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# Review on Recycling of Food Waste to Produce Plant Fertilizers

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***Abstract:** Sustainable waste management and agriculture are discussed in the perspective of food waste recycling into plant nutrients. The environmental, social, and economic effects of food waste are discussed in this review to highlight their global significance. Methods for turning food scraps into plant nutrients are compared and contrasted, with each approach's benefits and drawbacks highlighted. The staggering annual amounts of food wasted highlight the critical need for a comprehensive response to this problem. Putting food scraps to use as plant fertilizer is an eco-friendly option that follows the principles of the circular economy by reusing otherwise useless materials. Composting, anaerobic digestion, and vermicomposting are examined as three basic strategies for recycling food waste; each approach has its own benefits and flexibility. Anaerobic digestion, for instance, is well-suited to handling large quantities of organic waste, while composting is more suited to urban and domestic settings. It has been demonstrated that fertilizers made from food waste improve soil quality, stimulate plant growth, and add to overall agricultural output. Without the use of synthetic chemicals, these fertilizers increase soil structure, water retention, and plant nourishment. Furthermore, recycling helps reduce emissions of greenhouse gases, which is an important factor in slowing global warming. However, obstacles such as contamination worries, regulatory frameworks, public awareness, and technological developments stand in the way of widespread implementation of food waste recycling. The quality of the fertilizers that can be made from food waste relies heavily on the efficacy of collection and sorting processes. Guaranteeing the safety and efficacy of these items relies heavily on the establishment of regulatory standards and quality controls. Increasing public knowledge and understanding is critical if we are to see a shift in how people typically approach the recycling of food scraps.*
***Keywords:** anaerobic digestion, nourishment, Sustainable waste management, flexibility.*

## I. INTRODUCTION

As environmental sustainability becomes more and more important in this day and age, creative ways to deal with the worldwide problem of food waste are beginning to appear. Food waste management presents serious environmental and financial problems for homes, restaurants, and food processing businesses alike. But in the middle of this difficulty is an incredible opportunity: food waste can be recycled to become fertilizer for plants. In addition to keeping organic waste out of landfills, this environmentally responsible method produces a useful resource for improving soil and promoting plant development. In this investigation, we explore the exciting field of turning food waste into plant fertilizers, looking at the advantages it has for the environment, new technological developments, and its critical role in promoting a more regenerative and sustainable kind of agriculture.The problem of food waste in the modern world has gotten out of control. Approximately one-third of all food produced for human consumption is lost or wasted annually worldwide, according to the Food and Agriculture Organization of the United Nations (FAO)[1]. Approximately 1.3 billion metric tons of food, which could have fed hungry people, are wasted and end up in landfills where they release greenhouse gases and worsen the environment.Food waste is a complex issue that affects the food supply chain at many points, from the production and transportation phases to the retail and consumer stages. Despite significant attempts to decrease food waste, a large amount of food is still thrown away for a variety of reasons, such as spoiling, overproduction, and aesthetic flaws. As the extent of food waste becomes more apparent, creative and long-lasting solutions are needed. Reusing food waste to make fertilizer for plants is one approach to this problem, which solves the issue of food waste while also enhancing the sustainability of agricultural systems.

### *1) The Eco-Friendly Approach: Recycling Food Waste*

#### *a) Diverting Food Waste from Landfills*

Reusing food waste to make fertilizer for plants is important because it keeps organic waste out of landfills. Food scraps break down in landfills under anaerobic conditions and release methane, a powerful greenhouse gas that plays a major role in global warming. Food waste that is diverted from landfills not only lowers methane emissions but also eases the burden on landfill capabilities, which are frequently at capacity[2].

*b) Closing the Nutrient Loop*

A closed-loop nutrition system is created when food waste is recycled into fertilizer for plants. Food scraps don't lose their vital nutrients; instead, the soil receives them back. This strategy is in line with the circular economy's tenets, which emphasize waste reduction and resource efficiency. We can lessen our reliance on synthetic fertilizers, which can have negative effects on the ecosystem such nutrient runoff and soil damage, by replenishing the soil with nutrients[3].

