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Bio- Agro Waste Valorization and its Sustainability in the Industry: A Review

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Abstract: The application of bio-agro waste in industrial production has become extensive. Many industries have embarked on large scale production due to the broadness in the application of the bio-agro waste. This study vividly and succinctly surveyed the different bio-agro waste, its areas of application and its sustainability in industrial production. Several examples of bio-agro waste have been reported. Their relevance in bio-ethanol production has equally been discussed. More so, current research and development in harnessing the bio-agro waste were equally reported, to achieve better economic sustainability. Thus, the study has provided a new circular economic method for addressing the problems associated with bio-agro waste.

Keyword: Nano; Nanotechnology; Nanoparticle; Agrowaste; Bio-Agrowaste; Industrial; Production; Bio-ethanol; Bio-fuel

1. Introduction

Energy is the basis of industrial and economic development. It is a prerequisite for all human activities especially in space, lighting, water heating, cooking, food production and storage, health, education, industrial production, mineral extraction and transport [1]. However, the inadequacy of traditional sources of energy to meet these ever-increasing needs of humanity has led to researchers exploring other possibilities of harnessing energy from several other non-conventional (renewable) energy sources. Water, solar, wind and nuclear power are among the various sources of renewable energy [2]. Some of these alternative sources of energy have limitations on cost due to the lack of awareness by the public at large, lack of interest and/or responsiveness as well as lack of community participation. One opportunity for providing people in rural communities with a source of energy is to collect and use agricultural wastes [3]. Consequently, the inappropriate disposal procedure for wastes from



agricultural-based industries can lead to environmental pollution which is harmful to human and animal health. Majority of agro waste are untreated and are disposed-off by unplanned landfilling and burning. These kind of wastes usually create different challenges with change in climate by increasing the quantity of greenhouse gases [4]. Therefore, as part of the global responsibility of safeguarding the earth and in consistence with the Kyoto protocol agreed by the United Nations, governments around the world have developed bio-based energy policies. African countries have also been co-signatories to the agreement of the Kyoto protocol about the global reduction of carbon emissions which was put in place to address the challenge of global warming [5]. Bio-based energy is the renewable energy gotten from living organisms especially from agricultural wastes. In general, agricultural wastes are utilized to produce a wide range of value-added products. Virtually all these wastes can be used globally for power generation through various technologies, production of biofuels and as biogas in place of heat. Different substrates have their peculiar compositions and utilized in the production of a variety of value-added products based on these compositions [6]. Finally, this review is aimed at presenting a broad concept of bio-agro wastes, a renewable source of energy production [7].

2.0 Bio-Agro Wastes Volarization

Agricultural waste refers to the residue obtained from agricultural operations such as the processing and production of agricultural products like vegetables, crops, meat, poultry, fruits and dairy products [4]. In general, agricultural wastes can be classified to four groups namely livestock wastes, agricultural industry - wastes, and, fruit, vegetable wastes and crop-residues (FVWs) [8].

2.1 Crop Residues

At the field level, the waste residues gotten directly from agricultural production are mostly crop residues such as stovers, seed pods, leaves, straws and so on. These crop residues are regarded as the cheapest and most abundant organic waste that can easily be changed into a variety of value-added products [9]. Universally, corn stovers (or corn straws), wheat straws and rice straws are the three major crop residues actively being used in the production of bioethanol. These crops are readily available year-round, with a little portion being used in biofuel production or as fodder while the leftovers are burnt, hence resulting in grave environmental challenges [10]. Among these three major crop residues, rice straw is among the most promising and valued biomasses worldwide with a large production of about 731 million tons per year, and the leading producers being Asia [11].

Most of residue harvested from wheat is wheat straw which is projected to have an annual yield of 1-3 tons/acre while a global annual estimate of 354.34 million tons of wheat straws are produced [6]. For lingo-cellulosic ethanol, corn stover is among the most promising crop residues with 4.0 tons per acre estimated production and annual global production of approximately 128 million tons. Also, crop residues derived from oats, sorghum and barley contribute towards agro-wastes [12].

