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Production Of Fuels From The Agriculture Wastes Using Catalysts-A Review

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Abstract:

These biofuels are produced from crops and edible/non-edible materials and emit much lower pollution compared to fossil-derived fuels. Even though biofuels are effective alternatives, high operational costs with low production volume are the major limitations of this process, which the available technologies cannot handle. With increasing application of nanoparticles as catalysts in several sectors due to its unique properties such as high catalytic activity, surface to volume ratio, mechanical properties, etc., its application in biofuels production has been explored recently. Nano catalyst has superior activity in producing pure products with fewer side reactions. Agricultural waste-based heterogeneous catalysts are emerging as efficient and green catalysts. The present study explored the agricultural waste-based heterogeneous catalyst utilized in the production of biodiesel.

Keywords: Biofuels, Renewable green energy, nanoparticles, agricultural waste, pretreatment.

Introduction:

Agricultural waste refers to a wide range of organic and inorganic materials discarded after agricultural processes like crop production or livestock farming. Think crop residues (stalks, rice straw, leaves, or husks), animal manure, waste feed, agricultural chemicals, and all the packaging used in the production and supply chain. Given the diversity of these materials and the large amounts produced annually, agricultural waste is a double-edged sword. It has enormous potential when appropriately managed because it’s biodegradable and nutrient-rich. So, it can become a valuable resource through composting, conversion into biofuels or into biogas.

On the other hand, the effects of agricultural waste can impact life quality and ruin ecosystems. Improper handling of farming byproducts can lead to water pollution, reduced soil fertility, climate impact, and the loss of valuable organic matter. Plus, it can have significant effects on human health. So, farms need to implement cost-effective agriculture waste management systems to keep up with food production challenges. The world's population is growing, demanding food security and increased agricultural production. Farming activities will continue to generate large quantities of waste that mustn't end up in landfills. Farmers need to learn to recognize the potential of agricultural waste and adopt eco-friendly strategies for a more resource-efficient world.

Types of Agricultural Wastes

- **Crop residues:** stalks, leaves, husks, and straw that remain after harvesting wheat, rice, corn, sugarcane, and others
- **Animal manure**: feces, urine, and bedding materials
- **Agrochemical containers** of pesticides, herbicides, and fertilizers
- **Leftover feed**: grains, forages, and other feed materials
- **Harvest and processing waste**: fruit peels, vegetable trimming, damaged or rejected produce, and byproducts from food processing
- **Packaging materials:** plastic bags, cardboard boxes, and containers
- **Green waste:** trimmings, prunings, plant debris, leaves, branches, and grass clippings

The agricultural sector is one of the main sectors generating the largest quantities of agricultural solid wastes, which may be allowed to accumulate indiscriminately and constitute nuisance to global health and threat to food security or used as raw materials for bio-economy [1-2]. The benefits of recycling of agricultural solid wastes include reduction of greenhouse gas emissions and use as fossil fuel as well as contributing significantly to the development of new green markets, creation of jobs, production of bio-energy and bio-conversion of agricultural solid wastes to animal feed [3-4].

