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Review Article

Dehydrated Food Waste for Composting: An Overview

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ABSTRACT

Food waste disposal has recently received much attention worldwide due to its major impact on environmental pollution and economic costs. Using high moisture content of food waste has the highest negative environmental impact due to increased greenhouse gas emissions, odor, and leachate. Drying technologies play an important role in reducing the moisture content of food waste, which is necessary for environmental sustainability and safety. The first part of this review highlights that sun-drying is the most cost-effective drying method. However, it has not been widely recommended for food waste management due to several limitations, including the inability to control sunray temperature and the inability to control end-product quality. Thermal drying eliminates moisture from food waste quickly, preventing hydrolysis and biodegradation. Thermal dryers, such as the GAIA GC-300 dryer, and cabinet dryer fitted with a standard tray, are the best alternative to sun drying. The second part of this review highlights that dehydrated food waste products are slightly acidic (4.7–5.1), have a high electrical conductivity (EC) value (4.83–7.64 mS cm-1), with high nutrient content, due to low pH levels, dehydrated food waste is not suitable for direct use as a fertilizer for the plants. So, the dried food waste should be composted before application to the plants because the composting process will dominate the limitation of phytotoxins, anoxia, salinity, and water repellence. Trench compost can be a good choice for decomposing dried organic waste because trench compost relies solely on soil decomposing microorganisms and insects.

Keywords: Dehydration, food waste, thermal drying, trench composting

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INTRODUCTION

The increasing global population growth of 7.6 billion has increased waste generation worldwide. It has enormously impacted the climate, animals, and human beings, recently attracting great global attention (Thani et al., 2019). In 2016, the Food Aid Foundation announced that Malaysia lost almost 15,000 tonnes of food waste, including 3,000 tons of food per day (Sulaiman & Ahmad, 2018) and around 15 million tonnes (234 kg/person/year or 50% of food) ware lost annually in the United Kingdom (Salemdeeb et al., 2017). Food waste is one of the big problems in the world. Most developing countries lose billions of dollars per year due to food waste. This problem does not stop at the point where food is discarded. Around 95% of discarded food goes down in areas where anaerobic digestion processes nitrogen, carbon dioxide, or other gases, which has a catastrophic effect on global warming. Food waste issues appeared to be growing over the next 25 years because of intensive economic and population growth in most Asian countries, particularly Malaysia (Melikoglu et al., 2013).

Food waste exacerbates climate change. Because food waste produces methane, a gas that absorbs heat considerably more quickly than other greenhouse gases such as carbon dioxide, methane has a shorter lifetime than carbon dioxide, which results in the globe's rapidly warming (Zaki, 2019). In the last few years, food waste has increased in Malaysia, affecting the country's solid waste management system, including landfills and incineration. The government was currently constrained to alternative food waste disposal solutions such as compost, animal feed, and dehydration of food waste (Lim et al., 2016). Nowadays, significant factor considerations must be considered before implementing food waste disposal units as a wide-ranging solid waste management option, as solid waste is related to emissions of greenhouse gasses and other environmental damage. Continued research and development in food waste could better manage this choice to become a sustainable alternative to landfilling, incineration, and composting (Ismail et al., 2020a; Arumugam et al., 2021).

Utilizing a thermal GAIA GC-300 dryer is the best option for landfill and incineration. Food waste is called FORBI after it has been dried in this dryer; dried food waste that has high-calorie biomass with low moisture content, that product can be used to manufacture animal feed and raw material for compost (Papanikola et al., 2019). The dryer can handle 50 kg of food waste every eight hours. GAIA GC-300 dryer is becoming incredibly common due to its affordable price. It operates at 140 degrees and can eliminate any present microbes in the food waste by drying it out. Overall, this technique has reduced food waste in the long term (Vakalis et al., 2018). Dehydration has recently been investigated as a method of reusing food waste, especially in animal feed. According to an analysis of food waste conversion in a central animal feed manufacturing plant, substituting conventional animal feed can significantly reduce net greenhouse gas emissions (Hall, 2016). Dehydration of food waste resulted in a 70% reduction in mass and a lower energy cost than regular food waste treatment. The low water content of the post-dehydration material delays decomposition and decreases odor, allowing for less frequent waste disposal. Dried food's physical and chemical properties make it a useful feedstock for value-added products like compost and animal feed (Schroeder et al., 2020).

Food waste and leftovers can be exploited as raw materials for manufacturing vital commercial compounds because it contains carbohydrates, proteins, lipids, and nutraceuticals. As well, the latest food waste treatment policy focuses on waste production reduction and less on recycling (Ravindran & Jaiswal, 2016). At the same time, the moisture content of food waste is over 80%. Using food waste with a high moisture content of 75 to 95% has the greatest negative impact on the environment due to increased greenhouse gas emissions and leachate released into the soil. The best solution to this problem is to dehydrate the food waste, which can then be used as animal feed or raw materials for fertilizer (Sotiropoulos et al., 2016).

A direct application of dehydrated food waste as a soil amendment appears implausible. Since food waste rehydrates and creates fungus. Thus, dry food contains significant nitrogen and carbon and should be composted before being placed in soil. Trench compost is recommended for dehydrated food waste because it does not require determining moisture levels, aeration, or sifting as with a compost pile (Compost Education Centre, 2010). Removing excess moisture from the source by drying reduces the waste content and volume in the kitchen. Continued study and development in food waste management might help dehydration become a more sustainable alternative to landfilling. This review has two parts: The first part of this review defined in general which methods can be utilized to dry food waste, based on published articles and research papers. The second part of the study focused on the physicochemical qualities of dehydrated food waste products to use as a biofertilizer after composting. This study was done to identify and select the best suitable food waste treatment for dehydration before composting for future research.