*c) Minimizing Chemical Fertilizer Usage*

The utilization of synthetic fertilizers in agricultural practices has generated apprehension within the environmental community due to its capacity to infiltrate water sources, resulting in the contamination and eutrophication of aquatic ecosystems. The practice of converting food waste into organic plant fertilizers has the potential to decrease reliance on chemical fertilizers, thereby addressing the adverse environmental consequences associated with their use. Farmers have the ability to uphold soil health and fertility while simultaneously diminishing their ecological impact through the utilization of organic fertilizers as substitutes or supplements.

2) Technological Advancements in Food Waste Recycling
3) Technological improvements have significantly enhanced the viability and efficiency of the process of converting food waste into plant fertilizers, hence facilitating its widespread implementation[4]. These innovations span both small-scale, localized solutions and large-scale, industrial processes.

*a) Composting*

Composting is a time-honored and widely recognized approach for recycling organic waste, particularly food waste. The process entails the breakdown of organic materials by microorganisms, resulting in the production of compost that is abundant in nutrients and can serve as both a soil conditioner and fertilizer. The application of contemporary technology has resulted in the improvement of conventional composting techniques, exemplified by the utilization of composting machines that effectively streamline and accelerate the composting process[5].

*b) Vermicomposting*

Earthworms are used in vermicomposting, a type of composting, to break down organic materials. This process yields vermicompost, a nutrient-rich substance that also speeds up the breakdown process. Vermicomposting is an effective and environmentally responsible way to recycle food waste that may be used on a variety of scales, from modest home installations to huge commercial operations[6].

*c) Anaerobic Digestion*

Through the use of technology, food waste can be broken down in the absence of oxygen to produce digestate and biogas through anaerobic digestion. While the digestate can be utilized as a biofertilizer, the biogas produced can be used as a source of energy. This technology is especially beneficial for large-scale food waste recycling, like that which the food processing businesses carry out.

*d) Black Soldier Fly Larvae*

The larvae of the black soldier fly exhibit a highly efficient capacity for consuming organic matter, rendering them significant contributors to the process of recycling food waste. The larvae have the potential to be reared in controlled conditions and sustainably nourished with food waste. As the larvae mature, they effectively transform the food waste into frass, a substance rich in nutrients. This frass has the potential to be utilized as an organic fertilizer.

## II. RELATED WORK

Neto 2023 et. al the production and analysis of metallic particles with nanometric sizes that could be employed as plant support materials for nutrient supply. Nanoscale Zn, Mn, Fe, and Cu oxide particles were produced by microwave energy. Nanoparticles (NPs) were characterized using Fourier transform infrared (FTIR), X-ray diffraction (XRD), transmission electron microscopy (TEM), thermogravimetric analysis (TGA), specific surface area (SSA), and total chemical analysis. Characterization validated the crystalline nature, elemental proportion, size, shape, and surface structure of all the produced nanoparticles (NPs), all of which were in oxide form.

The results showed that the created NPs were all in the oxide forms of ZnO, Mn3O4, Fe3O4, and CuO, and that their sizes ranged from 20 to 50 nm[7].

Yaakop 2023 et.al An effective and environmentally beneficial method of producing clean, renewable energy is the microbial fuel cell (MFC). Several studies have shown that the generation of electrons due to insufficient usage of organic substrates is one of the primary challenges.

In contemporary molecular fusion, one of the most talked-about problems is the reuse of biological organic waste in a molecular fusion reactor (MFC). This paper concentrated on the effective cultivation of energy-producing bacteria using organic waste from households. The outcomes matched the distinct MFC activity, which over the course of 12 days of operation with 500 ohms of external resistance generated a voltage of 110 mV. The greatest recorded current density and power density, with an internal resistance of 117, were 21.84 mA/m2 and 0.1047 mW/m2, respectively. Acinetobacter schindleri, Pseudomonas nitroreducens, and Pseudomonas aeruginosa are the types of bacteria that produce energy, according to the results of the biological investigation[8].

Dalayya 2023 et. al Web scraping was used to determine public opinion and information needs on plant-based diets as recommended treatments for diseases like cancer. Text and sentiment analyses were conducted on data gathered from 82 social media sites to determine whether plant-based diets are used by cancer patients and non-cancer patients, how they have been consumed, how beneficial they are for preventing and managing cancer, what myths and fake news there are about cancer, and what features cancer patients need in a food app. The results of the text analysis exposed shortcomings in the currently existing apps, including their lack of trust as a result of the widespread dissemination of erroneous information and misconceptions about cancer that were endorsed by professionals. Future food applications should provide symptom management, customized diets based on meat or plants, credibility, a pleasurable user experience, and support for mental and emotional well-being[9].

