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A Glance on Biorefinery of Chemical Substitutes from Agriculture and Industrial By-products

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1.1 Introduction

The agricultural sector is among the important biological sectors that contributed to the production of biomass. This is vital to the bioeconomy development as the biomass produced is used as feedstock for various processes of value-added products. Koul et al. [1] characterized and listed the various sources of agricultural waste as shown in Figure 1.1:

The emerging field on the utilization of agricultural wastes and industrial by-products is the alternative way to find potential feedstocks for chemical substitutes. Chemical substitution focuses on finding new and less hazardous solutions for a particular process or product through advanced biorefinery approach. Due to the exponential rise in the demand for worldwide energy, the depletion of existing fossil fuel reserves is deemed as the vital issue, thus increasing the global interest in creating a new energy pathway via the bioprocessing of agricultural wastes as well as agro-industrial biomass [2]. Agricultural waste is defined as unwanted waste as a result of agricultural activities. Industrial biomass is known to be a solid inorganic residue, which may come from various sources, including mining and metal industry, chemical industry or building industry, energy production, and forest industry [3]. These biomass are potential feedstocks with abundant organic and inorganic nutrient composition.

Every year agricultural-based industries contribute a huge amount of residues, which may result in various environmental problems due to improper waste management. This situation will further have a negative impact on animal and human health. Unfortunately, the disposal of untreated agro-industrial wastes has been reported [4] to create other concerning problems associated with climate change. The common waste management procedures applied by the related agro-industry

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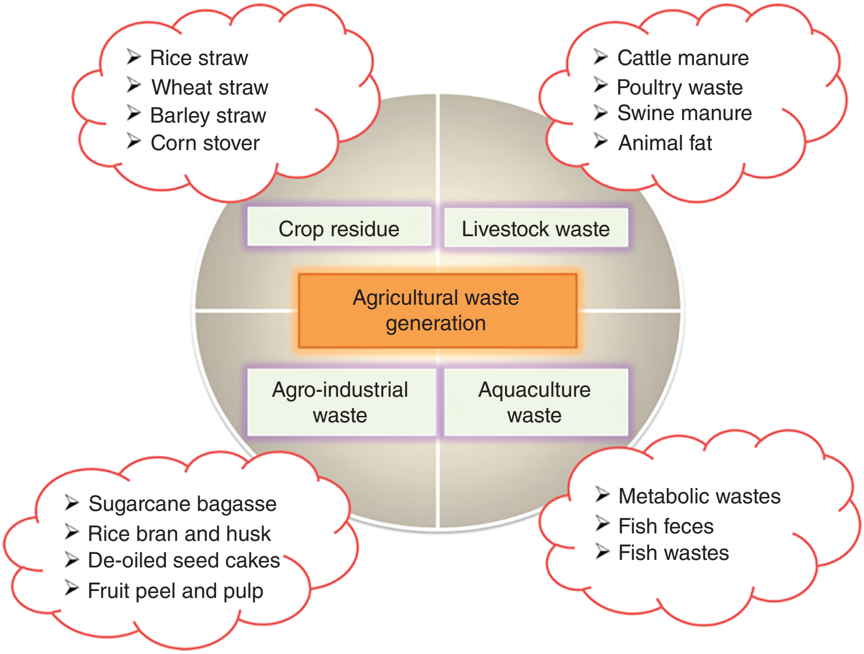

Figure 1.1 Various sources of agricultural waste. Source: Adapted from Koul et al. [1].

sectors, including burning, open dumping, and improper landfilling, should be improved with the availability and advancement of current technology.

The by-product from an industrial, commercial, mining, or agricultural operation is known as an "industrial by-product" if it is not a primary product and was not created independently throughout the process. The determination of the inorganic industrial by-product's composition and generic properties is specified by factors such as type of industry and the process. In depth, the environmental and technical properties of by-products are influenced by the equipment, process condition, and the feedstock. This further implies the suitability of the by-product for recycling material. As an example, reclaimed asphalt, waste concrete, and slag are recyclable materials, which have been used all over the world. However, the recycling rates of certain by-products vary among nations, and it can be challenging to locate precise data on the rates. The latter issue is likely caused by inadequate documentation of the amounts and end locations of by-products as well as differences in how trash is classified and how it is managed (e.g. whether filling mines is considered recycling) [5].