FOOD WASTE

Food waste is food collected from kitchen areas in restaurants and households which we cannot consume. A US Department of Agriculture (USDA) has found that 21% of fresh food at restaurants was not consumed. Usually, the restaurant service industry wastes 4–10% of the food before service to the customer (Sakaguchi et al., 2018). Food waste is a subset of food loss that consists of material meant for human consumption but not consumed. The border between food loss and food waste is not well defined. Food loss is common in the food value chain before it reaches the customer. It can occur during growing, harvesting, processing, or transportation. However, food waste happens due to mismanagement in the supply chain. Food waste is typically regarded as avoidable food loss. However, the core reasons and motivations of the people involved in food waste are now the significant variables distinguishing food waste from food losses (Kibler et al., 2018).

Food is wasted at every step in the food supply chain (FSC); many points along the supply chain degrade or lose edible food mass (e.g., post-harvest handling, processing, distribution, and consumption). Figure 1 shows how food waste is generated in the FSC (Papargyropoulou et al., 2014). Food is wasted to a large extent in middle and high-income countries, both at the consumer and manufacturing levels. However, in underdeveloped nations, food is wasted at the beginning of the food supply chain (Chauhan et al., 2021).

Food waste per capita is the most prominent in Europe and North America (95–115 kg/year), while rock-bottom in Sub-Saharan Africa and South/Southeast Asia (6–11 kg/year). More than 40% of food losses occur in developing countries after harvesting and preparing the produce. However, in developed nations, over 40% at the retail and customer levels, most of the food waste is generated. Figure 2 shows that per person, wasted food varies around the globe (Blakeney, 2019). The amount of food wasted by consumers in developed countries (222 million tons) is nearly equal to the total food supply in sub-Saharan Africa (230 million tons). Figure 3 shows the volumes of food waste produced by commodity groups in various regions (Blakeney, 2019).

Environmental and social impacts on food surplus and waste were prioritized, according to Papargyropoulou et al. (2014). The three themes that were proposed for the framework were as follows:

I. Food security and surplus
II. Avoidable and unavoidable food waste
III. Waste prevention and waste management

The food waste hierarchy is used to rank the options. The framework recommends recycling food waste into animal feed or composting after exhausting all preventative measures. If recycling becomes impossible, the next best option is the anaerobic digestion of food waste. Finally, when all other options have been exhausted, the only option left is disposed of in landfills. Figure 4 shows the framework for food waste (Papargyropoulou et al., 2014).

Classes of Food Waste

Disposed and abandoned food can be classified into two types, food waste and leftovers. Components of food waste can be separated from the original material. Most kitchen wastes was from food waste such as vegetables, fruit seeds, and peels (Al-Domi et al., 2011). In this grouping, inedible foods like coffee grounds were also included. Further, food waste consists of foodstuffs discarded during manufacturing, transport, and expired in stores, restaurants, and schools (Silvennoinen et al., 2015). Leftovers usually include the food residues left

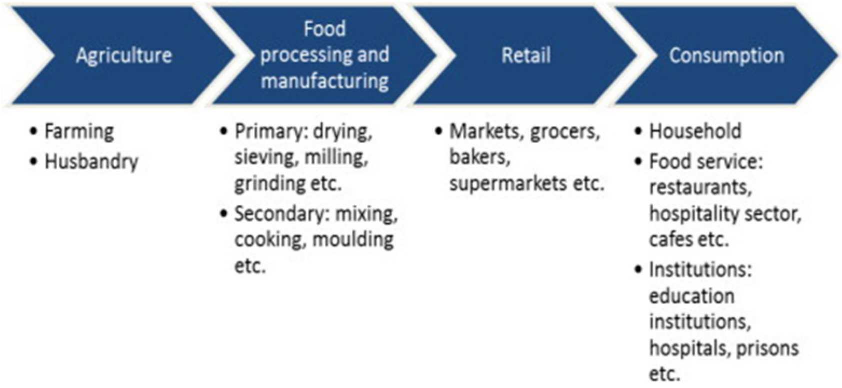

Figure 1. Activities that lead to food waste and losses in the food supply chain (Papargyropoulou et al., 2014)

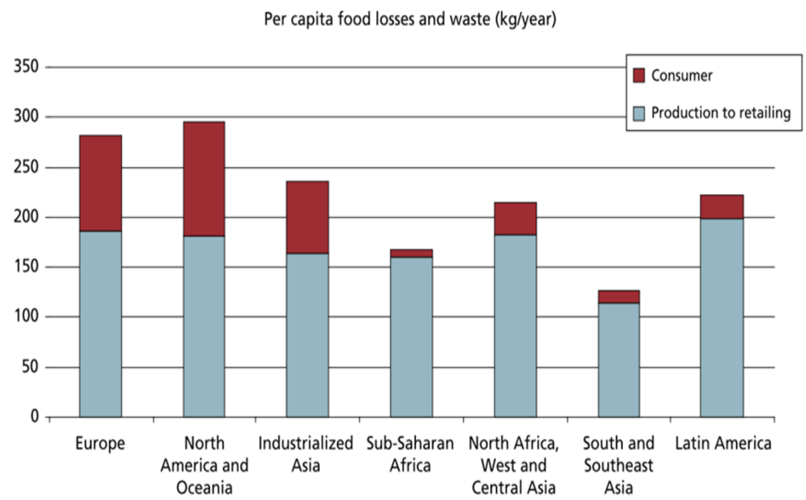

Figure 2. Food losses and waste per capita in various regions, at the consumption and pre-consumption stages (Blakeney, 2019)