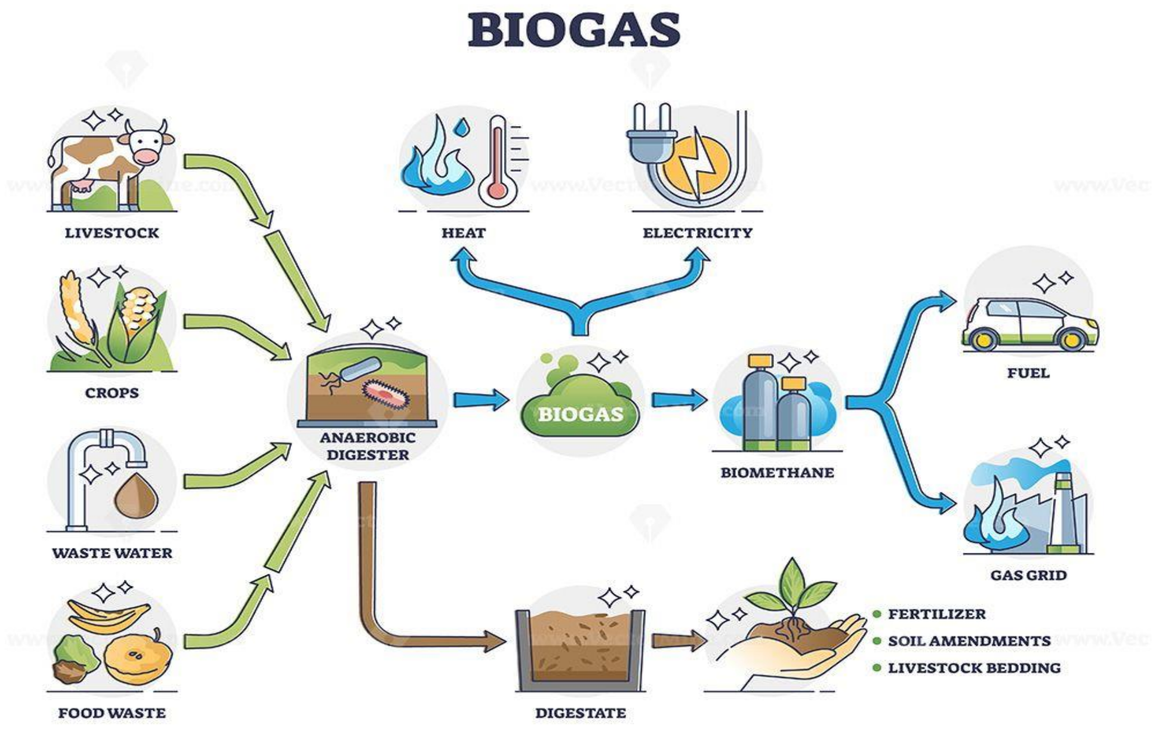
Increasing growth in human population has necessitated increased agricultural production. Agricultural production in the last five decades has been said to increase more than three times. Other factors responsible for increased agricultural production include technological advancement toward green revolution and expansion of soil for agricultural production [5-6]. It has been estimated that agricultural sector provides about 24 million tons of food globally with accompanying health risks and threat on ecosystems [7]. We cannot do without agriculture because food is a necessity across the globe, but the impact of agriculture on the environment is also evident. For example, it has been documented that about 21% of greenhouse gas emission comes from agriculture. The negative influence of agriculture on the environment, aquatic lives and human health have necessitated improvement in agricultural production, involving effective and efficient ways of handling agricultural solid wastes [8].

Due to the rapid increase in population and modernization, the daily consumption of fossil reserves is rising, posing a severe threat to their continued existence. In addition, the combustion of fossil-based fuels causes specific environmental issues, which is why developed nations are transitioning to carbon-neutral fuel sources. Carbon neutral fuels are derived from biomass, the combustion of which conserves the environment, and are regarded as viable alternatives to fossil-derived fuels. Over the past few decades, specific biomass sources have been recommended for biofuel production; however, it is believed that non-edible biomass is most suitable for biofuel production, as it does not cause the food *versus* fuel controversy and is thought to be more cost-effective than biofuels derived from edible biomass feedstock. Several types of non-edible biomass exist, including agricultural waste (biomass leftover from edible crops) and wild-grown biomass (which does not produce an edible product, such as rubber plants and jatropha plants, among others). Non-edible agro-waste is regarded as the most viable alternative to fossil-based fuels. By utilizing thermochemical and biological processes, agro-waste can be converted into biofuel. Biological methods are deemed unsuitable compared to thermochemical methods due to several benefits, including a higher biofuel yield and higher-quality products obtained *via* the thermochemical method. There are three thermochemical processes: gasification, pyrolysis, and direct combustion.

Biogas production

It is another source of energy can be obtained from a landfill biogas. There are other sources of biogas include manure, sewage, and industrial waste, agricultural waste. Biogas comes from microorganisms that digest (break) where organic waste into a mixture of methane and carbon dioxide. This is also called anaerobic digestion. It can be used for various purpose such as heating, cooking, lighting, and the production of steam and electricity production, and can be used as an alternative fuel in vehicles that use natural gas.

