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Editorial

Food Wastes: Feedstock for Value-Added Products

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Food is a precious commodity, and its production can be resource-intensive. According to the Food and Agriculture Organization of the United Nations, nearly 1.3 billion tons of food products per year are lost along the food supply chain, and in the next 25 years the amount of food waste has been projected to increase exponentially. Food waste is produced at any stage of the supply chain, which extends from the agricultural site to the processing plant and finally the retail market. The management of food waste should follow certain policies based on the 3R's concept, i.e., reduce, reuse, and recycle [1]. Generally, food waste is composed of a heterogeneous mixture formed by carbohydrates (starch, cellulose, hemicellulose, or lignin), proteins, lipids, organic acids, and smaller inorganic parts. Currently, most food wastes are recycled, mainly as animal feed and compost. The remaining quantities are incinerated and disposed in landfills, causing serious emissions of methane (CH_4), which is 23 times more potent than carbon dioxide (CO_2) as a greenhouse gas and significantly contributes to climate change [2]. Valorizing food waste components could in fact lead to numerous possibilities for the production of valuable chemicals, fuels, and products [1].

The present Special Issue compiles a wide spectrum of aspects of research and technology in the area of "food waste exploitation", and highlights prominent current research directions in the field for the production of value-added products such as polylactic acid, hydrogen, ethanol, enzymes, and edible insects.

Polylactic acid (PLA) is a biodegradable polymer with great potential in replacing petrochemical polymers. The morphological, mechanical, and thermal properties of the polymer are determined by the presence of different amounts of L- and D-lactic acid monomers or oligomers [3]. The microbial production of optically pure lactic acid has extensively been studied, because chemically synthesized lactic acid is a racemic mixture. Optimizing culture conditions and selecting the LAB strains capable of producing D-lactic acid with high yield and optical purity from orange peel waste as raw material can contribute to the development of biowaste refineries. Bustamante et al. [4] evaluated six strains of the species *Lactobacillus delbrueckii* ssp. *bulgaricus* for the production of D-lactic acid from orange peel waste hydrolysate. *L. delbrueckii ssp. bulgaricus* CECT 5037 had the best performance, with a yield of 84% w/w for D-LA production and up to 95% enantiomeric excess (optical purity).

Biomethanation (methane fermentation) is a complex biological process, which can be divided in four phases of biomass degradation and conversion, namely, hydrolysis, acidogenesis, acetogenesis, and methanation. The individual phases are carried out by different groups of micro-organisms (bacteria), which partly stand in syntrophic interrelation and place different requirements on the environment. Undissolved compounds like cellulose, proteins, and fats are hydrolyzed into monomers by enzymes produced by facultative and obligatorily anaerobic bacteria [5]. The use of a microbial consortium consisting of the microbial flora of methane production and microorganisms that can degrade cellulosic biomass like *Clostridium cellulovorans* was proven efficient in degraded mandarin orange peel without any pretreatments and produced methane that accounted for 66.2% of the total produced gas [6].

Hydrogen is a noncarbonaceous fuel and energy carrier possessing higher net calorific value compared to other fuels (120 MJ/kg versus 46.7 MJ/kg for gasoline). Microbes primarily produce hydrogen via photofermentation by the purple nonsulfur bacteria *Rhodobacter* and *Rhodopseudomonas*, and during dark fermentation by strictly anaerobic *Clostridium* species [7,8]. Depending upon the availability of substrate, the selection of functional microorganisms necessary for hydrogen production is an important step. Simulation of the exchange metabolic fluxes of monocultures and pairwise cocultures using genome-scale metabolic models on artificial garbage slurry resulted in the identification of one of the top hydrogen producing cocultures comprising *Clostridium beijerinckii* NCIMB 8052 and *Yokenella regensburgei* ATCC 43003. The consortium produced a similar amount of hydrogen gas and increased butyrate (attributed to cross-feeding of lactate produced by *Y. regensburgei*), compared to the *C. beijerinckii* monoculture, when grown on the artificial garbage slurry [9].