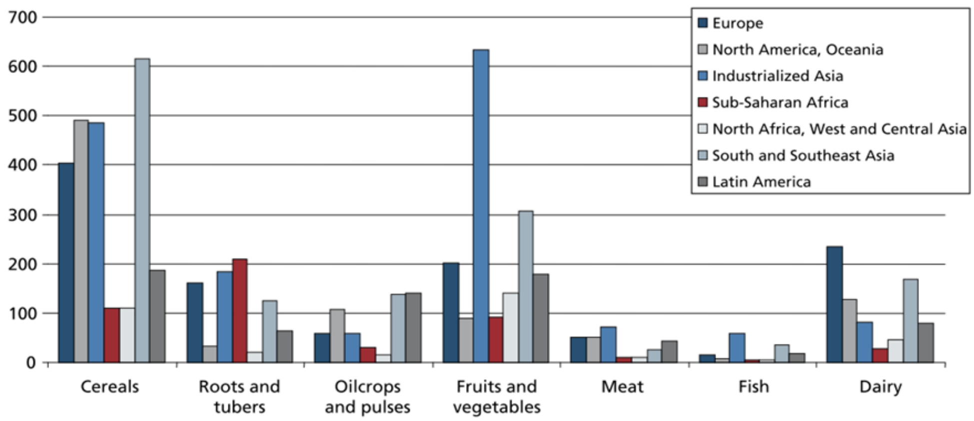

Figure 3. Commodity groups produce volumes of food waste in various regions (Blakeney, 2019)

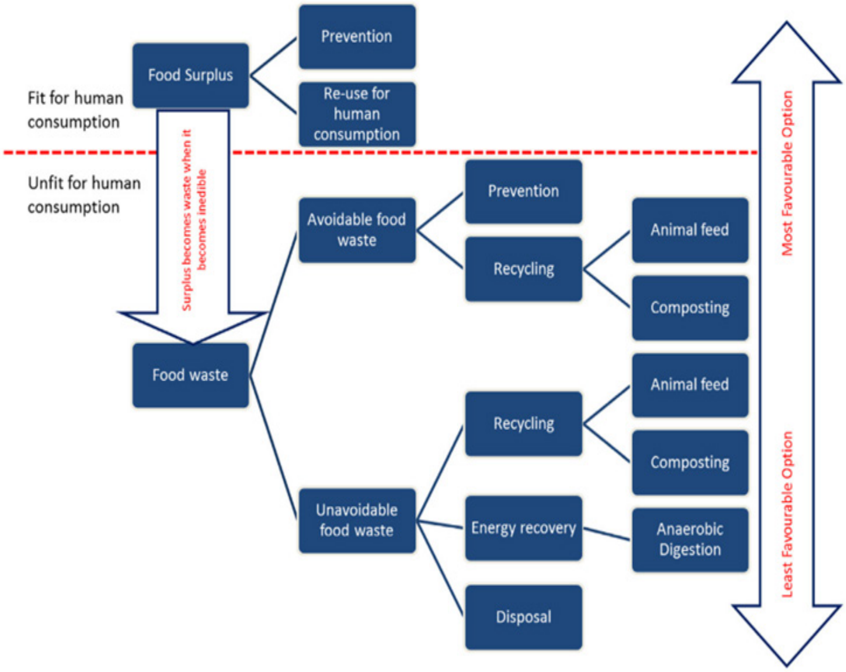

Figure 4. Framework for food surplus and waste (Papargyropoulou et al., 2014)

on plates that consumers dispose of. These wastes are also known as post-consumer food, and it usually includes domestic foods that have been discarded and are often co-mingled with yard debris upon disposal. This food waste can often be spotted in a large amount in dining restaurants, buffets, and hotels (McAdams et al., 2019). Leftovers were not consumed but were physically and economically unsustainable due to the environmental effects of manufacturing and processing raw materials into food. Discarded food scraps and leftovers were biodegradable wastes generated by many companies and homes, including the food industry, hospitality sectors, and households (Silvennoinen et al., 2015).

Cereals, roots and tubers, oil and pulses, fruits and vegetables, meats, fish and seafood, and dairy products are the seven subcategories of food waste. Functional compounds can be extracted from agricultural and food processing by-products. Therefore, it is necessary to understand analytical chemistry principles to extract and isolate these compounds from food waste (Galanakis, 2012). The applied methodologies are introduced with the following objectives:

I. increasing the target compounds' yield
II. meeting the needs of industrial manufacturing processes
III. removal of impurities and toxic compounds from the high-value ingredients
IV. processing and storing the product to ensure its integrity
V. ensuring the food-grade nature of the final product

Some steps were eliminated or overlapped in Galanakis's (2012) five recovery stages. Purification and encapsulation of target compounds occur after extraction of specific macromolecules Figure 5. This downstream scheme is used to recover two components or a macromolecule. Because proteins are macromolecules, this step can be skipped when the target compound is a protein (Galanakis, 2012). Before food waste can be used, it must undergo complex processing and extensive research. A thorough investigation of food waste type, volume, exploitation potential, and end-users are required to justify the investment. The environmental consequences of new manufacturing processes must also be considered. Finally, excessive food modification may pose health risks to consumers (Dhar, 2016).

