Production Of Bioplastic from Food Waste

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***Abstract*—Bioplastic production from upcycled food waste is advanced method aimed at addressing both plastic pollution and food waste management. This procedure includes the alteration of agricultural and food industry residues into biodegradable polymers using microorganisms (*Haloferax mediterranei)*. These microorganisms are proficient of constructing polyhydroxybutyrate (PHB), a type of bioplastic, in high-salinity environments, removing the need for sterilization and plummeting costs. Research focuses on optimizing fermentation parameters, enhancing PHB yields, and cultivating downstream processing techniques to make the process economically viable for industrial-scale production. The use of upcycled food waste as a substrate is particularly beneficial as it helps in reducing feedstock costs and provides another to conservative, more luxurious raw materials. Additionally, the valorization of upcycled food waste into valuable bioplastics contributes to sustainability by qualifying waste and reducing reliance on petrochemical plastics. The production process involves several stages including biomass production, PHB recapture, and the characterization of the produced bioplastics to ensure they meet required standards for various applications. The negative effects on the environment of the intensive use of synthetic, oil-derived plastics to variety products have given renewed impetus to the search for biopolymers derived from vegetable, animal or microbial matter that could verify to be a sound alternative in a number of applications. The real challenge is to variety new materials from upcycled food waste. It presents interesting experiments underway and envisages possible future scenarios.**

***Index Terms*—bioplastic, upcycled food waste, petrochemical plastic, design for sustainability**

I. INTRODUCTION

The Food and Agriculture Organization (FAO) of the United Nations reported that around 1.3 billion tons of food is lost or wasted every year globally. It is found that this amount agrees to one-third of all food resources produced for human consumption. Note that sources of food waste include household, commercial, industrial, and agricultural remains, while the compositional matrix of food wastes differs broadly based on source and type. Food waste means an extensive loss of other resources such as land, water, energy, and sweat. FAO defines food waste as "food losses of quality and quantity through the process of the supply chain taking place at production, post-harvest, and processing stages. In more specific terms, food losses occurring at the end of the food chain correspond to "food waste (FW)," which is contingent on consumer behavior, purchase intention, and vender marketing approach. In general, the most FW is being disposed of via landfilling, composting, and fermentation. Although European Union guidelines stated that food waste should preferentially be used as animal feed, it became illegal because of disease control concerns. Thus, the valorization of food waste through production of value-added products can be an ideal and practical end use. Depending on geographically-specific circumstances, the generation patterns of FW may differ greatly across the world. In broad terms, waste generation is affected by a list of variables, including crop production models.

Table: -1 Types of waste & their origins in the food industry

ORDER	Type of FW	ORIGINS
1	Waste from sugar factory	Sugar manufacturers
2	Waste from preparation and processing of fruit, vegetable, grain, edible oil	Fruit and vegetable processing plant, starch manufacturer, manufacturer of coffee, tea
3	Waste from production of baked foods and sweets	Bakeries, candy producers

II. CURRENT STATUS OF BIOPLASTIC PRODUCTION AND FOOD WASTE FEEDSTOCK COLLECTION AND SORTING

2.1. Desirable production of bioplastic from food waste

FW is being generated from all stages of the food supply chain including post-production, supervision/stowage, manufacturing, wholesale/retail, and consumption stages. In general, around 30 wt% food develops FW. In 2015, 39.6 million tons of FW (15.1 wt% of MSW) were generated in the US, but only 5.3 wt% of them is used for anaerobic breakdown and composting (Gunders and Bloom, is used for anaerobic breakdown and composting (Gunders and Bloom, among them, 38 wt% is originated from the food manufacturing sectors. Thus, the conversion of FW into charge-added chemicals can be the desired end use of food waste for increasing global sustainability. Manufacture of bioplastics such as PHA is an ideal strategy for FW disposal. One reason for this is that FW is landfilled and yields undesirable results, such as greenhouse gas (GHG) emissions and groundwater contamination. Production of bioplastics from FW is a renewable sustainable process, in which materials are synthesized from the carbon neutral resources. Some bioplastics are biodegradable and compostable under industrial conditions. Compostable bioplastics break down by 90% in several months but can also undergo industrial composting processes. Such bioplastics should chance the specifications and evaluation criteria of international standards for biodegradable plastics/products, such as composability. The environmental benefits from utilization of bioplastics are one of the driving forces to expand their further use. Ceresana in Constance, Germany, predicted that the world market for bioplastics in 2021 will be three times larger than that in 2014, generating a total of USD 5.8billion in revenue. For a specific cases.

Table 2.: properties of food waste applied in PHA production.