The evolution of the biorefinery concept was started during the late 1990s. Biorefinery covers spectrum of processes, as it defines as an overall concept of biomass processing plant conversion and/or extraction into various valuable products [6]. National Renewable Energy Laboratory (NREL) describes a biorefinery concept as the integration of biomass conversion processes as well as equipment to refine value-added products, including chemicals, fuels, and power. The International Energy Agency (IEA) Bioenergy Task 42 has defined a biorefinery as "the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat)." Thus, a biorefinery can be a process, a facility, a plant, or a cluster of facilities for the biomass conversion [7].

An inventive and effective method of using biomass resources for the synergistic co-production of power, heat, and biofuels alongside ingredients for food and feed, pharmaceuticals, chemicals, materials, minerals, and short-cycle CO_2 is biorefining. This process involves processing biomass sustainably to create a variety of marketable biobased products and bioenergy/biofuels. Biorefining is one of the vital technologies of the circular economy, closing loops of raw biomass materials, minerals, water, and carbon. Biorefining is the optimal strategy for large-scale sustainable utilization of biomass in the bioeconomy [8].

1.2 Analysis of Feedstocks for Composition and Potential for Chemical Substitutes

Agricultural wastes are vast, which cover the by-products generated from various agricultural products, including crops, dairy products, fruits, meat, poultry, and vegetables. They are the non-product outputs of the production and processing of agricultural products that may contain material that can benefit humans but whose economic value is less than the cost of collection, transportation, and processing for beneficial use. The physicochemical composition of the wastes varies based on the type of agricultural activities as well as the system, which further results in a different form of wastes, such as solid, liquid, and slurry [1].

Agricultural-based residues can be classified into two distinct types based on the point of waste generated, such as field waste and process waste. The field wastes are mainly generated from harvesting activity, which includes leaves, stems, seedpods, and stalks. Meanwhile, the process wastes are generally the by-products produced during processing activity of the harvested products into alternate valuable products [8].

Nowadays, the raising public concern toward major categories of agricultural waste has been deemed to be the main issue. Concurrently, these wastes also have been recognized to threaten the sustainability of agricultural regimes. In fact, several agricultural activities that are affected include livestock wastes (dung, urine, residual milk, wash water, and waste feed), slaughterhouse wastes (blood, bones, flesh, hair, hides, etc.), crop residues (leaf litter, seed pods, stalks, stems, straws, husks, and weeds), poultry wastes (bedding material, droppings, spilled feed, and feathers), agro-industrial wastes (bagasse, molasses, peels [cassava, orange, and potato], pulps [apple, orange, guava, mango, papaya, pineapple, pomegranate, tomato, etc.], oil-seed cakes (coconut, groundnut, palm kernel cake, soybean, mustard, etc.), and aquaculture wastes (fecal waste, uneaten feed) [9, 10].

Through advancement in bioprocessing technology, agricultural wastes, which is also known as biomass, have been determined to be the promising feedstock and alternative renewable resource that helps to reduce existing high dependence on fossil fuel-based sector. This is deemed as impactful approach as it can help in conserving the natural resources as well as alleviate the environmental impact. The major component of agricultural biomass is lignocellulosic biomass that has shown a promising platform in various bioprocesses, including biofuels, platform chemicals, and bioproducts [11]. Lignocellulosic biomass is made up of cellulose, hemicellulose, and lignin, as cellulose is identified as the most abundant biopolymer. Cellulose is accounted to make up 30–50% of the total biomass, which is determined to be a vital substrate in microbial transformation. Various efforts have been explored to provide the strategic management and valorization of lignocellulosic biomass for the production of value-added products, which further resulted in elevating the value chain of the biomass.

1.2.1 Different Types of Agricultural Wastes and Associated Risks

The agricultural sector is urge to discover well sustainable waste management due to its vital impact on the biodiversity, human societies and world economy [12]. Due to the rapidly increasing demand, sustainable resource management is mandatory. Agricultural waste production is not only limited to farming activities, but it also covers other activities associated with food chain and farming. In each and every stage, the waste generated poses a significant risk to the environment and humans, generally, due to poor management. Oluseun Adejumo and Adebiyi [13] explained that there are seven associated agricultural wastes, which are animal wastes, food and meat processing wastes, crop production wastes, on-farm medical wastes, horticultural production wastes, industrial agricultural wastes, and chemical wastes.