Gedif 2022 et. al Reducing environmental pollution, recycling, and utilizing textile waste items as resources could have significant potential. The purpose of this research is to produce unsaturated polyester composite reinforced with waste 100% cotton fabric for use in ceiling board applications using compression molding and a manual mixing process. The results of the statistical analysis showed that the mechanical properties of the produced composite samples, such as tensile, compressive, flexural, and impact strength, were affected by the fiber mixing ratio and matrix loading at $\alpha=0.05$. Maximum compressive strength was 1105.3 MPa, maximum tensile strength was 198 MPa, and maximum flexural strength was 30.1 MPa for the composite ceiling. It was reinforced with a 67 weight percent unsaturated polyester matrix and 33 weight percent discarded cotton fabric. The false ceiling board, on the other hand, had a reduced compressive strength of 867.5 MPa, a flexural strength of 21.5 MPa, and a tensile strength of 112.6 MPa due to its 90% unsaturated polyester matrix and 10% waste cotton fabric. Because less textile waste is being disposed of in landfills, the mechanical behaviors of the composites that were created are generally comparable to those of commercial ceiling boards that are now available on the market[10].

Yu 2022 et. al A technique for measuring the effects of various actions to facilitate evaluations and decision-making is life cycle assessment, or LCA. It can be challenging to choose the product waste management system that has the least negative consequences on the environment. Given that recycling entails collecting waste and turning it into new products, it is usually seen as having a positive environmental impact. This study suggests a waste recycling system based on product life cycle assessment to boost the utilization rate of waste products, motivated by the need for recycling. In order to provide a unified and scalable product life cycle, the proposed system integrated the Electronic Product Cycle (EPC) into the workflow. Furthermore, the suggested method preprocesses product life cycle data and extracts the overall weight of product life cycle evaluation indicators using a large data normalization technique. Additionally, the proposed approach aims to highlight the value of life cycle assessment (LCA) as a waste recycling tool when building a waste management framework and to pinpoint a research gap by creating a more effective framework[11].

Table-1Literature Summary of existing work

| Author / Year | Method | Accuracy | Ref. |
|---|---|---|---|
| Kumar/2022 | CNN model outperforms | 97.14% | [12] |
| Bharathi/ 2022 | GCMS analysis | Nanocatalyzed degradation produces 50% more methane and 23.5% more biogas than nonnanocatalyzed degradation. | [13] |

| | | | |
|---|---|---|---|
| Luo/ 2022 | Grey Prediction Model GM | 96.21%, 95.85%, 94.72% | [14] |
| Li/2021 | Food's Cropping Soil (FsCS), FWWB, FMF | 71.2% | [2] |
| Gull/ 2021 | Arduino UNO, Decision Tree Algorithm. | 92.65% | [15] |

## III. RECYCLING OF FOOD WASTE

Recycling of food waste is an environmentally and economically significant practice that aims to mitigate the growing challenges associated with food waste. This process involves the collection, separation, and transformation of food scraps and leftovers into valuable products, including compost, bioenergy, and animal feed. In a world where one-third of all food produced for human consumption is wasted, and landfills continue to overflow with organic matter, food waste recycling offers a sustainable solution to divert this waste stream from disposal sites and harness its potential. It plays a pivotal role in achieving waste reduction, resource recovery, and environmental sustainability[16].

The process of recycling food waste typically begins at the source, where households, restaurants, and food-related industries separate organic waste from other types of waste. This separation at the point of generation is crucial for ensuring the quality of the recycled products. Once collected, the food waste undergoes various treatment methods, each with its advantages and applications[17].