Biodiesel is prepared via several ways of which four different approaches have been reported, and these are dilution, pyrolysis or thermal cracking, microemulsion, and transesterification [9]. Transesterification, which is also known as alcoholysis, is one of the most effective and easiest methods for biodiesel generation in which triacylglycerols react with alcohol resulting in esters and glycerol as side-products in the presence of a catalyst [10-11]. Biodiesel is produced mostly by catalytic transesterification of fats or oils with lower alcohols such as methanol, ethanol, propanol, and butanol, of which methanol is most widely used due to its advantageous properties [12-15]. A variety of catalysts such as acid, base, and enzyme are being reported for the production of biodiesel [16-17]. Sulfuric acid (H_2SO_4), sulfonic acid (H_2SO_3), ferric sulfate ($Fe_2(SO_4)_3$), hydrochloric acid (HCl), phosphoric acid (H_3PO_4), organic sulphonic acids, etc., are some of the acid catalysts employed in the reaction of oil [18-19]. However, homogeneous acid catalysts have drawbacks, such as they are corrosive, require high pressure and temperature, and need a long reaction time, and accordingly, it is economically daunting to consider the process as efficient in biodiesel production [20-23]. Though a homogeneous base- (NaOH, KOH, $NaOCH_3$, etc.) catalyzed reaction requires milder conditions and produces biodiesel in a shorter time with high conversion, the soap formation and issues in catalyst separation from the mixture causing the generation of wastewater are the main limitations of the method [24-25]. Hence, this process can be considered not feasible for the economical production of biodiesel. Similarly, enzyme-catalyzed transesterification, despite its environmental friendliness and mild reaction conditions, faces economic issues due to the high cost of the enzyme [26].



Classification and causes/sources of agricultural solid wastes

Agricultural solid wastes are produced mainly from farming activities. However, it is not limited to the production but other activities associated with farming and food chain. Every stage and phase of the agricultural-food chain can generate significant agricultural solid wastes. The broad classification of agricultural solid wastes includes the following:

Animal production solid wastes;

Food and meat processing solid wastes;

Crop production solid wastes;

On-farm medical solid wastes;

Horticultural production solid wastes;

Industrial agricultural solid wastes;

Chemical wastes.

Animal production solid wastes—animal production solid wastes are solid wastes generated from the production of livestock for whatever purposes. Examples of such wastes include bedding/litter, animal carcasses, damaged feeders, and water-trough, etc.

Food and meat processing solid wastes—this class of agricultural solid wastes are produced from the processing of crop or animal products for human consumption, such as abattoir or slaughterhouses. Examples of food and meat processing agricultural solid wastes include hoofs, bones, feathers, banana peels, etc.

Crop production solid wastes—crop solid wastes are associated with agricultural solid wastes typically produced from agricultural activities involving crop production. Examples of such agricultural solid wastes are crop residues, husks, etc.

On-farm medical solid wastes—on-farm medical solid wastes refer to solid wastes that are generated from the use of drugs, insecticides or vaccines used on or animals. Examples of such wastes include vaccine wrappers or containers, disposable needles, syringes, etc.

Horticultural production solid wastes—this group of agricultural solid wastes refer to solid wastes generated from cultivation and maintenance of horticultural plants and landscape for beautification. Examples of such wastes are prunings and grass cuttings.

Industrial agricultural solid wastes—agricultural produce and livestock are not only cultivated and produced for dietary consumption. They are used for other uses and it is not unlikely that such activities result in agricultural solid wastes. Wood processing and cuttings readily come to mind as a source of agricultural solid wastes. Paper production using agricultural products as raw materials also generate some quantities of agricultural solid wastes.

Chemical wastes—chemical wastes in this context have to do with agricultural solid wastes generated from the use of pesticides, insecticides and herbicides on the farm or store, such as pesticide containers or bottles. Agricultural activities still depend on the use of pesticides, insecticides, and herbicides, being handled by many uneducated and untrained farmers in developing countries, resulting in abuse by these uneducated farmers [18, 19]. Some uneducated farmers mishandle pesticide containers, thereby resulting in unpredictable environmental hazards. It has been reported that about 2% of pesticides remain in the containers after use, which some ignorant and uneducated users may throw in the ponds or on the open field resulting in food poisoning, environmental and water pollution, causing death of many lives.

