, the total VFA production was 23.1 g DQO/L, but chain elongation only achieved an increase in butyric acid (C4) concentration, representing the 37.2% of the total VFA production, respect to the 1.0% of C4 achieved in the control reactors.

In the chemical industry, C4 is used in the production of many additives in foods, perfumes, flavorings or also in the pharmaceutic industry [1]. In the case of C6, it is used as an antimicrobial agent in the pharmaceutical industry, as an additive in human and animal feed or a possible precursor of biofuels [2]. In conclusion, with the addition of higher doses of ethanol a higher VFA total production is achieved and also a higher caproic acid concentration, while in the case of the lactic acid addition the chain elongation is favored until butyric acid.

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