Characteristics of Food Waste

Food waste characteristics generated worldwide were known as one of the top energy and substrata recovery solutions. Food waste values have varied, and 24% of these changes were due to their geographical origin, collecting source, and season (Fisgativa et al., 2016). The properties of the various types of solid waste were shown. Even as solid waste, all samples were disposed of certain samples (canned products, spent coffee, fruit and vegetable wastes, salad mix, and kitchen preparations waste have a solid content of < 30%). Substrates with

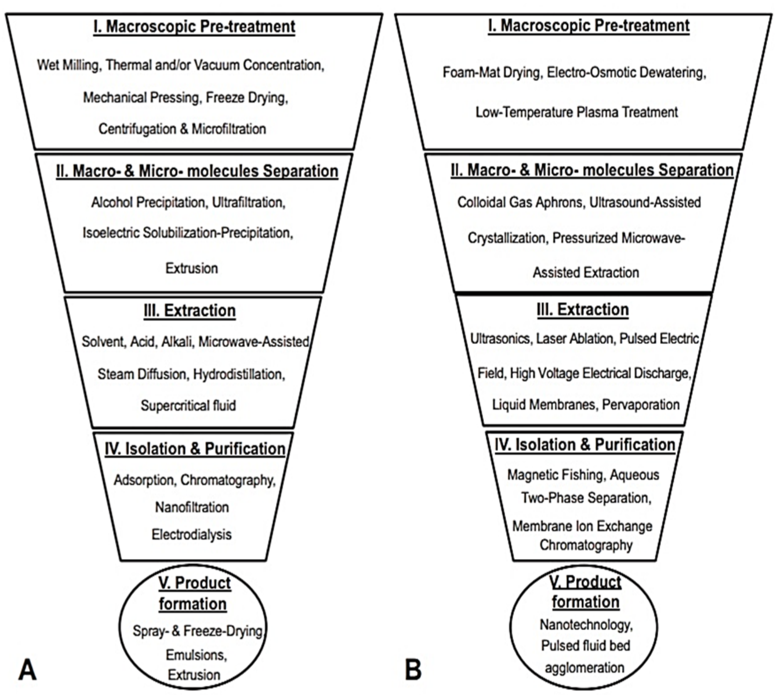

Figure 5. Food waste recovery stages: (A) Established (B) New Technologies (Galanakis, 2012)

high biodegradability have been highly rich in rapidly could be hydrolyzed carbohydrates and lipids. High-fat substrates led to increased synthesis of bio-methane compared with low-fat substrates (Ebner et al., 2016).

A typical kitchen waste contains 60–80% moisture, 3–5% ash, 40–60% carbohydrate, 18–30% volatiles, 10–30% protein, 15–40% fat, and 45–65% carbon. Fish and meat meals have three times the protein and moisture content of wheat meals, while wheat meals have a high composition of volatile matter and carbs (88–92%) (Palaniveloo et al., 2020). In 2012, researchers in the United States discovered the nutritional content of food waste. On average, food waste consumed 1,217 kcal of energy per day, 146.4 grams of carbohydrate, 32.8 grams of protein, 286.1 milligrams of calcium, 85.0 milligrams of magnesium, 450.3 milligrams phosphorus, 880.2 milligrams potassium, 264.2 milligrams sodium, and 3.9 milligrams zinc (Spiker et al., 2017). Various types of food waste were examined for potential value-added by-products. Many beneficial derivatives from fruits, vegetables, meat, and dairy products can be summarized in Figures 6A and 6B (Mirabella et al., 2014).

For the success of various valuation methodologies, various elements should be optimized. The physical/chemical features of the feedstock, like humidity, volatile materials and nutrient structure, pH and size, and configuration, determine, for instance, anaerobic digestion and biogas production (Ho & Chu, 2019). The addition of microorganisms plays a vital part in the anaerobic digestion of organic matter. The bacteria cause the effective breakup of complex organic compounds by a sequence of biochemical processes to create methane. By conversion of the organic waste part, biogas was created by the anaerobic digestion process. It contains numerous gases like methane, carbon dioxide, and others (60–65%). The organic component of the various waste (e.g., agricultural, kitchen, and local heavy waste) was used as a substratum for energy recovery in biogas. Besides process sustainability, the odor, sludge levels, and pathogens were minimized; digestate can even be used as a fertilizer. Finally, separating food waste by source and type can assist reduce the source and time-based composition variability, enhancing the consistency retrieval success of food waste products (Liaquat et al., 2017).

Moisture Content of Food Waste

Moisture content is one of the most significant performance variables affecting managing output and processing. There are two options to determine the moisture content, direct and indirect: In the first step, we can measure the moisture content after extracting the water. However, specific physical or chemical characteristics of the grain that influence moisture content are needed in the other potions, and then the humidity can be determined. The level of humidity is usually calculated either Based on a wet basis (% wb) or a dry basis (% db) (Obi et al., 2016). Moisture content (Xi) and drying rate (dXi/dt) were determined using respective Equations 1 and 2 (Ismail et al., 2020b).