1) *Composting:* Composting is one of the most prevalent methods for recycling food waste. It involves the natural decomposition of organic materials by microorganisms, resulting in nutrient-rich compost. This end product serves as a valuable soil conditioner and fertilizer. Composting can be practiced on various scales, from small-scale backyard composting to large-scale industrial operations, making it a versatile choice for managing food waste.
2) *Anaerobic Digestion:* Anaerobic digestion is a technology-driven approach that breaks down food waste in the absence of oxygen, producing biogas and digestate. The biogas, primarily composed of methane, can be utilized as a renewable energy source for electricity generation and heating. The remaining digestate can serve as a nutrient-rich biofertilizer. Anaerobic digestion is particularly beneficial for large-scale food waste recycling, such as that carried out by food processing industries and wastewater treatment plants[18].
3) *Vermicomposting:* Vermicomposting is a specialized form of composting that employs earthworms to accelerate the decomposition process. The worms consume organic matter, breaking it down into a nutrient-rich product known as vermicompost. This method is advantageous for its efficiency, as it produces high-quality organic fertilizers and soil conditioners.
4) *Bioconversion with Insects:* Certain insect species, such as black soldier flies, are highly efficient at consuming organic waste. They can be reared in controlled environments and fed with food waste, ultimately transforming it into nutrient-rich frass (larval excrement). This frass can be used as an organic fertilizer or soil amendment.

Recycling food waste offers a multitude of benefits, both from an environmental and economic perspective[19]:

a) *Waste Reduction:* Diverting food waste from landfills reduces the volume of waste that decomposes and generates methane, a potent greenhouse gas. This helps mitigate climate change and lowers the environmental impact of waste management.
b) *Resource Recovery:* Recycling food waste results in valuable products, such as compost, biogas, and organic fertilizers. These resources can be harnessed to enrich soil, produce renewable energy, and reduce the reliance on synthetic fertilizers.
c) *Soil Enrichment:* Organic fertilizers derived from recycled food waste enhance soil fertility and structure, promoting healthier plant growth and increasing crop yields. They provide essential nutrients, including nitrogen, phosphorus, and potassium, which are vital for plant development[20].
d) *Energy Generation:* Anaerobic digestion of food waste generates biogas, which can be used as a renewable energy source. This not only reduces energy costs but also lessens the carbon footprint associated with conventional energy production.
e) *Reduced Chemical Fertilizer Use:* By substituting or supplementing synthetic fertilizers with organic alternatives, recycling food waste can diminish the need for chemical inputs in agriculture, mitigating the environmental impact of nutrient runoff and soil degradation.

Despite these advantages, challenges persist in the recycling of food waste. Contamination of food waste with non-organic materials, such as plastics or hazardous substances, can compromise the quality of the recycled products. Effective waste sorting and management practices are essential to address this issue. Additionally, the scalability and infrastructure of food waste recycling processes can vary, requiring tailored solutions for different settings.

, recycling food waste is a sustainable and environmentally responsible practice that addresses the complex issue of food waste while simultaneously providing valuable resources for agriculture and energy production. Its ability to reduce waste, recover resources, and enhance soil quality makes it an integral component of a circular economy and a crucial step towards a more sustainable and responsible approach to waste management.

## IV. USING FOOD WASTE TO FERTILIZE PLANT

The use of chemical fertilizers has played a pivotal role in the history of agriculture, particularly following the introduction of high-yielding seed types in the mid-1960s. This development marked a turning point in agricultural practices, significantly increasing agricultural output, productivity, and incomes for farmers. As the world grapples with the challenge of feeding a growing population, the role of chemical fertilizers in enhancing agricultural production is expected to become even more significant in the years to come.One of the primary driving factors behind the increasing importance of chemical fertilizers is the realization that the world's growing demand for food can no longer be met solely through expanding agricultural land. The availability of arable land is limited and, in many regions, diminishing due to urbanization and environmental concerns. Similarly, water resources for agriculture are finite, and their sustainable use is critical. Therefore, to meet the rising demand for food, it is imperative to maximize agricultural productivity on existing land while conserving water resources.Chemical fertilizers are a key component in achieving this goal. They provide essential nutrients to plants, including nitrogen, phosphorus, and potassium, which are vital for growth and yield. As the demand for food continues to surge, the importance of balanced and increased fertilizer use, in conjunction with other agricultural inputs like irrigation and quality seeds, remains paramount. In the case of India, it is estimated that the demand for plant nutrients is expected to reach approximately 27 million tons by 2010-11[21]. However, this demand cannot be entirely met by organic manures due to their low nutrient content. Therefore, chemical fertilizers will continue to play a crucial role in meeting this demand.While chemical fertilizers are essential, it is equally important to recognize the complementary role of organic manures and bio-fertilizers[22]. These natural sources of nutrients can enhance soil fertility and improve its structure. The integration of organic manures and bio-fertilizers with chemical fertilizers is a key strategy to maximize agricultural efficiency. It is not just about the quantity of fertilizer use but also about the timing and application methods that influence its effectiveness[23].