The demand for using pesticides for growing crops to protect the yield of the land from weeds and insects is increasing. This is due to the impact of 42% reduction in global food production in the case of completely stopping pesticide application [14]. The main concerns in regard to this situation are the overexploitation of the pesticides, the leftover chemicals in the containers, and packaging in disposal manner. Extra measure should be taken for the disposal of these sources of waste in order to avoid a negative impact on the environment. This is even worse if they are thrown into ponds or fields because these types of agricultural wastes can contaminate the farmland with their lasting chemicals, and even lead to food poisoning. Alternatively, the usage of fertilizer to maintain the productivity of the land and the health of plants is one of the approaches used, in which organic fertilizer can be produced from the remains of farm animals using appropriate equipment. Animal waste in agriculture mainly comprises the carcasses of manure, livestock, and wastewater that come from the sanitation process of slaughterhouses. Proper management with the suitable equipment for carcass storage and disposal is necessary to avoid air pollution and bad odors. Additionally, if animal waste is not properly disposed of, it can pollute water sources, harm soil fertility, and produce greenhouse gases. One of the best ways to cut costs and waste is to reprocess animal waste into feed.

Improper management of agricultural wastes can contribute to several events, which pose a threat to living being. Based on the study reported by Adejumo and Adebiyi [13], there are three types of risks associated with improper management of agricultural wastes, which are food security, health and environmental implication, and flood. One of the main problems in the shortage of food supply is agricultural waste, associated with food wastage. This can be overcome by the recycling approach, subsequently improving food security by increasing animal protein production [15]. Apart from that, improper agricultural waste management subjected to indiscriminate burning and dumping results in various pollution, which subsequently endangers human health. Also, the indiscriminate dumping of agricultural wastes may result in the blockage of waterways, thus eventually causing floods.

1.2.2 Waste Utilization Routes

1.2.2.1 Fertilizer Application

The utilization of agricultural wastes has benefited various sectors and applications. One of them is the agricultural activity itself. The use of fertilizer from agricultural wastes, such as animal and organic (crop residue) manure, could enhance the yield of the crop. According to Wu et al. [16], the soil richness is affected by the organic fertilizer, due to the encouragement of rhizospheric microorganisms and the conditioning of the soil, such as texture and stability. In addition, the slow decomposition of organic residue is beneficial during vegetative growth process because of the slow nutrient release [17]. This could avoid the utilization of chemical fertilizer, which is associated with exposure to high-risk problems, including soil infertility, water pollution, and plant toxicity. In the case of post-chemical fertilizer-based water and land pollution, the treatment using integrated nutrient management (INM) is deemed to be vital in sustaining agricultural activity by reducing environmental pollution and elevating soil fertility [18].

In several case studies, the feasibility of agricultural wastes has been observed to give a positive impact on crop cultivation. Badar and Qureshi [19] have demonstrated that utilization of wheat bran composted with various microorganisms that has boosted soil fertility as well as enhanced the growth of sunflower cultivation. In another study conducted by Nisa et al. [20], the combination of agricultural waste biochar with straw compost as fertilizer has significantly improved the yield of paddy cultivation. These situations provide evidence of a promising approach to agricultural wastes in fertilizer application, which further enhance the productivity of crops and improve the soil condition. This further helps in conserving the environment by reducing the impact of chemically synthesized fertilizers, which contributed to various environmental pollutions.

1.2.2.2 Fibers for Textile Industry

Agricultural wastes are rich in valuable components that can be utilized in various industries, such as textiles. In the textile industry, the fiber component is one of the most important elements. The potential of agricultural wastes to be applied in the textile sector is vast due to main component of cellulosic fiber in most agricultural wastes. According to Das et al. [21], the most predominant features of textile's fiber are high cellulose and low lignin content. Therefore, the pretreatment of lignocellulosic biomass is necessary to remove the impurities of polymers, which are lignin and hemicellulose [22]. There are various agricultural wastes that have been identified to be ideal alternative fiber for the textile industry, including bagasse, cornhusk, oil palm biomass, pineapple, and leaves [1, 23, 24]. Among all the lignocellulosic biomass, bagasse has been found to have the highest cellulose content, which is determined as 65–70% in crude bagasse. The treatment of sugarcane bagasse fiber using alkali–H_2O_2 is found to have enhanced softness of fiber and improved mechanical properties [25]. In addition, corn husk fiber has been found to have a rough surface with a hollow cross-sectional view, which can be potentially applied as thermal insulation materials [26].

