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A Review on Insect-based food waste valorization

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ABSTRACT

Food processing industry is one of the fastest expanding sectors in the economy because of its increasing demand to alleviate hunger and demand of nutritious food. It has become a significant portion of the world's municipal solid waste causing various environmental, nutritional, social and economic impacts. Therefore, it is crucial to manage food waste in an environmentally friendly manner that is effective and feasible for economic and environmental reasons. The new technology, that uses insects such as Hermetia illucens, Tenebrio molitor and various other bio convertors as a carrier to carry out bioconversion with food waste to improve its role in the circular bio economy. This review aims to present the findings on the use of insects for food waste valorization to obtain value-added product (Frass fertilizers, biofuel, animal feed, and bio-preservatives), its advantages over conventional methods (landfills, incineration etc.) and challenges associated with these treatments.

Key words: *Food waste, Insects, Bioconversion, Value addition, Animal feed*

I. INTRODUCTION

Global food waste is at extremely high levels because of the ever-growing population, post-harvest processing, and leftover eatables (1). According to the aforementioned practices, it is predicted that about a third to half of the world's annual food production or around 1.3 billion tons is wasted (2). Various wastes are released into the environment because of the processing of fruits and vegetables, dairy products, meat, fish, grains, pulses, and nuts (Figure 1). The Food and Agriculture Organization of the United Nations (FAO) reported that globally about one-third of food produced is lost or wasted, the amounts to approximately 1.30 billion ton per year (3). Therefore, more and more countries are concerned about food waste and advocate recycling, recycling of food waste (4).

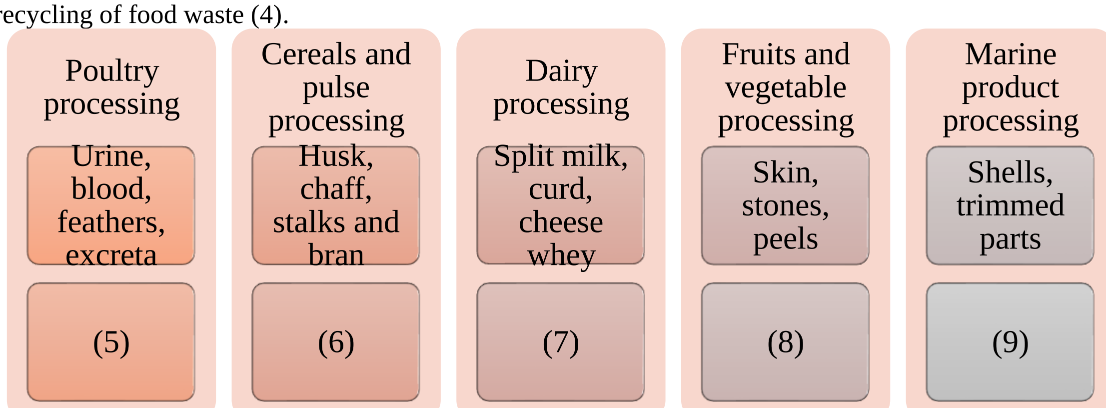

Figure 1: Food processing units and their wastes

Table 1 provides a summary of the amount of waste produced globally from various food sources. In the end, food waste poses a threat to human existence due to the abundance of organic biomass it contains, which attracts infectious diseases and other environmental dangers. The major contributors of food waste are cereals followed by meat and vegetables. Common practices such as burning or dumping waste from homes or processing facilities in open spaces, which has a number of negative health and environmental effects. However, from another angle, a number of items with functional potential that are value-added food additives can be obtained from food waste (10).

Table 1: Values estimated for the total waste produced by several food industries

Food processing sectors	Amount in million tons
Fish and fish products	8
Milk products and ice cream processing	404
Meat and meat products	150
Pulses	245
Fruits and vegetables	492

*Adapted data from (11)

II. IMPACT OF FOOD WASTE EXPOSURE

Food waste poses a threat to both the environment and human health. Release of greenhouse gases and water pollution are results of poor food waste management. Food waste generated during processing causes a number of nutritional, social, and economic issues in addition to environmental problems (12).