Studies suggest that an increase of 10% in fertilizer use could lead to an increase of about 1% to 1.5% in the cost of cultivation. However, the resulting increase in farm revenue can be as high as 3.23%. This underlines the economic significance of judicious fertilizer use.The chemical fertilizer industry in India has made significant progress in meeting the demand for various types of fertilizers. The sector's journey began with the establishment of the first Single Super Phosphate (SSP) plant in Ranipet, Tamil Nadu, in 1906. Subsequently, large-sized fertilizer plants like the Fertilizer & Chemicals Travancore of India Ltd. (FACT) and the Fertilizers Corporation of India (FCI) were set up in the forties and fifties to achieve self-sufficiency in food grain production[24].

The 'Green Revolution' in the late sixties provided a significant impetus to India's fertilizer sector, resulting in a substantial increase in manufacturing capacity. By January 2005, India had become the world's third-largest producer of fertilizer. This growth has been facilitated by a favorable regulatory environment, attracting investments in the public, co-operative, and private sectors.

Today, India boasts a robust fertilizer industry with numerous large-scale fertilizer plants and byproduct facilities producing a wide range of nitrogenous, phosphatic, and complex fertilizers. The indigenous fertilizer sector has made remarkable progress, and it plays a crucial role in enhancing agricultural productivity and ensuring food security[25].

Despite this progress, there are regions in India where fertilizer consumption remains notably low compared to the national average. While Punjab uses 184 kg of nutrients per hectare of cultivated land, other states fall far below the national average of 90 kg per hectare. Addressing this discrepancy is essential to ensure balanced and efficient fertilizer use across the country. Alongside increasing fertilizer consumption, there is a need for improved and sustainable farming practices, where fertilizer companies can act as advisors to farmers, promoting better and more effective agricultural methods.The importance of secure fertilizer supply, both in terms of availability and cost, cannot be underestimated. The domestic production of fertilizers is essential to meet the growing demand and reduce dependence on imports. The stability and expansion of the indigenous fertilizer sector are pivotal in ensuring food security and agricultural sustainability.chemical fertilizers have played a pivotal role in increasing agricultural productivity, particularly in the context of rising food demand and limited land and water resources[26]. Their balanced and efficient use, in conjunction with organic manures and bio-fertilizers, is essential for sustainable agriculture.

The fertilizer industry in India has made significant strides in meeting the demand for various types of fertilizers, contributing to the country's food security[27]. However, it is imperative to address regional disparities in fertilizer consumption and promote judicious fertilizer use for enhanced agricultural efficiency and economic prosperity.

## V. FOOD WASTE MANAGEMENT

The imperative of effective waste management has long been recognized as a fundamental prerequisite for sustainable development, as documented by the United Nations Environment Programme (UNEP, 2011) and the United Nations Human Settlements Programme (UNHSP, 2010). Historically, the primary objective of public waste management in urban areas was the relocation of potentially hazardous chemicals and materials away from populated regions, as emphasized in the works of Wilson et al. (2012) and Velis et al. (2009). However, as the environmental, social, and economic ramifications of unsustainable resource utilization and escalating waste generation in both the short and long term came to the forefront (The Government Office for Science, 2011a; Stern, 2006), waste management underwent a transformative shift from pollution control to a more comprehensive approach. This shift was driven by the recognition that unsustainable resource usage and escalating waste production could pose significant challenges to the environment, society, and the economy.In response, various frameworks and concepts were introduced to guide sustainable waste management[28]. These included the waste hierarchy (illustrated in Figure 1), the '3Rs' (Reduce, Reuse, and Recycle), extended producer responsibility, the polluter pays principle (Engel et al., 2008), life cycle assessment, and Sustainable Consumption and Production (SCP) (Pires et al., 2011). The term 'sustainable resource management' was coined (Barton et al., 1996), underlining the notion that what is traditionally considered "waste" might, in reality, be a valuable "resource." Sustainable resource management (Bringezu & Bleischwitz, 2009) serves as the foundation for mitigating greenhouse gas emissions associated with climate change while promoting economic and social benefits (Barrett & Scott, 2012; Defra, 2011; WRAP, 2010).