Apart from that, over the years, there has been an increase in interest in utilizing pineapple leaf fiber (PALF) due to its properties, which are beneficial in various applications including textiles. Asim et al. [24] summarized that the PALF has tensile strength ranging from 126.6 to 1627.0 MPa and Young's modulus of 4.41–82.5 GPa. The development of PALF-reinforced composite enhanced the properties of the composite to be versatile to be applied in the textile industry. The reinforcement of the composite is done by cooperating PALF with other composites, including epoxy [27], polypropylene [28], polyester [29], and polycarbonate [30].

1.2.2.3 Mushroom Cultivation

Agricultural wastes contain rich nutrients, and one of them is lignocellulosic content, which is a promising component for mushroom cultivation. Various types of edible mushrooms have been known to be effectively grown using agricultural wastes, including Button – *Agaricus*, Chinese mushroom – *Ganoderma*, Oyster – *Pleurotous*, Shiitake – *Lentinula edodes*, and straw – *Volvariella volvacea* [31]. Apart from helping in waste management, these mushrooms contain high nutritional values, which benefit the consumers. Several studies have been conducted to assess the feasibility of various types of agricultural wastes in mushroom cultivation. Goswami et al. [32] revealed that paddy straw has been commonly utilized as a substrate in paddy mushroom cultivation. In other cases, Kwon and Kim [33] explained that various sources of agricultural residues, including rice straw, sugarcane straw and bagasse, maize straw, wheat bran and straw, and soybean husk, have been used in *Calocybe indica*, oyster, and *Volvariella*.

Zakil et al. [34] have demonstrated the combination of various agricultural biomass, including oil palm biomass, sugarcane bagasse, corncob, and rubber tree sawdust, in cultivation of oyster mushroom, *Pleurotus ostreatus*. Based on the results obtained, this biomass contains a rich amount of potassium, which is vital in mushroom growth. In addition, the optimum condition determined to enhance the growth of *P. ostreatus* was the combination of sugarcane bagasse and rubber tree sawdust with a 1:1 ratio. In another study, Baktemur et al. [35] determined the feasibility of several other agricultural wastes, including corncob, peanut shell, poplar sawdust, wheat stalk, and vine pruning waste, in the cultivation of shiitake mushroom (*L. edodes* [Berk.] Pegler). It was concluded that the type of agricultural waste used has a significant impact on the composition of volatile aroma of the mushroom. This situation is due to the sulfur content of the biomass, which is subsequently important in the odor formation for shiitake mushrooms. All in all, the utilization of agricultural wastes in mushroom cultivation has been widely studied for their feasibility and corelation in the growth of mushrooms.

1.2.2.4 Organic Acids

The production of organic acids from agricultural wastes has been documented for the past decades, including acetic acid, citric acid, formic acid (FA), succinic acid, and a few other organic acids [36]. Kumar et al. [37] explained that the utilization of lignocellulosic biomass is one of the promising approaches for the production of various types of organic acids. In acid catalysis of lignocellulosic biomass, the formation of acetic acid, levulinic acid (LA), and FA can be observed. Citric acid, which is known as the second-largest fermentation product, is mainly produced by *Aspergillus niger* [38]. Various agricultural wastes have been utilized in citric acid production, including apple pomace [39], cassava bagasse [36], oil palm empty fruit bunch [40], and sugarcane bagasse [38].

Succinic acid is one of the most valuable chemicals in various industries, including agricultural, food, and pharmaceutical. The utilization of agricultural wastes is deemed to be a potential substitute for the current petroleum-based chemical processes. Various studies have been conducted to explore the potential of agricultural wastes as an alternative substrate for the production of succinic acid. Liu et al. [41] have demonstrated that the production of succinic acid achieved is 39.3 g/l using sugarcane bagasse hydrolysate by *Escherichia coli* BA305. The feasibility of cornstalk hydrolysate in succinic acid production has been successfully demonstrated with a yield of 0.85 and 23.1 g/l of succinic acid produced [42]. The utilization of agricultural wastes into organic acids is highly promising for sustainable production.

