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Editorial

Editorial: Biomass Derived Heterogeneous and Homogeneous Catalysts, 2nd Edition

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1. Introduction

There are plenty of challenges related to the current energy situation. For instance, conventional energy sources, mainly derived from petroleum or oil, are continuously decreasing due to different factors such as population growth, continuous industrialization (including developing areas), and unsustainable transportation models. On the other hand, energy dependency due to traditional energy sources is a real menace for those countries or regions without any alternatives, as geopolitical factors are becoming increasingly present in international settings, making prices unstable in many sectors, such as energy, raw materials, etc. [1].

As a consequence, this situation is a global concern, and many of the above-mentioned problems have sought to be avoided through the use of sustainable alternatives, such as the implementation of green chemistry or circular economy policies, where biorefineries can play an important role [2]. In that sense, the production of biofuel and bioproducts that can present properties compared to equivalent compounds derived from oil can contribute to the implementation of these facilities. However, there are also some challenges that new research should address, such as the possible competition between food and land use or the impacts of biomass processing [3]. In these cases, the valorization of waste could be interesting, and the use of catalysts could alleviate some of the related problems by making these processes more efficient and allowing new processes to reduce the environmental impact of these practices.

Even though these processes are very different (covering a large number of natural raw materials and wastes, including endless opportunities for their valorization), they share some common points. For instance, new research focuses on innovative sources, such as the use of oilseed crop residues [4], lignocellulose [5,6], or microalgae [7], to produce biofuels and biochemicals in different ways, such as using thermochemical (including, for instance, hydrothermal gasification [8]), physicochemical, or chemical processes [9]. On the other hand, the conversion of biomass could offer products with very competitive properties compared to traditional ones (as in the case of alcohols obtained from furfural), demonstrating their added value [10]. In any case, these processes should present high atom economy and energy efficiency, which can be achieved via the use of catalysts, mainly in order to reduce the activation energies of chemical reactions. Thus, homogeneous and heterogeneous catalysts are used, including enzymes (as in the case of immobilized lipases for biodiesel production [11,12]). In that sense, new sustainable catalysts are obtained, for instance, from wastes to produce biochar (a bioproduct by itself with many uses [13]) or nanocatalysts [14] that could act as catalysts if they are suitably prepared [15] for biofuel and bioproduct synthesis.

2. An Overview of Published Articles

Considering the above, this Special Issue aims to cover new trends in the use of catalysts for biofuel and bioproduct generation, addressing the above-mentioned challenges.

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As inferred in the Introduction, there is a wide variety of alternatives that can be used to make biofuel and bioproduct generation competitive and efficient through the use of catalysts, and this Special Issue only mentions a sample of the possibilities proposed by the scientific community.

Some studies have focused on the valorization of waste and the introduction of innovative catalysts, as in the case of the work carried out by Hanif et al. (Contribution 1), who used different waste plant oils to produce biodiesel through transesterification using a novel nano-catalyst (Li-TiO_2/feldspar). The use of heterogeneous catalysts is a challenging and interesting approach in this process, which could considerably reduce the number of post-treatments to purify the final biodiesel. However, lower yields compared to homogeneous catalysts are usually obtained. In this study, high conversions (above 90%) were obtained at relatively low temperatures (50–60 °C) and typical catalyst concentrations (2%), requiring high methanol/oil ratios (usually 10:1). The properties of the biodiesel that was obtained complied, in general, with standard requirements. The same authors of the previous study (Contribution 2) produced biodiesel from waste oils using novel nano-magnetic CaO/Fe_2O_3/feldspar catalyst, the use of which allowed high-yield ranges (93.6–99.9%) at low temperatures (40 °C) for 2 h, with methanol/oil ratios ranging from 5:1 to 10:1. Equally, the use of environmentally-friendly and reusable catalysts is the main subject of the work carried out by Khosa et al. (Contribution 3), where the synthesis of combined CaO nanocomposite and cellulose nanocrystals was carried out to produce biodiesel from waste cooking oil, with high conversion levels and the possibility of regeneration of the catalyst (up to three cycles without any changes in catalytic performance).

In that sense, biodiesel production can present a starting point for a biorefinery concept, for instance, to produce biolubricants. Thus, Nogales et al. (Contribution 4) carried out a review study centered around the factors that affect catalytic performance during biolubricant production, and they found that it contributed to high conversions of raw materials (including residues like waste cooking oil), obtaining a final product with interesting and versatile properties depending on the operating conditions.

One recurring byproduct obtained in many syntheses covered in this Special Issue (especially concerning biodiesel production from fatty acids) is glycerol, which can be used in different reactions to produce energy or a wide range of products. For instance, in the study carried out by Cornejo et al. (Contribution 5), glycerol was used to produce higher tert-butyl glycerol esters through acid-catalyzed etherification with tert-butanol, employing *p*-toluensulfonic acid as a catalyst.