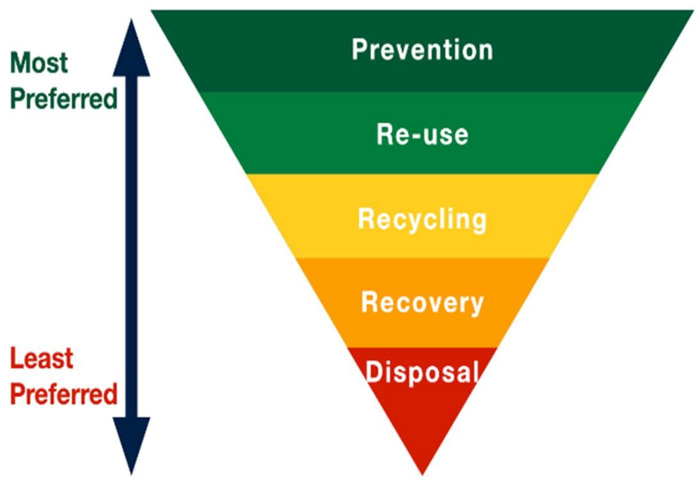


Figure 1: Waste Management Hierarchy

In the constantly evolving realm of waste management, an area receiving increasing attention is the management of food waste. The negative environmental, social, and economic implications of food waste have become increasingly evident. The global food security crisis, compounded by the severity of food waste, has highlighted the key role food waste plays in addressing the global waste challenge (EPA, 2012; Defra, 2011; Government of South Australia, 2010).This study aims to address the research question, "how can food excess and food waste be managed more sustainably?" Given the significance of food waste, interviews were conducted with food waste professionals to gain insights into current practices, future trends, challenges, and opportunities for more sustainable food excess and waste management. Using Grounded Theory (GT), the key themes emerging from these interviews guided the development of a comprehensive framework for food excess and waste management across the entire food supply chain. This framework not only conceptualizes food waste but also interprets and applies the waste hierarchy within the context of food waste management[29]. The resulting food waste hierarchy serves as a guide for determining suitable solutions to combat the burgeoning issue of food waste.Research conducted in both developed and developing nations has shed light on the extent of food waste and losses occurring in the food supply chain during both production and consumption phases (Gustavsson et al., 2011; Parfitt et al., 2010; Smil, 2004).

These studies have revealed significant information gaps regarding global food losses and waste. Lundqvist et al. (2008) estimated that up to half of all food produced is lost or wasted before or after it reaches consumers. Figure 2 illustrates the magnitude of food losses and waste throughout the global food supply chain in 2000. Postharvest losses are estimated at 2,600 kcal per capita per day, encompassing losses in distribution and homes, alongside animal feed and waste[30].

## VI. CONCLUSION

The overview of food waste recycling to make plant fertilizers emphasizes a crucial and evolving area of sustainable waste management and agriculture. The environmental, social, and economic impacts of food waste management make it a global issue. This review examined methods for recycling food waste into plant nutrients and their pros and cons.This review emphasizes the necessity to manage food waste comprehensively. With millions of metric tons of food wasted annually, efficient waste reduction techniques are needed. Reusing food waste as plant fertilizer is a sustainable approach. We limit our environmental impact and support the circular economy by turning food waste into resources. Food waste can be recycled into plant fertilizers through composting, anaerobic digestion, and vermicomposting. Each method has benefits and may be scaled and adjusted. Anaerobic digestion can manage vast amounts of organic waste, while composting is good for cities and homes. Food waste-derived fertilizers improve soil and plant growth, enhancing agricultural production. These fertilizers increase soil structure, water retention, and plant nutrition without synthetic chemicals. Food waste-derived fertilizers also cut greenhouse gas emissions, mitigating climate change. Food waste recycling must overcome obstacles to become mainstream. Contamination, regulations, public awareness, and technology are examples. Food waste collection and separation methods must be efficient to assure fertilizer quality. To ensure product safety and efficacy, regulatory frameworks and quality standards should be implemented. Education and public awareness campaigns are essential to altering food waste recycling habits.A increasing worldwide population and the need for sustainable agriculture make food waste recycling into plant nutrients a potential option. It reduces food waste and promotes nutritious food production without chemical fertilizers. As this subject evolves, waste management professionals, agricultural scientists, legislators, and the food business must work together to maximize food waste recycling for plant nutrients.

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