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Editorial

New Perspectives on Lactic Acid Production from Renewable Agro-Industrial Wastes

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Since its initial discovery in sour milk by Swedish chemist C.W. Scheele in the 1780s, lactic acid (2-hydroxypropanoic acid) has been widely applied in food, animal feed, cosmetics, medicines, and materials industries [1]. With the increasing emphasis on biodegradable polymers for environmental sustainability and carbon neutrality, polylactic acid (PLA) has emerged as a superstar alternative to petrochemical polymers such as polyethylene (PE), polypropylene (PP), polystyrene, and polyester [2]. This significant rise in PLA usage has consequently driven up the demand for its precursor chemicals, the chiral lactic acids (L-lactic acid and D-lactic acid). The global lactic acid market was valued at USD 2.6 billion in 2018 and is expected to annually grow at 20% to reach USD 9 billion in 2025 [3].

Currently, microbial fermentation is the only method for producing lactic acid from starch or sugar feedstocks. However, the microbial production of chiral lactic acid for PLA synthesis is still an immature technology compared to the production of petrochemical polymers [4]. The consequence is that the production cost of PLA is too high to compete with petrochemical plastics. This situation adversely limits its practical application scenarios and raises investors' concerns about its future industrial development prospects.

Industrially, the predominant problem in the production of chiral lactic acid is the challenge in identifying a suitable substrate that is both economically viable and does not compete with food and feed resources. These feedstocks also should be abundant, readily available, renewable, easily processed, and free of racemic lactic acid, including agricultural wastes (crops wastes, forest residues, energy plants, etc.) and industrial biomass (corncob residue from xylose extraction or furfural production, corn fibers, DDGS, fruit residues, etc.). Various novel renewable biomass resources are gradually being explored for lactic acid production. Ricard Garrido and his colleagues demonstrated the significant potential of utilizing lignocellulose-rich cow manure for lactic acid production, with their economic analysis showing the minimum lactic acid selling price below 1.0 EUR/kg [5]. Agro-industrial wastes also exhibit differences according to season and region. Wan Abd Al Qadr Imad Wan-Mohtar and his colleagues summarized the underutilized agro-industrial wastes in Malaysia, particularly those generated from the processing of coconut, oil palm, rice, and sugarcane [6]. They highlighted the potential of these wastes to serve as sustainable carbon sources for lactic acid production. They are confident that with the support of the government, research institutes, farmers, investors, and other stakeholders, it is possible to fully leverage these valuable natural resources, realize their potential benefits, and contribute to a sustainable future for Malaysia.

Furthermore, having in mind that the use of agro-industrial biomass for lactic acid production can lead to more complex fermentation broth components (residual pentoses and hexoses, inhibitors, organic acids, soluble lignin, protein, pigments, and salts), more complex and costly downstream processing will be required [7]. Based on the feasibility of industrial scale-up, Priscilla Zwiercheczewski de Oliveira and his colleagues have developed a technology for the production of lactic acid using sugarcane juice as the raw material combined with the purification of the lactic acid product using anionic and

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Citation: Zhang, B.; Bao, J. New Perspectives on Lactic Acid Production from Renewable Agro-Industrial Wastes. *Fermentation* **2024**, *10*, 534. https://doi.org/10.3390/fermentation10100534

Received: 17 October 2024
Accepted: 18 October 2024
Published: 21 October 2024

cationic exchange resins [8]. This one-step method for lactic acid purification does not require successive washing with chemical solvents, thereby reducing the wastewater generation and improving the product productivity and yield. Feedstock characteristics and process parameters also play crucial roles in stabilizing the lactic acid fermentation process. Employing advanced fermentation techniques to cope with different agro-industrial biomass resources for lactic acid production can improve the fermentation process efficiency and reduce the downstream costs. Jiaqi Huang and his colleagues comprehensively summarized traditional and advanced fermentation techniques for lactic acid production from different agro-industrial wastes [9]. Punnita Pamueangmun and his colleagues further complemented the advanced fermentation method for lactic acid production by developing a consolidated bioprocessing technology [10]. The newly isolated *Weizmannia coagulans* MA42 strain can secrete complex lignocellulose-degrading enzymes and directly produce L-lactic acid from the pretreated sugarcane bagasse, corn stover, rice straw, and water hyacinth. Further bioprocess development and genetic engineering would enhance the efficiency of lactic acid production from lignocellulose biomass through consolidated bioprocessing.

All in all, this thematic Special Issue of *Fermentation* provides state-of-the-art research outcomes on lactic acid production from renewable agro-industrial wastes. The collected contributions were authored by experts in the field and have undergone a standard peer-review process, and they emphasize the necessity for producing lactic acid from renewable agro-industrial wastes while also addressing the technical and economic feasibilities. Further research should prioritize the chirality of lactic acid products and the low pH tolerance of lactic acid-producing strains. We expect this Special Issue to propel the upgrading of lactic acid production technology, and fuel the innovation and application in the biodegradable plastic industry. Through the collaborative efforts of scholars worldwide, the technology of producing bio-based chemical monomers from waste biomass will be constantly updated, enabling the widespread adoption of biodegradable bioplastics in various aspects of everyday life. It has been a great privilege for us to serve as the Guest Editors for this Special Issue in *Fermentation*.

Author Contributions: Conceptualization, J.B. and B.Z.; writing—original draft, B.Z.; writing—review and editing, J.B. All authors have read and agreed to the published version of the manuscript.

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

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