1.2.2.5 Industrial Enzymes

Bioconversion of agricultural wastes also benefited enzyme-based related industry. In the production of enzymes from agricultural wastes, there are two modes of fermentation involved, solid-state and submerged fermentation. Despite having gains and losses, solid-state fermentation is the most popular technique of choice in the larger scale for enzyme production. This situation is mainly due to the higher production of enzymes obtained, resulting from enhanced interaction between microorganisms and substrate as well as a supportive medium for the growth of microorganisms [43]. According to Koul et al. [1], several enzymes have been recognized in high market demand, including cellulases, lignases, proteases, pectinases, and xylanases. In the literature reviews, several studies have successfully demonstrated the production of these enzymes using bioconversion of various agricultural wastes. Ferreira da Silva et al. [44] have utilized banana pseudostem, jatropha, and coconut fiber in an attempt to produce lignin peroxidase and cellulases. The results showed that the highest production of lignin peroxidase and cellulases was 49 916 U/g and 19.5 FPU/g using jatropha and banana pseudostem, respectively. In another study, other agricultural wastes have been documented to be potentially used as substrates for the production of cellulases and xylanase. According to Dhillon et al. [45], the highest enzyme activity was recorded in the fermentation using the combination of rice straw and wheat bran. These situations have elevated the value chain of agricultural wastes, as the processes using negative-cost agricultural wastes benefited various industries as well as the environment.

1.2.3 Industrial By-products

In term of chemical substitutes from industrial by-products, various waste materials can be utilized based on the source.

1.2.3.1 Agriculture, Horticulture, and Landscaping

The use of a by-product in agriculture or horticulture presumes that it has properties favorable to plant growth. The positive effect can be related to the supply of nutrients or conditioning soil by altering its chemical, physical, or biological composition. In the former case, the nutrients need to be soluble or transformable to a form that is available to plants. By-products that have liming properties, which can correct soil acidity and increase crop yield, have been used for ground improvement. Blast furnace slag, steelmaking slag, and ash from wood combustion are the most common by-products used for this purpose. Kiln dust is also suitable for agricultural purposes.

According to US Environmental Protection Agency (USEPA) [46], industrial by-products containing potentially toxic metals, including nickel, lead, and cadmium, have been used in the production of zinc fertilizer, which is closely monitored by the USEPA of their maximum contamination limit. The calcium- and magnesium-based by-products contained in steelmaking slag and sludge are observed to provide a positive impact on herbage cultivation. The motivation for using wood ash is to avoid depleting essential soil nutrients and reduce the harmful effects of acidification of forest soils and surface waters. Wood ash also releases potassium, sodium, boron, and sulfur. In other cases, the utilization of red mud from mining industry has been extensively studied for its potential. According to Hua et al. [47], the positive responses of soil contaminated with metal/metalloid with the addition of red mud as an immobilizer have revealed its potential use. Seawater-neutralized red mud has also shown a good capacity to immobilize soluble acid and metals, particularly aluminum, zinc, and copper, from acid-sulfate soil solutions. This feature makes it a desirable alternative for lime if leaching is an issue.

1.2.3.2 Use as Raw Material or Additive of New Products

Some by-products have proven to be practical raw materials for new products. For example, blast furnace slag (BFS) has been widely used in the manufacture of concrete owing to properties similar to Portland cement, whereas fiber sludge with high inorganic content has been proven to be a suitable raw material in the manufacture of cement. Fiber sludge has also been used as the base raw material in some industrial sorbent and animal bedding products [48]. Blast furnace slag can be combined with silica or alumina and can be converted to fibers for rock wool. Spent foundry sand can be used as a source of silica in this process.

Fly ash can be mixed with the main raw material to produce ceramics, floor and wall tiles, sound insulation panels, fillers in polymers and rubbers, and zeolites and inorganic fibers [38], among others. Besides ash, foundry sand, in particular, is used as an additive to provide fines in cement and concrete. Some applications, such as the manufacture of cement, may require mechanical activation that enables the use of higher proportions of ash and the attainment of improved quality for the new product. At the same time, the potential effect on the durability of concrete structures has raised some discussion about the suitability of ash for this purpose.

1.3 Potential Application of Chemical Substitute Extracted from Selected Agricultural Wastes and Industrial By-products

The book consists of 17 chapters that discuss the selected agricultural wastes and industrial by-products as precursors or substrates for chemical substitutes or themselves as the chemical substitute.