In the same way, there are other wastes that can be valorized. For instance, Olivares-Marín et al. (Contribution 6) optimized the hydrothermal carbonization of a waste derived from the removal of an invasive floating plant (water hyacinth) by adjusting Al and Fe content during this process. Thus, an interesting porous carbon was obtained, presenting a feasible alternative for the environmental management of this invasive species. In the same way, the valorization potential of biomass containing glucose (for instance, in agricultural or forest residues) via isomerization to fructose and subsequent dehydration to obtain 5-hydroxymethylfurfural (HMF) was studied by David et al. (Contribution 7). In this study, an effective catalytic consortium was used with the following operating conditions: $CX_4SO_3H/NbCl_5$ (5 wt%/7.5 wt%) using water/NaCl and MIBK (1:3) at 150 °C for 17.5 min. The resulting catalyst was successfully reused up to seven times, keeping the HMF yield constant. Considering HMF as the cornerstone for the synthesis of biofuels and fine chemicals, Mitra et al. (Contribution 8) used hybrid phosphonates for 5-HTC production from carbohydrates derived from biomass, obtaining yields exceeding 90% through microwave-assisted reactions. Parralejo Alcobendas et al. (Contribution 9) also offered a study where the role of nanoparticles was important in biogas production from pepper waste and pig manure, increasing the methane production rate. For energy exploitation, biogas steam reforming is an important resource that can be used to produce hydrogen, the catalytic process of which is essential to improve its efficiency. As explained by Nogales et al. (Contribution 10), there are different key factors that clearly affect catalytic steam reforming, like the presence of H_2S, coke deposition, or sintering, and the synthesis of innovative and resistant catalysts is required for this purpose.

To sum up, the studies that are included in this Special Issue are diverse, and they focus on different aspects like catalyst optimization or the search for new raw materials, including a wide range of wastes that can be used to valorize them.

3. Conclusions

In conclusion, the studies covered in this Special Issue pointed out some interesting ideas, like the following:

- The latest research has focused on waste valorization as a means to produce both energy and high-value products, with interesting properties that can be used to replace traditional energy sources, such as petrol-based products;
- The use of catalysts has made these different processes more competitive, presenting an interesting starting point for the implementation of such technologies at an industry level in a biorefinery context.
- Operating conditions have an important impact on catalytic performance and the quality parameters of final products.
- New challenges should be addressed, like an increase in the life cycle of catalysts or the requirement of exergy analyses to obtain a real grasp of the above-mentioned processes.

Conflicts of Interest: The authors declare no conflicts of interest.

List of Contributions

- **Contribution 1**: Hanif, M.; Bhatti, I.A.; Shahzad, K.; Hanif, M.A. Biodiesel Production from Waste Plant Oil over a Novel Nano-Catalyst of Li-TiO_2/Feldspar. *Catalysts* **2023**, *13*, 310. https://doi.org/10.3390/catal13020310.
- **Contribution 2**: Hanif, M.; Bhatti, I.A.; Hanif, M.A.; Rashid, U.; Moser, B.R.; Hanif, A.; Alharthi, F.A. Nano-Magnetic CaO/Fe_2O_3/Feldspar Catalysts for the Production of Biodiesel from Waste Oils. *Catalysts* **2023**, *13*, 998. https://doi.org/10.3390/catal13060998.
- **Contribution 3**: Khosa, S.; Rani, M.; Saeed, M.; Ali, S.D.; Alhodaib, A.; Waseem, A. A Green Nanocatalyst for Fatty Acid Methyl Ester Conversion from Waste Cooking Oil. *Catalysts* **2024**, *14*, 244. https://doi.org/10.3390/catal14040244.
- **Contribution 4**: Nogales-Delgado, S.; Encinar, J.M.; González, J.F. A Review on Biolubricants Based on Vegetable Oils through Transesterification and the Role of Catalysts: Current Status and Future Trends. *Catalysts* **2023**, *13*, 1299. https://doi.org/10.3390/catal13091299.
- **Contribution 5**: Cornejo, A.; Reyero, I.; Campo, I.; Arzamendi, G.; Gandía, L.M. Acid-Catalyzed Etherification of Glycerol with Tert-Butanol: Reaction Monitoring through a Complete Identification of the Produced Alkyl Ethers. *Catalysts* **2023**, *13*, 1386. https://doi.org/10.3390/catal13101386.
- **Contribution 6**: Olivares-Marin, M.; Román, S.; Ledesma, B.; Álvarez, A. Optimizing Al and Fe Load during HTC of Water Hyacinth: Improvement of Induced HC Physico-chemical Properties. *Catalysts* **2023**, *13*, 506. https://doi.org/10.3390/catal13030506.
- **Contribution 7**: David, G.F.; Delgadillo, D.M.E.; Castro, G.A.D.; Cubides-Roman, D.C.; Fernandes, S.A.; Lacerda Júnior, V. Conversion of Glucose to 5-Hydroxymethylfurfural Using Consortium Catalyst in a Biphasic System and Mechanistic Insights. *Catalysts* **2023**, *13*, 574. https://doi.org/10.3390/catal13030574.
- **Contribution 8**: Mitra, R.; Malakar, B.; Bhaumik, A. Organically Functionalized Porous Aluminum Phosphonate for Efficient Synthesis of 5-Hydroxymethylfurfural from Carbohydrates. *Catalysts* **2023**, *13*, 1449. https://doi.org/10.3390/catal13111449.
- **Contribution 9**: Parralejo Alcobendas, A.I.; Royano Barroso, L.; Cabanillas Patilla, J.; González Cortés, J. Pretreatment and Nanoparticles as Catalysts for Biogas Production Reactions in Pepper Waste and Pig Manure. *Catalysts* **2023**, *13*, 1029. https://doi.org/10.3390/catal13071029.