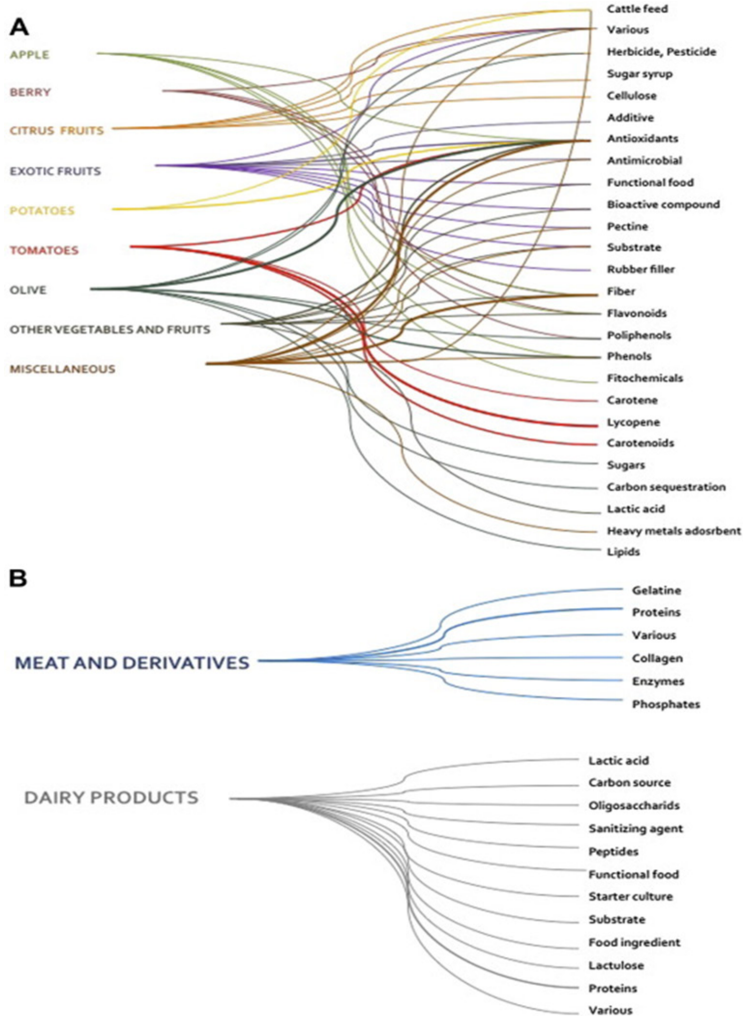

Figure 6. A. Valuable compounds derived from fruits and vegetables. B. Valuable compounds are derivable from meat and dairy (Mirabella et al., 2014).

$$Moisture\ content(\%wb), X_i = \frac{M_i - M_{bd}}{M_{bd}} \quad (1)$$

$$Moisture\ content\ (\%db), \frac{dX_i}{d_t} = \frac{M_i - M_{i+1}}{t_i - t_{i+1}} \quad (2)$$

Where: M presents the mass sample, t shows the drying time at (s), t_i is drying time in a time of (i), and bd presents the bone dry solid. The free humidity X vs time t graph looks like this.

One of the important factors is estimating the amount of moisture content in the organic material before drying (Ismail et al., 2020b). Because of the high moisture content, organic waste has a low calorific value, resulting in incomplete combustion and the release of dioxins and other toxic gases. Researchers discovered wet basis moisture content of food waste was 92.2%, and for leftovers, it was 64.4% (Liu et al., 2016). Furthermore, the moisture content of food waste gathered from various sources was typically over 65%, while the morning market food waste was 90% (Chua et al., 2019).

Moisture affects microbial activity and physical structure, affecting food waste biodegradation. In addition, moisture content impacts decomposition rate and is important in composting. Composting requires wet basis moisture concentrations of 25 to 80%, with 50 to 70% ideal (Makan et al., 2013). The high moisture content of food waste limits its ability to recover energy. However, there are currently various alternative strategies to reduce the moisture content of food waste, such as bio-drying as a zero-leachate generation technology. Also, dehydration near the source of food waste formation may benefit from reducing mass and transit costs for downstream upcycling processes like animal feed manufacturing, composting, or anaerobic digestion (Schroeder et al., 2020).

DRYING METHOD

Drying technologies have been implemented in developed and developing countries to enhance the efficiency of urban food waste to use solid wastes for sustainable sources of vitality, minimize fossil fuel dependencies, and ensure that waste is cleaner at sites. In developed and emerging countries, drying methods have been used to increase the performance of food waste to use solid wastes for environmental liveliness, make trash safer, and reduce the reliance on fossil fuels on-site (Tun & Juchelková, 2019). The most popular methods were freeze-drying, microwave, sun, and thermal drying.

Freeze-Drying

Freeze drying is commonly used to process dehydrated high-quality fruit and vegetables. The water solid-state, low temperatures, and the process of moisture sublimation during freeze-dry protection help protect the primary structure and form of the products, which also have low bulk density, high porosity, and stronger rehydration (Taylor et al., 2011).

Freeze-drying requires extracting a liquid formulation solvent, which is frozen and exposed to low pressure for the solvents' sublimation and then subject to a final desorption process for removing the unfrozen solvent (Nowak & Jakubczyk, 2020). Therefore, the method of drying can be divided into two stages: sublimation (primary drying) and desorption (secondary drying) because two similarly critical processes occur, i.e., freezing, in which almost all solver has been transformed into a frozen solid, and drying process, in which the mixture eliminates almost all solvent (frozen or unfrozen) (Assegehegn et al., 2020).