- **Environmental impacts:** 21% of the methane (stronger than carbon dioxide) release is result of valorization of food waste in landfills. The estimated global per capita greenhouse gas emission from food waste in 2011 was 323 kg CO_2. Hence, food waste treatment is necessary to preserve biodiversity and to produce other value-added products.
- **Nutritional impacts:** Food waste nutrient profiling can give idea into its nutritional capacity especially if these nutrients leads to shortage in the population of interest. Food types such as dairy and eggs, meat and fish, fresh vegetables were found to be responsible for the chosen waste nutrients.
- **Social and economic impacts:** Social impacts includes deficiency disorder, nation throwback, and self-sustainability weakness and hunger prevalence whereas economic impacts includes transportation expenses, GDP breakdown and Trade-off issues.

III. CONVENTIONAL AND CURRENT APPROACHES TO FOOD WASTE MANAGEMENT

Fig. 2 illustrates physical, chemical, and biological strategies that have been chosen to manage the disposal of food waste. However, developing nations today frequently use anaerobic digestion, composting, landfilling, incineration, and animal feeding as forms of treatment. Illegal exposed dumping and landfill channels have occasionally been identified in the literature as prevalent methods (13, 14). Despite the fact that landfills are one of the greatest options for organized garbage disposal, careless disposal has a significant impact on the ecosystem, contributing to greenhouse gases, climate change, unpleasant odour, and harm to wildlife as well (15). Leachate is another danger that occasionally results from landfills. Leachate increases the amount of nitrogen and phosphorus in water, speeds up algal blooms, and harms aquatic life. It also causes acidity of surface water, which causes methemoglobinemia in young children and stomach cancer in the elderly (16). Therefore, it is justified that effective waste management strategies are a means of obtaining constituents of human relevance with lower greenhouse gas emissions. Prevention or source reduction is the most preferred choice while to manage food waste. Companies such as Apeel, Full harvest and wasteless are dealing with such techniques**.** Phenix, the startup which divert food scraps to feed animals and by selling extra food to non-profit organizations or consumers or businesses, food waste can be reduced.

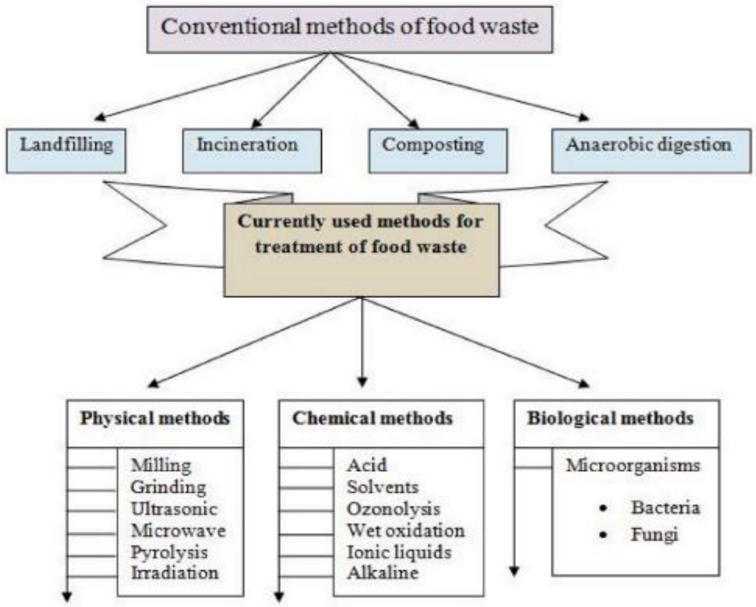

Figure 2: Conventional and current approaches for food waste management

IV. INSECT-BASED FOOD WASTE MANAGEMENT

Due to insects ability to convert low value substrate into high quality animal feed and organic fertilizers, insects are gaining attention (17,18). Compared to plants and livestock animals, insects have a number of benefits, including a short life cycle, the capacity to develop on inexpensive feedstock (organic waste), a limited requirement of water and land, a high rate of conversion, low gas emissions, and high sustainability (19). Edible insects such as the yellow mealworm (YMW), the black soldier fly (BSF), *Hermetia illucens* and *Tenebrio molitor* L., can be utilized as effective, sustainable, and high-quality sources of protein for both humans and animals, with less environmental impact (20). For instance, BSF showed a significant bioconversion rate of 6.9%, fat content 26% (21). Agricultural wastes such as corn, wheat and rice straw can be degraded into feed source with the help of *Musca domestica* and House Fly Larvae (HFL) (22). It also plays an important role in high reproduction rate and scavenging behavior.