2.2 Agricultural Industry Wastes

The second group of agro-waste comprises of agricultural industrial processing waste. This includes by-products and residues gotten from food processing industries like sugarcane bagasse, fruit peels and vegetables, fruit marc/pomace after extraction of oil or juice; meat, eggs, chicken skin and animal fat from meat processing industries and slaughterhouses [13]; starch residue (also known as cocoa shells) from starch-manufacturing industries; de-oiled

seed cakes from edible oil manufacturing industries; molasses/black treacle from sugar manufacturing industries [7]. Amongst several agro-industrial wastes, sugarcane bagasse tops the list. This bagasse is the dry pulpy fibrous residue obtained from industries after the juice has been extracted. The projected globally availability of sugarcane bagasse is around 180 million tons [14]. Orange peel, apple pomace and fruit wastes derived from the extraction of the fruit juice, cider, and other food processing units are also considered as agro-industry wastes. Besides these, certain nonfood-based agro-industries such as de-oiled seed cakes gotten from non-edible oil plants like *Pongamia pinnata* and *Jatropha curcas* are categorized as agro-industry wastes [15].

2.3 Livestock Wastes

Crop cultivation and livestock production provide livelihoods for millions of farming families around the world. Using livestock manure as a source of energy is practical and, in some communities, widely practiced for biogas production or simply by making manure cakes for burning [16]. Typical examples include chicken litter/burned, animal slurry/digested and large quantities of straw providing fuel for combined heat and power generation [1]. In many cases, however, these projects are only economically viable if a market can be found for the heat produced (e.g. for use at nearby factories) and for the by-products (e.g. fertilizers for farms). Power can be used on the farm or in nearby communities to which it can be reticulated/piped, and waste heat can be used on the farm [1].

2.4 Fruit and Vegetable Wastes

fruits and vegetable wastes (FVWs) consists of unprocessed fruits and vegetables such as tomatoes, orange, mango, jack fruit, pineapple and banana, and many more, which form an integral part of agro-wastes. FVWs generated from food processing industries, as well as wholesale markets, are enormous [17]. Also, these organic waste poses a huge concern for environmental pollution owing to their highly perishable nature [4]. Statistics show that the wastes generated from processing, packaging, distribution and consumption of fruit and vegetable in countries such as the United States, China, Philippines and India, are approximately 15, 32, 6.5 and 1.8 million tons respectively [4]. Presently in India, approximately 5.6 million tons of FVWs are produced annual and are disposed of by dumping on the outskirts of cities [18].

2.5 Biofuels

Biofuel can be gotten from agrowaste and bio-waste and this can be characterized into biogas, bio-ethers, solid biofuels, biofuels, bio-alcohols, biodiesel and vegetable oil. They are widely classified as first to fourth generation [19]. Year 2035, the global biofuel output is projected to meet 8 percent of total road transport fuel requirement from the present quota of 3 percent. Ethanol is the chief biofuel, accounting for 75 percent of the total biofuel used to date. The United States Brazil, China, India and the EU are the highest demand regions for biofuel and accounts for roughly 90 % of global biofuel demand until 2035 [11]. The first-generation or conventional biofuels refers to biofuels that have been obtained from sources such as sugar, starch, animal fat and vegetable oil. Vegetable oils are utilized as biofuels after undergoing a reduction in viscosity and appropriate atomization. Biodiesel is a fuel that contains mono-alkyl (methyl, ethyl and propyl) esters of long-chain fatty acids and is synthesized by the chemical reaction of lipids (transesterification) such as animal fat (tallow) or vegetable oil [10]. Bio-ethers such as fuel oxygenates, fuel ethers, etc., are used as octane enhancers. They lower the emission of pollutants which in turn improves fuel quality. On the other hand, biogas is the gas produced resulting from the break down (fermentation or decomposition) of

an organic matters by anaerobic bacteria. The main components contained in biogas are methane and carbon dioxide. Synthesis gas (also known as syngas) is a fuel gas mixture composed primarily of carbon monoxide, hydrogen and traces of carbon dioxide [20].