Agricultural solid wastes are usually generated through agricultural activities involving preparation, production, storage, processing and consumption of agricultural produce, livestock and their products. Agricultural solid wastes are produced via:

Farming activities

Poor road network

Poor electricity or lack of rural electrification

Inadequate drying technique and storage facilities

Food spoilage

Kitchen-generated agricultural solid wastes

Farming activities—the main source of agricultural solid waste generation is agriculture. Beginning from land clearing till harvest, every phase of farming activities results in the generation of agricultural waste. From preparing the pen for the arrival of the animals to the farm, preparation of pasture/paddock till the animals are slaughtered and sold, solid wastes are generated.

Poor road network for transporting harvested produce from the farm to the market or storage is another avenue of generating large quantities of agricultural solid wastes. This happens largely as a result of the bad road network in some developing countries, which may result in a road accident or delay of agricultural produce from farms to markets. When road accident occurs, perishable agricultural produce result easily in wastage, and when delayed, the same result may occur. The spoilt produce is either thrown away on the road or separated to be discarded once the farmer gets to the market. Figure 1 shows agricultural produce being transported in a city in Nigeria.

Poor electricity or lack of rural electrification—the epileptic power supply and lack of rural electrification in some parts of developing countries with significant agricultural activities are contributing in no small measure to the generation of agricultural solid wastes. Stable electricity could have facilitated the cold storage of the harvested produce and thereby reduce spoilage and consequently agricultural solid wastes.

Inadequate drying technique and storage facilities—spoilage of much agricultural produce could be prevented with adequate drying techniques. If farmers have access to adequate drying technique or moisture monitor, it would have gone a long way in militating against food spoilage and agricultural solid waste, thereby enhancing food security and reducing the impact of agricultural solid waste on human health and the environment. Many of the farmers depend largely on the unpredictable solar system to dry their produce before they are stored, as well as rely on the conventional method of moisture monitoring which is neither effective nor accurate. Inadequate monitoring of moisture content in grain before storage has been reported to result in aflatoxin infestation. Aflatoxin is produced by Aspergillus flavus. Aflatoxin infestation is both a cause and a product of food spoilage and its contamination of food and livestock feed can lead to significant annual crop losses globally.

It has been estimated that about 10% of global crop harvest is destroyed by filamentous fungi through contamination of food and feed with mycotoxins. Aflatoxins have been reported to produce liver carcinogens, impair human health in developing countries, and result in the huge economic losses, in the U.S. corn alone amounting to about $280 million annually. The economic losses could be as high as 1 billion dollars if other crop-infestation such as cotton, peanuts and tree nuts are included. Aflatoxins B1 and B2 which cause preharvest and postharvest crop infestation are produced by Aspergillus flavus.

Kitchen-generated agricultural solid wastes: in most cases, the end result of agricultural activities is family consumption. Usually, the consumption of agricultural produce at the family level is not without the production of agricultural solid wastes. Some of these wastes are generated out of necessity. For example, orange peels and banana peels are discarded as agricultural solid wastes in many homes. However, agricultural solid wastes may also be generated unintentionally, arising from food spoilage. Kitchen-generated agricultural solid wastes become significant when restaurants are included as kitchens (commercial kitchens).

Conclusion

Food wastage is an important source of agricultural solid wastes. Hence, the prevention of food wastage at all levels before they are created will salvage some of these wastes and prevent unnecessary ill-health and environmental disadvantages as well as huge economic losses. Biodiesel, the emerging alternative to Petro diesel, is reported to be synthesized typically from triglyceride sources via catalytic transesterification, wherein the agricultural waste-derived heterogeneous catalysts are endorsed as one of the most promising, cost-effective, and green protocol solutions. The cost-effectiveness of the produced biodiesel is influenced by various parameters such as oil feedstock, reactor used, type of catalyst, catalyst concentration, MTOR, reaction time, reaction temperature, and biodiesel yield.

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