It begins with a glance at biorefinery of chemical substitutes from agriculture and industrial by-products (Abd-Aziz et al.: Chapter 1). Agricultural waste is defined as unwanted waste as a result of agricultural activities, while industrial by-products are leftover from industrial activities with abundant organic and inorganic nutrient composition. The advanced biorefinery is capable of utilizing agricultural wastes and industrial by-products to various chemical substitutes or value-added products. This chapter, in general, will cover the consolidated bioconversion, bioprocessing, and downstream process of the significant chemical substitutes produced from agriculture and industrial by-products about the specific chemical substitutes that will be discussed in each chapter.

Antioxidant bioactive molecules can be extracted from agro-industrial wastes and can potentially be alternative nutrient sources to produce dietary supplements for health benefits (Jenol et al.: Chapter 2). In view of this, the chapter provides an overview of the various antioxidant bioactive molecules found in numerous agro-industrial wastes and biological approaches for their recovery from agricultural wastes. Also, their potential applications in pharmaceutical industries and food production as food and animal feed additives are incorporated in this chapter.

One of the components in lemongrass (*Cymbopogon citratus*) that shows high potential in bioactive activities is oleoresin (Md Salleh et al.: Chapter 3). Oleoresins are a natural mixture of essential oils and resin extracted from lemongrass leaves. Oleoresins in lemongrass provide a number of advantages over traditional spices as flavoring agents. Oleoresins can also be standardized for flavor and have a long shelf life for application in the food industry. Nowadays, the increase in demand for natural food flavors in the European market has opened more opportunities for suppliers of oleoresins in developing countries.

Seaweed is a promising biomass resource for producing high-added-value materials such as food or usable flavoring to improve the nutritious quality of food preparation and active components with antioxidant and anti-excitant properties, an alternative renewable resource for biofuel production, chemicals, and nanocarbon materials (such as activated carbon, graphene, and carbon nanotube). This chapter focuses on the options of developing those materials from seaweeds

(Prakaso et al.: Chapter 4), which these structures have encountered applications in various technological fields, such as adsorption, catalysis, hydrogen storage, and electronics.

Spent Mushroom Substrate (SMS) is the by-product of mushroom cultivation (Sabaratnam et al.: Chapter 5). It is the unutilized lignocellulosic substrate, which contains lignin, cellulose, hemicellulose, mycelia, sugars, enzymes, and chemical entities left after the harvesting of commercial mushrooms. As the mushroom industry is rapidly growing, it is facing challenges in disposing SMS. The potentials of using SMS for the production of value-added products include the production of bulk hydrolytic enzymes such as laccase, xylanase, lignin peroxidase, cellulase, and hemicellulose from SMS, and their applications can be explored. This chapter reviews the scientific research and practical applications of SMS as a readily available and cheap source of enzymes for the bioremediation of harmful soil and water contaminants, as well as for the hydrolysis of complex components into simple components for fermentable feedstock production.

Pineapple is a popular tropical fruit consumed worldwide. After processing pineapple for human consumption, large amounts of waste materials are generated, including the crown, peel, and core. These wastes are usually disposed of in landfills, causing environmental problems. However, pineapple wastes contain valuable compounds, including essential oils, that can be extracted and utilized for various applications. There are various techniques that can be used to extract pineapple essential oil, including steam distillation or hydrodistillation, solvent extraction, and supercritical fluid extraction. However, further research is required to optimize the extraction methods and explore the full potential of these essential oils. The use of essential oils derived from pineapple waste can also contribute to sustainable waste management practices and environmental preservation (Ibrahim et al.: Chapter 6).

Poultry processing plants produce huge amounts of chicken feathers. The common feathers disposal methods cause environmental pollution. As feathers are composed of 91% keratin, they form feather hydrolysate after being subjected to chemical, biological, or combined treatments. This chapter provides the treatments available for the conversion of feathers into protein hydrolysate that can be further used to produce feather meals, biofertilizers, and bioplastics. Keratinase enzyme plays an important role in the hydrolysis of feathers and has been applied in leather, feed, detergent, and cosmetics industries. The upstream process that applies molecular approaches to improve the keratinase characteristics will be discussed in this chapter. In addition, the challenges of the bioprocessing of feathers and the upstream process are highlighted (Lai-Yee et al.: Chapter 7).