Furthermore, solid biofuel includes agro-waste, domestic waste, fodder waste, wood, sawdust, leaves and dried animal dung. Primarily, energy is derived from direct combustion for domestic use and small-scale businesses [21]. The major setback with this energy source is pollution. Bio-alcohol or bioethanol is obtained by fermenting carbohydrates, either simple sugar such as sucrose or xylose, or complex ones such as cellulose and starch [22]. Cellulosic bio-alcohols are difficult to derive because their molecular structure makes the hydrolysis process challenging and expensive. Materials such as corn, sugar beets, sugarcane, and wheat can be used as raw materials to produce bioethanol. [23]. Second generation biofuel is also known as advanced biofuels are fuels obtained by processing a variety of non-food biomass or lignocellulosic biomass. Agricultural residues (such as crop straws, corn stover), forestry residue, short-rotation woody crops, wastepaper, herbaceous crops, etc., fall in this category. The objective is to collect the ample carbohydrate reserved in the biomass in the form of cellulose or the complex lignocellulose content in woody materials as substrate to produce ethanol [24]. Third-generation biofuel refers to biofuel derived from algae and these biofuels are called 'oilgae'. Algae are generally low input biomass and are considered the best alternative for overcoming the shortcomings of the first- and second-generation biofuel [25]. Fourth-generation biofuel refers to fuels obtained from specially engineered biomass than may possess higher yield potential or ability to be grown on waterbodies or non-agricultural land or reduced barriers to cellulosic breakdown [26].

3.0 Bioethanol: Production, Biomass and Microbes

Ethanol is an excellent alternative fuel for use in modern internal combustion engines. Ethanol has an impressively higher-octane number of 98 which is better than that of gasoline with an octane number of 80 [27] and experiences lower evaporative loss due to its lower vapour pressure compared to gasoline. Ethanol is less flammable in the air than traditional gasoline, making it a safer choice as fuel [28]. Ethanol can be also be utilized in motor compression engines with a compression ratio of 12:1 than the 8:1 of gasoline, making it a better fuel choice. Also, ethanol is 15 % more efficient by virtue of its higher compression ratio, which in turn compensates for its lower energy density [29]. Bioethanol is made by the fermentation of simple sugars present in biomass via the enzymatic digestion performed by microorganisms. Ethanol is produced industrially by the synthetic processing of a petroleum product like ethylene. These are for industrial purposes, synthetic of ethanol is preferred to biomass-derived ethanol because it is cheaper to produce [30]. While a projected blending level of 20% is to be achieved by 2017, for biodiesel and bioethanol [31].

The important natural monosaccharides are pentose with five carbon atoms and glucose with 6 carbon atoms. Plants contain disaccharides predominantly sucrose, which is found in crops such as sugar beets, sugarcane, apples, oranges, etc [32]. Biomass required to produce ethanol can be obtained from crops meant for food industries, either in form of crop residues like corn stover or wheat straw, etc. or as cereal grains such as wheat or corn. Molasses and sugarcane bagasse residues obtained from sugarcane industries are other sources which give the by-product as a substitute for bioethanol [33]. Top-tier producers of bioethanol like Brazil and United states divert their excess harvest in crops (for instance, sugarcane in Brazil and corn in the United States) towards the industrial production of bioethanol. The interdependence between agriculture in particular food crops and bioethanol then became a noteworthy factor contributing to the unpredictable prices of ethanol as fuel [34]. These

factors greatly outline the need for the second- and third-generation biofuel. Feedstocks harvested are delivered to ethanol plants where they are stored, therefore, following which conditioning of the same is done in a bid to limit unsolicited contamination and fermentation. Fermentable carbohydrates are pretreated to enhance their quantity. Several fermentation techniques specifically batch, fed-batch or continuous fermentation [35-37] may be implemented. To increase the efficiency of the system, recycling of substrates and immobilization of yeast cells are done which in-turn enhances productivity [38].