Order	Type of waste	Potential materials	Characteristics
1	Used cooking oil	Soyabean oil, rapeseed oil, sunflower seeds	High content of lipid can be converted into biodiesel
2	Animal by-products	Blood, fats	High nitrogen content of BOD & COD
3	Mix domestic waste	Waste bread, cheese whey, and nut	High content of protein & starch

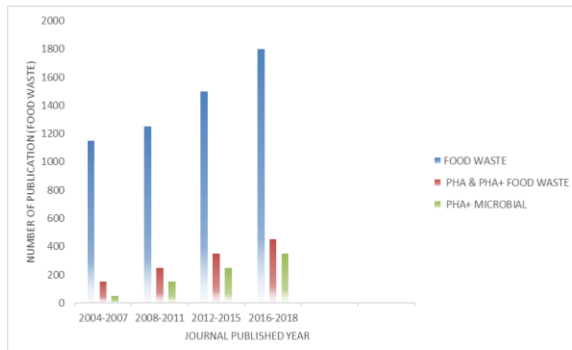
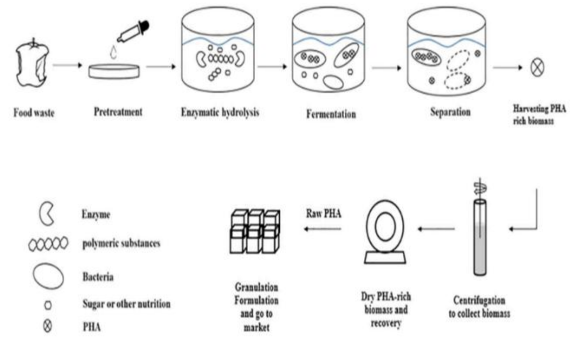


FIG. 1: - science citation index publication on PHA and food waste from web of science

2.2. Producing bioplastics from upcycled waste: the challenge leading & interesting diagnoses

Bioplastics certainly have a light environmental shipment than synthetic ones, but the base quantifiable they are made of is of no small standing as favors both the environment and ethical concerns. Today, the material most used for their production is corn; although the quantities at stake pale in comparison with the global production of this cereal, this still raises an important question: is it right to use for other resolves a crop that can be eaten, that provides basic sustenance for a part of the world's population? It is the same question postured for biofuels. Corn prices are soaring; given the effects on the world food system, and the hoarding of immense landholdings by rich nations in the poorest countries in directive to plant crops for these resolutions, the question is not only a genuine one.



2.3. Converting food waste to fermentable substrate

Although FW is a good initial feedstock for production of bioplastics, it must be pretreated to recover or alter the Physico-chemical and biological assets. This section discusses the commonly used pretreatment technologies (i.e., physical, chemical, and biological Processes) and enzymatic hydrolysis and their effects on bioplastic making yield. several methods can be merged into a single treatment system to achieve better performance. For example, bioplastic making with physical/acid treatment (i.e., 60 min heating at 121 °C followed by 2% sulfuric acid digestion) of industrial FW mixture was able to achieve the highest 3-hydroxyvaleric acid (3 HV) mole fraction of 22.9% in experiments. summarizes the sub-products made/disconnected from FW transition procedures and their requests.

2.4. Thermal conversion of food waste to fermentable organic compounds

Physical pretreatment is conducted by the mechanical and thermal conversion processes. Ultrasound, microwaves, milling, and heating methods are also being used for pulverization to increase surface area, separation rate, biological conversion, or fermentable substrates (including glucose, proteins, fats, fatty acids, and starch).

Physical pretreatment is usually applied at the beginning to change the particle size or to separate the materials for the processing in the next steps. Thus, the physical pretreatment would not be applied alone but is always combined with other treatment methods.

2.5. Enzymatic hydrolysis of food waste

Hydrolysis is the main mechanism to breakdown polymers into their consistent monomers and/or intermediates. Enzymatic hydrolysis promotes the hydrolytic ability of FW and reduces volatile adjourned solids. Altering polymeric structures into fermentable products is a critical step in this process. FWs containing lignocellulosic are a complex matrix of cellulose, hemicellulose, and lignin. Although cellulose and hemicellulose yield fermentable sugars via an enzyme hydrolysis step, lignin is one of the most recalcitrant structures as it consists of phenylpropanoid units. the effect of pretreatment with commercial enzymes on hydrolytic solubilization of raw FW collected from a cafeteria. The authors found that protease exhibited the highest decrease rate of volatile suspended solids among three types of enzymes, namely carbohydrases, proteases, and lipases, and the mixed enzyme handling displayed better reduction productivity than that of single-enzyme treatment. Certain types of FW do not contain sufficient amounts of nutrients to maintain biological activity during fermentation, which can be resolved by utilizing a mixture of different FWs. Mixed enzymes produced through solid-state fermentation can hydrolyze proteins and sugary compounds in FW through different path.

III. FOOD WASTE COLLECTION AND SORTING TECHNOLOGIES

Most parts of FW can be recycled (if divided), and recycling will help diminish the overall outflows on waste managing. Also, it is important to improve the recycling rate of food waste, especially for FW from complex MWF. Gathering and sorting from the spring of waste generation can effectively reduce the cost of the subsequent steps to offer a strategic means for exploiting yield and profit, to reduce environmental burden, and to improve the reuse efficiency of material. FW can be clandestine as industrial, agricultural, and household. The total amount of FW from industrial procedures and agriculture is large.