Agricultural wastes, such as corncob, wheat straw, and bagasse, are available as cheap and natural carbon sources for enzyme production. The pulp and paper industry has started to phase out chemical bleaching agents with enzymes, such as cellulases, xylanases, and laccases, specifically for the pre-bleaching step and the delignification step. Using enzymes will be beneficial not only economically but also environmentally as the process contributes to less toxic waste. Multiple studies have researched producing cellulase, xylanase, or laccase in varying production methods. This chapter aims to highlight the potential of agricultural wastes with high lignocellulosic content for enzyme production, explain the usage of bio-bleaching enzymes, and analyze the techno-economical aspect through a case study (Alifia et al.: Chapter 8).

Natural rubber latex (NRL), the white sap that comes from the *Hevea brasiliensis* tree, is an important raw material for the production of various rubber products, such as gloves, tires, and tubes. However, during the processing of NRL, a protein-rich fraction (the serum) is generated and is treated as waste. The fraction generally consists of significant quantities of enzymes, namely lysozymes and chitinases, which can be industrially useful. This chapter draws attention to the general characteristics and potential applications of the enzymes and assay developments for the enzymes' activity. This chapter subsequently explores the recoveries of plant-derived lysozymes and chitinases and proposes a strategy for recovering the enzymes from the NRL. The strategy ultimately promotes the transition toward circular and sustainable bioeconomy through waste valorization (Tan et al.: Chapter 9).

In Southeast Asia, the sago palm serves as one of the most important starch providers, which has been utilized as food for centuries. In Malaysia, specifically in Sarawak, sago starch-based agro-industry is one of the major revenue sources for the state. In the near future, the sago industry will eventually be facing major challenges related to the waste management due to the rising demand of the products. The processing of sago palm into starch generates a huge amount of several types of waste, including bark, hampas, wastewater, and sago frond. The bioconversion of these wastes into value-added products (biosugar and bioproducts derivation, including L-Lactic acid, cellobiose, silage, enzymes, and kojic acid) will be reviewed. The prospects and challenges in the sago wastes biorefinery will be discussed (Jenol et al.: Chapter 10).

Sugarcane is one of the most important food crops in Asian countries for more than a millennial. As part of the industrial crops, the strategy for improving the efficiency of the agricultural sector for a vast and sustainable industry is required. Sugarcane bagasse is a main residue produced by sugar industries as the milling by-product. Chemically, it is a fibrous residue of sugarcane bagasse that contains mainly cellulose, hemicellulose, and lignin. The utilization of sugarcane bagasse and other residues in supporting industrial processes has been developed. Various chemicals are generated by conversion and bioconversion of sugarcane by-products, including biofertilizers, soil improvers, and biocomposite. In addition, the future prospects of sugarcane by-product development to support sugarcane industrial activity are presented (Fatimah et al.: Chapter 11).

Tengkawang (*Shorea stenoptera*) is a potential endemic plant of Kalimantan. However, its production process is currently still carried out traditionally. Tengkawang butter has the potential to be a cocoa butter equivalent (CBE) because it has a fatty acid composition and melting point close to cocoa butter (CB). The fatty acid profile of the tengkawang butter is dominated by palmitic acid (16–24%), stearic acid (40–47%), and oleic acid (31–33%). The melting point of tengkawang butter is at the human mouth (body) temperature of 35–37 °C. Physical and chemical processing of tengkawang is carried out to obtain the quality of tengkawang butter according to the standard butter material. This chapter also discusses the economic feasibility based on process simulation. The utilization of tengkawang butter as a substitute for CB has drawn attention as a strategy to achieve cost-effective food material production and conservation of endemic plants in Kalimantan (Darmawan et al.: Chapter 12).

Bio-succinic acid production is gaining attraction globally due to fossil fuel depletion and environmental deterioration. The production process also offers excellent performance, is less environmentally damaging, allows the use of abundant biomass resources, and is closely related to the sustainability agenda, i.e. responsible consumption and production. This chapter provides an overview of the recent insights on bio-succinic acid and the importance of its production through biochemical routes (Luthfi et al.: Chapter 13). Technologies related to the lignocellulosic valorization in bio-succinic acid production, including pretreatment, hydrolysis, and fermentation of various microbial workhorses, configurations, and strategies, as well as the purification and recovery of succinic acid are some of the recent interesting features highlighted in this chapter. Finally, the application of bio-succinic acid as a precursor to various products is also presented.