Biomass witnessed an intense demand in the generation of power, heat energy, and transport sectors. In 2013, the stated final primary energy usage of biomass reached roughly 57 EJ. For the year 2012, the global share of total energy consumption is 19 percent renewable energies (in terms of solar, wind, geothermal, hydropower, biofuel and so on), 2.6 percent nuclear power and 78.8 percent fossil fuels [39]. Biomass is classified as conventional or contemporary. Where conventional biomass implies combusted solid biomass which is frequently utilized within the rural communities of developing countries. Conversely, contemporary biomass signifies energy sources obtained effectively from gaseous, liquid and solid biomass fuels for present-day applications [40-41]. Numerous feedstocks have been tested in laboratories while others are utilized in the commercial production of bioethanol. At commercial level, the global production of bioethanol is predominately via sugarcane and corn feedstocks [42]. Other commercial feedstocks include wheat and sugar beet [43]. Depending on the class of carbohydrate, feedstocks are categorized as lignocellulosic biomass, starch feedstock and sucrose feedstocks. Sucrose is mostly derived from crops like sweet sorghum, sugarcane, sugar beet, etc. These crops served as the first-generation biofuel and few works of literature are available on these feedstocks [44-47]. Sugarcane was a preferred feedstock because it was inexpensive while sweet sorghum required less fertilizer etc. Still use of feedstock in the production of fuel was a chief drawback as it could hinder the world economy. Starch feedstock contains two d-glucose homopolymers of glucose units, with their type of linkages along the chain [48].

Corn contains 60 percent starch and is the major feedstock used in producing bioethanol. The additional starch-based feedstock used to produce bioethanol is cassava, which contains 50-70 percent starch [49-50]. The prime constraints in the fermentation of starch with *saccharomyces cerevisiae* (a species of yeast) rests in its incapability of to ferment starch and as a result, the addition of glucoamylase and α -amylase enzymes to break α -1,4 and α -1,6 linkages respectively are required. Furthermore, starch necessitates the cooking of starch substrate at elevated temperature [51-52]. Production of reducing sugar through the hydrolysis of corncob material was carried out using *Streptomyces* sp. cellulose and ethanol fermentation of cellulosic hydrolysate. It was observed that the harvest of reducing sugars could be promoted with *Streptomyces* sp. T3-1 culture with the production of Avicelase, β -glucosidase and CMCase activity of 3.9, 3.8 and 3.8 IU/ml, respectively [53]. The conversion of cellulose to glucose was preferred by β -glucosidase Avicelase and CMCase [54]. Another observation was that the synergistic interaction of β -glucosidase, exoglucanase and endoglucanase showed effectual hydrolysis of the cellulosic substrate [55].

3.1 Sustainability of Agro Waste in the Industry

The recent urbanization and the challenges of agricultural wastes has led to high request of natural resources in the developed nations of the world have generated opportunities utilization of agro-waste in various industries. Numerous agricultural wastes are presently been used as replacement substitutes for reinforcing materials[56]. Yearly, a large amount of residues are been produced by agricultural industries, inappropriate disposal of such waste can result to pollution of the environment and hazardous to human and health. Generally,

agro-waste are not properly treated which leads to improper waste disposal practices such as open air burning, landfilling and dumping in unauthorized areas. Various greenhouse gases are generated as a result of untreated waste thus leads to change in climate. Furthermore, the use of non-renewable energy sources also, contributes to the depletion of ozone layer. Consequently, the advancement of other cleaner and renewable energy is now a universal concern[57]. The crucial demand for agricultural end products as resulted to a significance increase in waste generation thus causing disposal challenges.

4.0 . Conclusion

Agricultural industrial residues or wastes are rich in bioactive compounds (phytonutrients) and nutrient compounds. These wastes comprise of inconsistencies in their configuration in terms of sugars, proteins and minerals; thus, they should be referred to as “raw materials” not “waste” for other industrial processes. The presence of such nutrients in these residues provide desirable circumstances for the proliferous development of microorganisms. These microorganisms possess the ability to reuse the wastes as raw materials for their development via fermentation processes. Depending on the structure of agro-wastes, a befitting avenue to produce biofuel can be predicted. Various types of agro-wastes can be used independently or in a mixer (as co-substrate) to boost biofuel production. Lignocellulosic biomass can be changed into biofuels by both thermochemical and biochemical routes. The biochemical route is more ecologically benign, and the by-product(s) gotten from the production process of biofuel can be used as value-added products or further used as feedstock to produce other biofuels.

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