Frozen, which consolidates food, is the first stage in freeze-drying. The freezing rate is crucial for the development and size of ice crystals—slow freezing is greater than or reciprocally than ice particles. In the food business, freeze-drying is limited to high-added-value products such as coffee, ingredients for ready-to-eat dishes (fruits and vegetables, meat and fish), and aromatic herbs (Wang et al., 2014). The MEADOW processor Freeze Drying Solid Waste has extensively treated solid waste items generated during extended human-crewed space flights. Freeze drying and vacuum drying were the principal drying methods explored. In either mode, a Peltier condenser gathers water vapor from the waste and converts it back into relatively clean water. The water activity level of the dried waste product is lower than that required for microorganisms to maintain metabolic activity. For the treated waste to remain stable, it must be stored and confined in a manner that prevents water from being reabsorbed (Wheeler et al., 2007). Many studies have demonstrated that freeze-drying is a good way to reduce food waste. However, they claimed that, due to its high cost, freeze-drying was an unsuitable method of waste disposal. Nevertheless, the special condition will help to reduce wastage.

Microwave Drying

Microwave drying is becoming increasingly popular as an effective drying process for different foodstuffs, such as fruits, vegetables, snack products, and dairy products (Wang et al., 2004). The drying of microwaves depends on the variation of electromagnetic energy into thermal energy by the polar molecules of the material. The motion between the bipolar molecules induces heating of the material; in this orientation method, the material generates ample heat to evaporate humidity from the mass. In addition, the bipolar molecules' rapid mobility provides a complete pressurizing gradient that facilitates the quick flow of liquid water and vapor to the material surface, which results in speedy drying without overheating the atmosphere (Khodifad & Dhamsaniya, 2020).

The microwave drying method is based on a particular volumetric heat mode facilitated by electromagnetic radiation of 915 MHz or 2450 MHz. The loss reaction of a dielectric component causes a fast power interaction with or dried up moisture and signal strength. A significant dropping time reduction usually involves the enhanced quality of the substance, making it a good drying technique (Feng et al., 2012). Microwave heating depends on the weight, weight, shape, size, simple thermal power, the composition of the sample, and dielectricity (Durance & Yaghmaee, 2011). Microwave drying is a revolutionary method; it is possible to dry food waste rapidly and efficiently using microwave drying techniques because there are several advantages to using microwaves over conventional drying methods, such as faster drying and lower energy use. In addition, the pore structure of raw materials improves from microwave drying (Liu et al., 2016). In general, using a microwave reactor to break down food waste has the potential to produce alternative fuels for energy generation and transportation. In addition, microwave drying has aided in the thermal decomposition of trash and is a viable method for decreasing food waste (Anis et al., 2018).

Sun Drying

Sun drying is a traditional method of direct solar radiation and natural wind force. Most developing countries use open-air (sun drying) systems for drying agricultural products. It is a low-cost drying method for preserving and storing agricultural products (Dhumne, 2016). There are two types of direct and indirect solar dryers. Direct solar drying is called "sun drying" the product is heated directly by the sun's rays, and the natural circulation of air removes moisture due to density differences. The hot air is transmitted over the drying material at indirect solar dryers and often passes through a solar collector, releasing moisture from the substance. The sun is the most powerful carbon-free energy source world has ever known. Sun-drying with free solar energy might also help save money on drying (Bennamoun & Li, 2018). Sun drying is a low-cost process, but this commodity is less consistent because of the possibility of bacterial runoff, pollen, birds, animals, and rainfall. The ability to exercise in ultraviolet radiation also adds to the lack and dryness of supplements, nude testing, and unacceptable color changes (Hegde et al., 2015).

Thermal Drying

One of the effective ways to improve materials quality is to use thermal drying. This mechanism can use for periodic drying. Therefore, products' thermal and physical attributes for suitable dryer designs, such as water activity, moisture diffusion, heat transfer, and primary energy usage, become essential (Ismail et al., 2021). The thermal drying method can be classified into three types: atmospheric drying, low air drying, and hot air drying. Low-temperature processing offers lower corrosion risks and low capital and operating costs, but the process is sluggish and does not work well under some climatic conditions. Typically carried out at 15 to 501°C temperatures, the air is heated around 1 to 61°C (Al-kharabsheh & Goswami, 2004). On the other hand, low air drying is an option for drying unstable materials, mostly leafy vegetables, and it is the best way to preserve enough ascorbic acid (Venkatachalam et al., 2020).

Hot air drying has been the superlative widely used industrial drying process. Heat is transmitted through convection from hot air to the crop, and the liquid is evaporated by convection to air. Hot air drying is a viable means of fully exploiting the bioactive compounds' possible physiological findings and the analysis of fruit waste. It is a complex process involving heat and mass transfer under the temporary structure, defined by several factors, including internal feeding and physicochemical properties and external properties, including temperature, flow, and drying humidity (Sozzi et al., 2021).