In large-scale food production facilities, such as farmsteads and food industrial plants, recycle systems are generally reserved for unpackaging and peeling functions. For example, a turbo separator can deal with 8–10 tons of FW per hour. In commercial Applications, one system can serve two roles of collection and arrangement. STREAM Concern (Malaysia) effectively gathers wet FW from kitchens and transfers waste in containers or delivers them directly to FW treatment plants.

TABLE 3- Organic residues and their application

Order	Organic residues	Application in bioplastic synthesis
1	Fruits and vegetable	Antioxidants, flavonoids, phenols, carotenoids & lipids
2	Waste oil	Fatty acid & methyl esters
3	Dairy products	Carbon & nitrogen source

3.1. Biological conversion of food waste to fermentable substrates

Biological conversion of food waste to fermentable substrate, White rot fungus aids in delignification, which in turn improves White rot fungus aids in delignification, which in turn improves enzymatic saccharification rate and productivity. Several studies have adopted fungi as a FW pretreatment method selected white-rot fungi to improve carbohydrate yield from wheat straw and investigated the effect five different fungi on enzymatic hydrolysis of wheat straw.

3.2. PHA production using food waste as a substrate

The feasibility of PHA production using food waste as a substrate has been intensively evaluated, including information related to maximum PHA accretion capacity, storage yield, and production rate. Saccharides (e.g., fructose, glucose, maltose, lactose, and xylose arabinose), collected with n-alkanes, n-alkanoic acids (e.g., acetic acid, propionic acid, butyric acids, valeric acid, lauric acid, and oleic acid), n-alcohols (e.g., methanol, ethanol, octanol, and glycerol), gas and acid are measured key carbon source for biosynthesis of PHA. Most of the carbon applied in commercial PHA production is relatively expensive, such as unadulterated carbohydrates (glucose and sucrose) and fatty acids. Unadulterated nutrients (amino acids and phosphate) are unaffordable, resulting in unwieldiness of the mainstream of advanced biotechnological instruments.

3.3. food waste as a carbon source

Fruits and vegetables can be used as the carbon substrates in the fermentation process to yield PHA. Some fruit foodstuffs (e.g., citrus juice) are made through 50% extraction of fresh fruit, with the residues subsequently remaining as wastes. These wastes contain high amounts of sugars but low measures of proteins. Citrus wastes are used to produce enzymes (in particular pectinase) of citric acid, succinic acid. dietary fiber, prebiotic oligosaccharides, and natural antioxidants, which can improve productivity.

TABLE 4- PHA production from food waste by fermentation.

A: (unadulterated culture & mixed culture)

ORDER	STRAIN	BIOPLASTIC
1	Defluviicoccus vanus	PHA
2	Cupriavidus necator	P(3HB)
3	Activated sludge consortia	PHA
4	Activated sludge consortia	PHA

TABLE 5- Raw material extracted from food waste using physical methods.

Result for mechanical and thermal conversion

Order	Technology	Provided characteristics & effect
1	Ultrasound	Mechanoacoustic & nonchemical effect
2	Milling, grinding	Reduction in particle size to extract sugars
3	Thermal pretreatment	Enhance enzyme hydrolysis for fermentable substrates

IV. CASE STUDY OF PHA PRODUCTS FROM FOOD WASTE/AGRICULTURE

The bioplastic production efficiency from food/agronomic waste/biomass and its economic viability are contingent on several factors (e.g., type of waste generated in the selected area, processing cost, availability of the biomass, transport expenses, raw materials expenses, and other common manufacturing expenses). Apart from high competence, industrial bioplastic production should observe with government values for environmental pollution. As the type of waste produced in each season can vary, the production of bioplastics can be affected by changes in season, which hampers the supply of convinced raw materials in a certain period. In general, only the feasibility of the synthesis cost has been tested at workroom scale.

Several research groups focused on using the advanced methods for bioplastics through a cost analysis of the methods. However, incomplete case studies of biorefineries have been published. Here, considering the type of raw material and location for installing biorefineries, we reviewed some case studies that directly provide indication on the production of biomass-based products, techno-economical potentials, and cost analysis.

V. CONCLUSION

Bioplastic is a natural polymeric material that has been advanced widely over the last two aeras due to its good biocompatibility, biodegradability, and physical properties. As such, bioplastic production has become one of the most active research areas in recent years. Bioplastic can be practical in wrapping industries, spray materials, practice materials, electronic products, agricultural products, mechanization products, chemical media, and solvents. In the production of bioplastics, the interlinkage of biotechnology processes is a key strategy aimed at exploiting the use of food waste and increasing the potential revenue of the entire bioprocessing chain. Given that mass generation of FW is unavoidable, the environmental problems arising from waste disposal (e.g., water contamination and GHG emissions) should be mitigated. Therefore, this review confirmed the potential of FW as a raw physical for bioplastic production to address significant environmental problems. Hence, physical, thermo-chemical, and biological methodologies required for groundwork of bioplastic raw materials from FW are reported. Moreover, production of PHA based on unadulterated/mixed culture and fermentation machineries was highlighted.

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