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Editorial

Biorefinery for the Sustainable Biochemicals Production: Process Design and Technological Advances

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To fulfill the demands of an ever-increasing population and ensure sustainable development, the implementation of a bio-economy based on renewable resources is necessary [1]. Most chemicals are produced using fossil-fuel resources and thus their depletion and subsequent waste generation are major challenges. A shift towards the use of renewable resources for biochemical production (food, feed, chemicals, and materials) and bioenergy (biodiesel, bioelectricity, and biogas) is a suitable alternative for a sustainable economy [2–4]. A biorefinery is a clean and green technology analogous to petroleum-based refineries. In this system, plants and microorganisms can be utilized to produce a variety of biochemicals [5,6]. Different types of biochemicals can be produced using direct extraction from plants, microbial fermentation, and a biotransformation approach [7–9]. Although the advantages of the biorefinery are well known, biochemical production at the commercial level is still hindered by the unavailability of inexpensive raw materials, the inability of microbes to utilize feedstocks efficiently, and low growth and productivity. Together, advances in molecular biology, fermentation technology, reactor designs, and downstream processing have been able to overcome some of these challenges, but there is a long way to go. This Special Issue focuses on biobased refineries and includes nine published review and research articles covering topics on itaconic acid production, biodiesel synthesis, biogas, and syngas fermentation (Figure 1 provides a word cloud of the articles published in this Special Issue).

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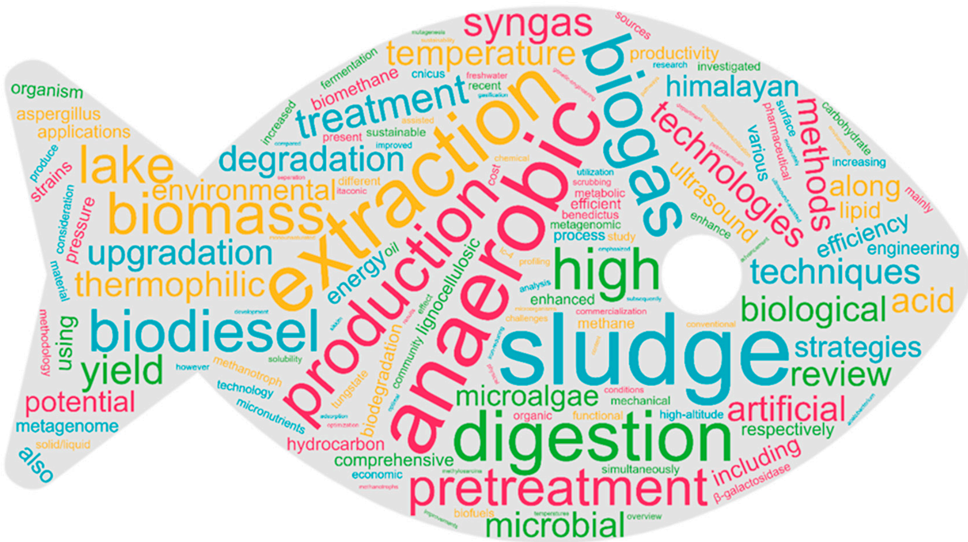

Figure 1. Word cloud of articles published in the Special Issue. The most frequent words are displayed in a larger font.

Biochemical production using microbial fermentation is attracting attention due to its environmentally friendly and reduced waste generation characteristics. Itaconic acid is a bio-based organic acid used in several industries due to its wide applications in the plastics, textile, paint, and pharmaceutical sectors. Numerous microbes have been reported to produce itaconic acid, among which *Aspergillus terreus* is well known for commercial scale production. This review discusses itaconic acid's synthesis, yield improvement, and applications in food, pharmaceuticals, and textiles [10]. With the increase in the global population, the demand for renewable energy resources such as biodiesel and biogas is also increasing in order to reduce greenhouse gas emission. *Cnicus benedictus* fruit oil can be used as a raw material for biodiesel production. Two extraction methods have been tested, and a response surface methodology was used to optimize the process's efficiency. The optimal working conditions were different for each extraction technique, with ultrasound-assisted extraction being more efficient. The extracted oil was esterified with methanol to produce biodiesel, which was characterized and whose fuel properties were determined [11]. Cheap and abundantly available raw materials are desirable for the economization of the biorefinery process. Microalgae offer high potential for biofuel production, but their low lipid content renders them expensive. Suitable algal strains can be identified and genetically modified to maximize lipid production. Adjusting environmental and nutritional parameters is another option. This review provides an overview of approaches to enhance lipid productivity, including DNA manipulation, and discusses the economic and commercial status of microalgae biofuels [12].

Biogas is another type of fuel that can be produced by the anaerobic digestion of feedstock. Various sludge treatment techniques can be used to improve solubility and biodegradation. Mechanical pretreatment, with or without low-temperature heat treatment, significantly enhances solubility and biomethane yield. Anaerobic digestion time is reduced from 28 to 10 days with pretreated sludge. Mechanical pretreatment and heat treatment offer high potential with respect to increasing treatment capacity in sludge treatment plants [13]. Methane production can be further improved using thermophilic anaerobic digestion (TAD) technology. TAD has several advantages over mesophilic anaerobic digestion (MAD) and is being widely explored for its efficient enzymatic systems and economic sustainability. One review included in this Special Issue highlights the relevant role of thermophilic microorganisms as inocula in the anaerobic digestion of organic matter and the strategies for enhancing the efficiency of TAD [14]. Biogas is a mixture of CO_2, CH_4, and H_2S, which restricts its utilization as a vehicular fuel, thereby rendering biogas upgradation a necessary step. Conventional upgradation technologies are expensive and require maintenance. Biological upgradation methods are being investigated as a potential solution, and the following review discusses the various available technologies and their challenges, limitations, future perspective, and scope [15]. Methane can also be transformed into other valuable products. Researchers studied *Methylosarcina* sp. LC-4 regarding its role as a potential organism for the production of biodiesel from methane. The organism's methane uptake rate was enhanced by supplementing it with copper and tungstate micronutrients. A modified nitrate minimal salt media (NMS) yielded a high FAME content of $13 \pm 1\%$ (w/w), which is suitable for biodiesel production [16]. Syngas can also be transformed into valuable products. Chemical sequestration is costly, so researchers are investigating the potential of microorganisms such as algae and bacteria to sequester carbon from the gas phase. The following article also highlights the challenges of scaling up the employed technology, including with respect to microbial contamination and inconsistent syngas composition [17]. Microbes can also be used for bioremediation. The hydrocarbon degradation potential of an artificial lake in the Sikkim Himalayan region was examined through metagenomic analysis, revealing the presence of genes for the degradation of hydrocarbons and iron-reducing bacteria. The site was also found to be rich in β-galactosidase genes and similar to freshwater lakes at taxonomic and functional levels, which could have industrial significance in the mining of genes encoding relevant enzymes [18].

As the Editor of this Special Issue, I have observed that the utilization of waste materials as feedstocks for microbial fermentation to produce biochemicals and biofuels can improve the economic considerations of the process. I am sure that this Special Issue will pique the interest of researchers in this area and provide readers with a broad and updated overview of this topic.

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