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Increasing Trend towards Production of High Value Bioproducts from Biomass Feedstocks

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Burgeoning population coupled with demanding agricultural production and improved living standards caused a rapid increase in volume and types of waste agricultural biomass. Besides agricultural byproducts, other important sources of biomass are food processing, biotechnological industries, marine processing wastes, and municipal wastes and livestock by-products, among others. For instance, currently the annual worldwide production of biomass is estimated to exceed 100 trillion kilograms [1]. Among this, 140 billion metric tons of biomass is generated every year from agriculture [2]. Generally, the waste generated during manufacturing and processing is nearly ten times higher than the amount of finished product obtained. Although there is a growing trend towards the utilization of biomass for energy and other industrial products, it is still largely under-utilized. The major portion of waste biomass is generally landfilled resulting in CH_4 emissions and leaching. Moreover, the open burning by the farmers to clear the land generates CO_2 and other pollutants and hence becoming a burgeoning problem. The improper management of waste biomass is contributing towards climate change, water and soil contamination, and air pollution.

Due to rapidly depleting non-renewable fossil fuel reserves, the waste biomass is viewed as a potential source of renewable and sustainable energy, chemicals and other materials. The utilization of renewable biomass as an alternative for fossil fuels started back in the mid-1800's when biomass, mainly woody biomass, supplied over 90% of U.S. energy and fuel needs. However, after that the biomass energy usage began to decline as fossil fuels became the preferred energy resources. The commercial utilization of biomass energy and fuels has been again revived and increased gradually after the First Oil Crisis in 1973–1974 [3]. Biomass feedstocks are of high value with respect to material and energy recovery.

Recently, the focus has been shifting towards production of high value bio-based products from waste biomass [4]. Bio-based products can be synthesized from various biomass feedstocks and can be categorized into first (synthesized from edible biomass such as starch-rich or oily plants) and second generation products (synthesized from biomass consisting of the residual non-food parts of current crops or other non-food sources, such as perennial grasses or algae). Products derived from algae are sometimes also referred to as third-generation products. The products derived from biomass feedstocks are generally considered as having a significantly higher potential to replace non-renewable fossil-based products. These biomass feedstocks typically contain on dry weight basis 40–60% cellulose, 20–40% hemicellulose, and 10–25% lignin [5]. The second and third generation feedstocks hold tremendous potential for the production of high value bio-products. However, it is technically more difficult to convert lignocellulosic biomass into value-added products as compared to first generation feedstocks. Multidisciplinary research efforts have generated a significant level of technical and commercial success towards these bio-based materials. However, still the most pressing challenge for bio-based industries is to improve the economics of production through up scaling and industrialization in order to bring competitive solutions to the market.

The biomass feedstocks can be transformed to a variety of high-value bio-based products through biological transformation [5]. Besides, the waste biomass contains many extractable compounds of high-value which can be extracted directly from waste biomass. Various higher value compounds, such as flavour, fragrance and bioactive compounds are mainly found in the fruit and vegetable peels, where they play an important role to deter pests. For instance, apple pomace is an excellent source of natural antioxidants, such as catechins, procyanidins, caffeic acid, phloridzin, phloretin glycosides, quercetin glycosides, chlorogenic acid, among others. Apple pomace, including seeds, contains polyphenolics with the strong antioxidant activity of quercetin glycosides, phloridzin and its oxidative products. The other high-value products derived from apple industry wastes are recently reviewed in detail [6]. Citrus peels are rich source of flavonoids, saponins, steroids, terpenoids, tannins and alkaloids. Global production of citrus fruits exceeds 88 million tonnes annually [7] and about half of the processed citrus, including peels, segment membranes, and seeds end up as citrus waste. The tomato industry wastes, such as peels and seeds contain carotenoids, such as lycopene, lutein, β-carotene, and cis-β-carotene. Similarly, strawberry/blackberry/raspberry pomace is highly rich in aromatic compounds, such as anthocyanins, tannins, starches, saponins, polypeptides and lectins, polyphenols, lactones, flavones, and phenon. The potato processing wastes includes peels and waste potatoes. The potato peels are rich in gallic acid, caffeic acid, vanillic acid [5]. Likewise, various other fruit wastes are rich source of various natural oxidants and hence can be viewed as excellent sources of bioactive phenolics. Xylitol (sweetener), a rare sugar that exists in low amounts in nature can be produced from brewer's spent grain (BSG) through acid hydrolysis and yeast fermentation. BSG requires no preliminary detoxification steps and overall production of xylitol is favored by the presence of high xylose concentrations. Besides, BSG can be used for the production of ferulic acid, hydroxycinnamic acid and pullulan (an extracellular water-soluble microbial polysaccharide produced by strains of *Aureobasidium pullulans*) through fermentation processes. The by-product from the food and fruit processing industries has the potential to provide a range of high-value compounds, offering

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a more profitable and environmentally profitable alternative to current waste use practices.

Similar to food/fruit processing wastes, the agricultural wastes are rich source of high- value compounds. The agricultural wastes, such as rice husk and straw, sugarcane bagasse/molasses and corn steep waste, wheat bran flour, coconut oil cake, peanut shells, corn pomace/husk/cob, wheat bran, cassava peels, coconut oil cake, groundnut oil cake and ground nut shell have been used for the production of antibiotics, e.g. neomycin (*Streptomyces marinensis*), cephalosporin (*Acremonium chrysogenum*), cyclosporin A (*Tolypocladiumin flatum*), tetracycline and oxytetracycline (*Streptomyces strains*) and rifamycin B (*Amycolatopsis sp.*) through solid-state fermentation. The major agricultural by-product, wheat straw contains a range of valuable compounds including natural waxes. Waxes are used in numerous high-value applications ranging from surface coatings to cosmetics. The aroma compounds, such as 2-phenylethanol, acetoin and vanillin are found in beet molasses, sugarcane molasses, waste residue of rice bran oil [5].

The production of chemicals from renewable resources is gaining global interest. However, currently only 5% of chemicals are derived from renewable resources [8]. The International Energy Agency (IEA) estimate current annual production of bio-based chemicals and polymers at around 50 million tonnes, including high value fermentation products, such as amino acids, vitamins and antibiotics, with a value €22 billion by 2013. For bulk chemicals, the renewable market has been estimated at €2.4 billion in 2010 growing at compound annual growth rate of 23% up to 2015. Under favourable market conditions bioproducts derived from renewable feedstocks could represent nearly 40% of bulk chemicals by 2050 [9]. In future, waste biomass will provide the feedstocks for production of high-value bio-based products. Novel, efficient, economical and ecofriendly technologies are sought for reliable extraction, separation and transformation of chemicals from biomass feedstocks.

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