Hot air as a heat carrier is often used in a drying operation. The concept uses air heat and mass transfer to push into a closing structure. The famous dryer is designed to retain air uniformly over perforated racks where food waste spreads in the dryer chamber. Hot air drying is the least expensive dryer (Salim et al., 2017). Special low-cost thermal dryers such as the Schematic dryer and the cabinet drier with a traditional tray are used to dry food waste to minimize leachate and greenhouse gas. The main advantage of the cabinet dryer is that it can save energy as the temperature and airflow rose. According to the report, when food waste was subjected to dry at 70°C with 2m/s air velocity, it took just 120 minutes to dry, and the total amount of energy needed to dry food waste was found to be between 119.62 and 59.41 kWh (Branch & Borghei, 2021). The comparative findings from various drying processes recommended the thermal drying method since the thermal drying techniques for solid industrial items are accessible, efficient, and economical. Table 1 summarizes the drying processes mentioned in this section and their influence on the quality parameter.

Table 1
The characteristics of a few standard drying processes

Drying Method	Type of Feed	Mechanism	Advantage	Disadvantage	References
Freeze Drying	All types of food	Two steps: first, freezing water out of the source material; heating the frozen solid to induce the moisture sublimation mechanism	Reduce chemical compound changes; Minimum reduction and soluble solid transition; Helps avoid oxidation damage; Retention of volatile chemicals.	The cost of facilities is relatively high; the procedure is slow and costly.	Taylor et al (2011) Wang et al. (2014) Nowak and Jakubczyk (2020) Bhatta et al. (2020)
Microwave Drying	Different foodstuffs (fruit and vegetable)	The drying method is based on a particular volumetric heat mode facilitated by electromagnetic radiation of 915 MHz or 2450 MHz. The loss reaction of a dielectric component causes a fast power interaction with or dried up moisture and signal strength.	Quick heating in volume; Greater flow speed; short drying time; improved product quality; Shrinking energy uses a lower cost of operation.	High price for dryers at the start; Severe fragrance reduction and adverse perceptual alterations;	Wang et al. (2004) Changrue and Raghavan (2006) Feng et al. (2012)

Table 1 *(Continue)*

Drying Method	Type of Feed	Mechanism	Advantage	Disadvantage	References
Sun Drying	Fruits, vegetables	Two types: direct and indirect; the product is heated directly by the sun's rays. The hot air is transmitted over the drying material at indirect solar dryers and often passes through a solar collector, releasing moisture from the substance.	Low-cost drying method for preserving and storing agricultural products; The most significant carbon-free supply of energy worldwide	Extended drying time. The risk of bacterial rush in birds, animals, and plumage is less constant.	Dhumne et al. (2016) Maragkaki et al. (2016) Hegde et al. (2015) Bennamoun and Li (2018)
Thermal Drying	Fruits, vegetables	Two processes occur concurrently during thermal drying: Heat transfer to raise the temperature of the wet material and evaporate the moisture content.	Contribute to increased energy efficiency and decreased thermal drying time	Two main disadvantages are low costs and a long drying time in the lower rate cycle. In addition, the low thermal conductivity during this period limits the standard heat transmission to the inner parts of the material.	Cam et al. (2017) Rahman ad Perera (2007) Wang et al. (2004)

EFFECT OF DEHYDRATION ON QUALITY OF FOOD WASTE FOR COMPOSTING

In recent decades, excess supply has resulted in increased waste nature generations in urban and industrial installations. Implementing sustainable policies to conserve environmental sustainability is essential in this respect. That is a renewable technology for the disposal of organic pollution and the regulation by scale and volume removal of smelly greenhouse gas for various organic waste. It is a highly successful process in terms of current costs, compost generation, and decreased air and water pollution by treating process parameters more effectively than other waste management options (Dhamodharan et al., 2019).

Composting is one of the most viable options for converting the natural fracture into a beneficial organic fertilizer known as compost among the advanced techniques (Artola et al., 2009). The commodity from the composting process can be used as a bio-fertilizer containing plant-based and livestock-based nutrients such as potassium and nitrated (sodium, calcium, magnesium, and chloride). In addition, Composting is used to recycle organic waste into a marketable product in advanced waste management techniques (Abdullah et al., 2018).

Composting is a simple process for producing a full-nutrient product from low-cost organic resources, which has a high-value commodity in agriculture and positively influences soil health (Pergola et al., 2020). Sustainable solid waste management is essential since it provides a means of handling biodegradable waste fractions. It has been used streamlined and promoted as a safe conversion of future organic waste to sustainably manageable solid waste (Ishola & Ishola, 2019). Some arguments say that composting reduces the overall greenhouse gas emissions, and others claim that it increases the amount of carbon dioxide (CO_2) and greenhouse gas (GHGs) emissions.

Composting is a convenient way to get rid of organic waste, but applying industrial drying methods before composting can preserve organic material quality and slash the time it takes to produce it (Ermolaev et al., 2019). Nowadays, significant factor considerations must be considered before implementing food waste disposal units as a wide-ranging waste management option, as are their related emissions of GHGs and other environmental damage. Continued research and development in food waste could better manage this choice to become a sustainable alternative to landfilling (Iacovidou et al., 2012). Dehydration of food waste is a technique that dewaters food waste to produce a low moisture product, greatly reducing the kitchen's waste content and waste volume (Sotiropoulos et al., 2015).