Household food waste is a complex biomass containing various components that make it a source of potential fermentative substrates. The general scheme of bioethanol production from such complex materials involves a pretreatment step that increases the digestibility of the material—enzymatic hydrolysis—to liberate the monosaccharides and fermentation of these sugars to ethanol. In terms of cost, the most demanding step, which significantly increases the total cost of the production of bioethanol and is identified as a barrier in the further deployment of ethanol production, is enzymatic hydrolysis. If the necessary enzymes could be efficiently produced on-site, the cost could be significantly reduced. A recent study has estimated that the cellulase cost can be reduced from 0.78 to 0.58$/gallon by shifting from the off-site to the on-site approach of cellulase production [10]. The mesophilic fungus *Fusarium oxysporum* F3 grown under solid state cultivation on wheat bran produced a multienzyme system capable of hydrolyzing the carbohydrates present in household food waste. The use of mixed-microbial cultures in bioethanol production step consisting of *F. oxysporum* solid state culture and the yeast *Saccharomyces cerevisiae* increased bioethanol volumetric productivity, compared to mono-culture of the fungus. Bioethanol production increased by approximately 23% when the mixed microbial culture was supplemented with low dosages of commercial glucoamylase [11].

Carrión-Paladines et al. [12] evaluated two *Xylaria* spp. of the dry forest areas of southern Ecuador, for ligninase and cellulase production under solid state fermentation using residues obtained from the Palo Santo essential oil extraction. The Palo Santo is considered a vital resource for the local communities of the dry forest, as different parts of the tree are used in traditional medicine, as well as for the extraction of essential oil. The essential oil extraction process generates abundant organic waste, which is commonly discarded directly into the natural ecosystems or burned. Laccase, cellulose, and xylanase activities of *Xylaria feejeensis* and *Xylaria* cf. *microceras* were generally higher than those of the control fungus *Trametes versicolor* (L.) Lloyd, furthering the understanding of the potential use of native fungi as ecologic lignocellulosic decomposers and for industrial proposes.

Beer production generates large quantities of spent yeast during the fermentation and lagering process. The spent yeast is an efficient starting material to produce yeast extract, which is generally defined as the soluble content of a yeast cell that remains once the cell wall has been destroyed and removed. The variety of different physiologically valuable substances in yeast cells offer the possibility of use as a yeast extract in different areas of the food industry. Jacob et al. [13] demonstrated that the composition of various physiologically valuable substance groups of a yeast extract depends on the biodiversity of the spent yeast from beer production, indicating that brewer's spent yeast should be carefully selected to produce a yeast extract with a defined nutritional composition.

In many cases, food wastes are difficult to utilize for the recovery of value-added products due to their biological instability or potentially pathogenic nature. Fusarium head blight (FHB), a fungal disease caused by several *Fusarium* spp., is one of the most significant causes of economic loss in cereal crops. *Fusarium* spp. produce various amounts and types of trichothecene mycotoxins, with deoxynivalenol being the major one, which are highly toxic to humans and livestock. A method to recover the nutrients from the affected cereals, without the mycotoxins, was reported by Gulsunoglu et al. [14]. The infected grains were initially fermented under solid state cultivation with *Aspergillus oryzae* and/or

Lactobacillus plantarum. The fermented material was provided to black soldier fly larvae, which consumed deoxynivalenol-contaminated materials and converted them in insect biomass without accumulating deoxynivalenol in their bodies. This treatment technology using black soldier fly larvae may contribute to reducing the burden of animal protein shortages in the animal feed market.

Varelas [15] compiled up-to-date information on the mass rearing of edible insects for food and feed based on food wastes. Edible insects are insect species that can be used for human consumption but also for livestock feed as a whole, parts of them, and/or protein, and lipid extract.

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