Furfural is one of the building block materials that can react to produce various fine chemicals. Furfural is widely used as a solvent in the petroleum processing industry, agrochemicals, and pharmaceuticals. It can be further converted into derivatives, such as furfuryl alcohol, furan, and tetrahydrofuran. Furfural is produced from the dehydration of xylose (Muryanto et al.: Chapter 14). Furfural production depends on the condition of hemicellulose/xylose content, catalyst used, solvent for process, and the condition of hydrolysis and dehydration process. Xylose is derived from lignocellulosic biomass. This chapter discusses furfural and its derivatives, its hydrolysis and purification processes, and the bagasse and corncob feedstock for furfural production. Techno-economic analysis is discussed based on process simulation and selected case studies.

Lignocellulose biomass can be converted to FA and LA. LA has been identified as a promising platform chemical for the next generation, such as biodiesel additives. FA represents one of the most promising modern fuel sources for membrane fuel cells. LA production commences with depolymerizing the biomass cellulose fraction into oligosaccharides and glucose. Next, pentose is hydrolyzed to 5-hydroxymethylfurfural (HMF) and dehydrated into LA and FA. The temperature and pressure of the reaction are susceptible to the products. Sugarcane bagasse and rice straw are among industrial and agricultural waste biomass. This chapter discusses the availability of these biomass and alternative production processes of LA and FA. This chapter also discusses the economic feasibility of process simulation and available studies (Panjaitan and Gozan: Chapter 15).

Cellulases are a group of diverse enzymes that are significant for a number of industrial applications, especially the conversion of lignocellulosic feedstock into monomeric sugars in biorefinery process. In recent years, the market demand for these enzymes has been continually raised due to the growth of the biorefinery industry, which also caused an increase in the commercial enzyme price. Several strategies have been proposed to reduce the cost of cellulase, while the utilization of agricultural wastes as an inexpensive source for cellulase production is mainly described in this chapter. Furthermore, cellulase classification, potential strains with high-level cellulase production, co-culture (mixed) system, and consolidated bioconversion are also discussed (Bankeeree et al.: Chapter 16).

Biodiesel is a renewable energy alternative to diesel, and during its production, abundant crude glycerol is generated as a by-product. As a waste product, crude glycerol needs to be treated before disposal. Alternatively, it can be converted into valuable products, such as 1,3-propanediol (1,3-PDO; $CH_2(CH_2OH)_2$) and butanol (C_4H_9OH). The present chapter focuses on the utilization of microbes for the production of 1,3-PDO and butanol from crude glycerol. Pathways associated with the production of 1,3-PDO and butanol, as well as characteristics and impurities in crude glycerol, are highlighted. In addition, applications of 1,3-PDO and butanol and the downstream purification and recovery processes are examined. Finally, challenges and future research perspectives on the production and application of 1,3-PDO and butanol are also noted (Kongjan et al.: Chapter 17).

The overall highlight of the book discussed the sustainable production of chemical substitutes from agricultural and industrial by-products as a way to preserve resources and protect the environment. Hence, significant attention is directed toward developing green technologies to valorize these by-products. This increase in value can make the economics of chemical substitute production from by-products more feasible and workable. However, the cost of synthesizing chemical substitutes and productivity barriers is still very challenging. This chapter provides the policies and initiatives for the sustainable development of selected countries, as well as case studies on assessing the sustainability of selected chemical substitute production strategies, considering three perspectives, i.e. environmental, economic, and social. This chapter presents two case studies on cellulase and biofertilizer production. The case studies discuss the cost and pinch analysis using the process simulation software Aspen Plus. The challenges and market opportunities will be covered (Lai-Yee et al.: Chapter 18).

1.4 Conclusions

The development of sustainable solutions for the management of by-products and food waste is one of the main challenges in our society. These solutions must be able to take full advantage of the biological potential of biomaterials and achieve economic, social, and environmental benefits. With the nutritional problems faced by society today (hunger indicators and the growing world population), the use of food waste for human food should be a priority. Wastes and by-products produced in developing countries have a powerful nutritional and functional use in their formulation and a powerful tool in minimizing hunger. In addition, the added value generated by the diversification of the productive chains can create job opportunities for the residents, generating an additional social benefit.

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