- **Contribution 10**: Nogales-Delgado, S.; Álvez-Medina, C.M.; Montes, V.; González, J.F. A Review on the Use of Catalysis for Biogas Steam Reforming. *Catalysts* **2023**, *13*, 1482.

References

1. Vakulchuk, R.; Overland, I.; Scholten, D. Renewable Energy and Geopolitics: A Review. *Renew. Sustain. Energy Rev.* **2020**, *122*, 109547. [CrossRef]
2. Palmeros Parada, M.; Osseweijer, P.; Posada Duque, J.A. Sustainable Biorefineries, an Analysis of Practices for Incorporating Sustainability in Biorefinery Design. *Ind. Crops Prod.* **2017**, *106*, 105–123. [CrossRef]
3. Gallezot, P. Catalytic Conversion of Biomass: Challenges and Issues. *ChemSusChem* **2008**, *1*, 734–737. [CrossRef] [PubMed]
4. Yong, K.J.; Wu, T.Y. Second-Generation Bioenergy from Oilseed Crop Residues: Recent Technologies, Techno-Economic Assessments and Policies. *Energy Convers. Manag.* **2022**, *267*, 115869. [CrossRef]
5. Ma, R.; Xu, Y.; Zhang, X. Catalytic Oxidation of Biorefinery Lignin to Value-Added Chemicals to Support Sustainable Biofuel Production. *ChemSusChem* **2015**, *8*, 24–51. [CrossRef] [PubMed]
6. Pattnaik, F.; Tripathi, S.; Patra, B.R.; Nanda, S.; Kumar, V.; Dalai, A.K.; Naik, S. Catalytic Conversion of Lignocellulosic Polysaccharides to Commodity Biochemicals: A Review. *Environ. Chem. Lett.* **2021**, *19*, 4119–4136. [CrossRef]
7. Kowthaman, C.N.; Senthil Kumar, P.; Arul Mozhi Selvan, V.; Ganesh, D. A Comprehensive Insight from Microalgae Production Process to Characterization of Biofuel for the Sustainable Energy. *Fuel* **2022**, *310*, 122320. [CrossRef]
8. Elliott, D.C. Catalytic Hydrothermal Gasification of Biomass. *Biofuels Bioprod. Biorefining* **2008**, *2*, 254–265. [CrossRef]
9. Hansen, S.; Mirkouei, A.; Diaz, L.A. A Comprehensive State-of-Technology Review for Upgrading Bio-Oil to Renewable or Blended Hydrocarbon Fuels. *Renew. Sustain. Energy Rev.* **2020**, *118*, 109548. [CrossRef]
10. Iriondo, A.; Agirre, I.; Viar, N.; Requies, J. Value-Added Bio-Chemicals Commodities from Catalytic Conversion of Biomass Derived Furan-Compounds. *Catalysts* **2020**, *10*, 895. [CrossRef]
11. Pasha, M.K.; Dai, L.; Liu, D.; Du, W.; Guo, M. Biodiesel Production with Enzymatic Technology: Progress and Perspectives. *Biofuels Bioprod. Biorefining* **2021**, *15*, 1526–1548. [CrossRef]
12. Encinar, J.M.; González, J.F.; Sánchez, N.; Nogales-Delgado, S. Sunflower Oil Transesterification with Methanol Using Immobilized Lipase Enzymes. *Bioprocess Biosyst. Eng.* **2019**, *42*, 157–166. [CrossRef] [PubMed]
13. Kumar, M.; Xiong, X.; Sun, Y.; Yu, I.K.M.; Tsang, D.C.W.; Hou, D.; Gupta, J.; Bhaskar, T.; Pandey, A. Critical Review on Biochar-Supported Catalysts for Pollutant Degradation and Sustainable Biorefinery. *Adv. Sustain. Syst.* **2020**, *4*, 1900149. [CrossRef]
14. Nasrollahzadeh, M.; Soheili Bidgoli, N.S.; Shafiei, N.; Soleimani, F.; Nezafat, Z.; Luque, R. Low-Cost and Sustainable (Nano)Catalysts Derived from Bone Waste: Catalytic Applications and Biofuels Production. *Biofuels Bioprod. Biorefining* **2020**, *14*, 1197–1227. [CrossRef]
15. Kang, K.; Nanda, S.; Hu, Y. Current Trends in Biochar Application for Catalytic Conversion of Biomass to Biofuels. *Catal. Today* **2022**, *404*, 3–18. [CrossRef]