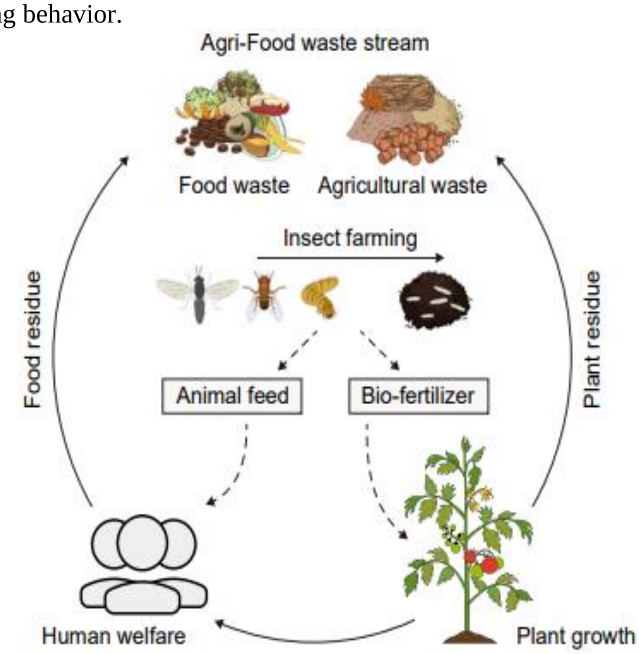

Figure 3: Insect-mediated waste bioconversion to value-added products within the concept of sustainable agriculture

Table 2: Advantages of Insect-based food waste management over conventional methods

	Conventional method	Insect-based method
Environmental impact	Incineration can release harmful pollutants into environment. Composting does not utilize food waste efficiently.	Produces less greenhouse gas emission
Resource recovery	Limited resource recovery	Production of Nutrient-rich biomass
Scalability	Scalability can be constrained by disposal infrastructure.	Insect farming can be scalable, especially in controlled environments.
Nutrient Recycling	Nutrients are often lost in conventional disposal methods.	Insects recycle nutrients from food waste back into the ecosystem.
Circular Economy	Conventional methods often don't close the loop in the food system.	Insects can contribute to a circular economy by transforming waste into valuable resources.

According to the report, 53.08 g of dried larvae with high protein (57.06%) and oil (15.07%) contents were produced using 1 kilogramme culture feeds (23). The crude protein and fat content of fly larvae (insect biomass) fed on kitchen waste were found to be 45.1% and 48.1%, respectively (24).

V. CHALLENGES

- **Environmental impact:** Large scale insect farming requires huge amount of land, water and energy.
- **Consumer Acceptance:** Due to culture, ethical and psycological factors it is difficult to convince consumers to accept such technique since they find the concept unappealing.
- **Nutrient balance:** Nutritional composition varies according to insects diet which can lead to imbalances in final animal feed.
- **Research and development:** In order to improve the efficiency, sustainibility and cost-effectiveness of the process, there is a need for ongoing research to focus on insect selection, rearing conditions and processing.

VI. CONCLUSION

- Conversion of food waste using insects has been recognized as a viable waste manegment technique.
- Maintaining the sustainability of animal production systems appears to be possible with the incorporation of insects into livestock animal feed.
- The support of the regulatory agencies, academic sector, waste management organizations, as well as insect and livestock producers and consumers is necessary to incorporate insects as sustainable protein source.
- Further research is necessary to study insects fertilization qualities and safety of protein consumption.
- The profitability of insect farms needs to be determined through more research, as the economics of insect production has not gotten much attention.

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