The product created from thermal dehydration of food waste may be more suited for soil application than compost and aerobic digestion because dehydrated food waste has a high concentration of Carbon, Nitrogen, and nutrition content that plant needs. In addition, using plant-growth-promoting microbes in dehydrated food waste, such as Azo spirillum, can improve nutrient availability and soil health (Mahmood et al., 2019). Due to the characteristics of dehydrated food waste, it can be used on various crops. Organic waste that has been dehydrated provides several advantages, including being light, dry, odorless, and biologically inert. Organic biofertilizer or livestock feed is made from the high nutrient content of this product. Before putting dried food waste into the soil, it must be composted or buried. These methods will aid in eliminating phytotoxins, anoxia, salinity, and water repellence (O'Connor et al., 2022). The dehydrated organic raw material was also discovered to slow decomposition and decrease odors, allowing for less frequent trash collection. Furthermore, it was determined that the dried food waste's physical and chemical properties make it appropriate as a feedstock for value-added items such as compost and biofuels (Schroeder et al., 2020).

Compost made from dehydrated food waste requires much oxygen to function properly. When young, composted products are applied to soils, their high oxygen demand can stymie seed germination and plant growth. When water is added to dehydrated food waste, the decomposition process begins. This method can store food waste for an extended period without losing nutritional value. To begin the composting process, add water to the dehydrated food waste (O'Connor et al., 2022). Food waste has a reduced moisture content, which can assist in controlling the water content of the organic substrate throughout the composting process. Also, purified dry food waste is pathogen-free, contains an appropriate amount of carbon and nitrogen, and is ideal for use as a compost feedstock. Dehydration not only retains the nutritional value of the raw material but also boosts productivity. Additionally, the remaining material may be archived for future reference. Otherwise, food waste will decay and become inert, eventually disappearing due to biodegradation (Loizidou, 2015).

According to the studies, due to some challenges dried food waste cannot be applied directly to the soil. Organic molecules made from dehydrated food waste have a high oxygen demand and are extremely phytotoxic, which can harm plant growth. Due to the increased oxygen demand, the nitrogen content of immature compost decreases when it is added to the soil. For a short period, food waste that has been dried can be stored and will not break down unless it is introduced to water. Adding water to the product completes the composting process since it sustains many microorganisms (O'Connor et al., 2021; Toundou et al., 2021).

Since dehydration of food waste has many advantages, it also has several drawbacks, one of which is the risk of financial loss. Therefore, using a laboratory drying system to treat food waste will have a significant economic impact. However, thermally GAIA Food Waste Dryer has recently overcome this difficulty by giving a non-biological, effective alternative to food waste dehydrators in terms of volume and bulk reduction (Dhar, 2016). Also, sun drying was the most cost-effective drying method, but it has not been widely suggested for food waste management due to several limitations, including the inability to control sun ray temperature and the inability to control product quality (Tony & Tayeb, 2011).

Physicochemical Properties of Dehydrated Food Waste for Compost

A proposed answer to the worldwide food waste disposal issue is to use food waste as biofertilizers. Dry food waste products had excellent electrical conductivity (4.83–7.64 mS cm^{-1}) and mild acidity (4.7–5.1) (O'Connor et al., 2022). pH is one of the critical characteristics of soil tests. It defines the soil considerably more than simply whether it is acidic or basic. The number of critical nutrients and toxicity of other elements can be anticipated due to their known pH relationship (Twain, 2020). Since Food waste is usually acidic in the early stages due to the creation of organic acids, it depends on the level of food waste and composition. Overall, the pH value in wet food waste ranged from 5–5.5 to 6.9–7.3. Due to microbial activity, the pH value will rise from 6 to 9% after composting (Kannah et al., 2020). In terms of acidity, the pH value of dried waste is very close to wet food waste. Thus, many experts believe that dry food waste can be used as raw material for composting.

Electrical conductivity stands for EC. It measures how well a substance drives electricity for the solution. The higher the conductivity, the more electrolytes. Furthermore, the greater the load, the higher the conductivity each particle carries. According to experts, the ideal EC values for agriculture compost fertilizer range from 2.0 to 3.5 mS/cm (Zaha et al., 2013). Compost with high EC rates might be very rich in nutrients since minerals have an outstanding performance. EC measures are supported by all ions charged into the soil solution. Some essential micronutrients, including NO_3, NH_3, and K, have reduced the requirement for additional fertilizers by their presence in compost. However, EC monitoring does not play the same function in soil feeding, and it is thus always suggested to follow the manufacturer's instructions (Crohn, 2016).

The effects of organic disposal on crop productivity depend on the material's different chemical compositions and sources. The main factors determine the composition and use of organic waste, such as C, N, K, P, and accessible biological germination experiments (Guerra-Rodríguez et al., 2001). As a soil-plant system, compost application is one of the most successful strategies. It might provide soil-plant systems with nutrients, stable organic material, and beneficial microorganisms (Haouas et al., 2021).

According to previous research findings, dried food waste can also be used as a raw material for composting. Because it is nutrient-rich, the amount of nutrient content in dehydrated food waste: Carbon 48.3%, nitrogen 3.26%, C/N 14.8%, and Sulphur 0.23% (Mahmood et al., 2019). One of the most important recent using dried food waste in compost to reduce total CH_4 emissions. Adjusting the moisture level during composting might help minimize greenhouse gas emissions and the environmental impact: For example, greenhouse gas emissions from composting food waste at two different humidity levels of 44 and 66% were examined over 20 days at 50°C and 16% oxygen. The total estimated Methane emission during the composting process was 35 g CH_4-C kg^{-1} initial C at a moisture content of 66%. However, it was reduced to 0.04 g CH_4-C kg^{-1} initial C at a moisture content of 44%. (Ermolaev et al., 2019).

Other parameters that need to be considered include the oxygen content and bulk density. Aeration is required to supply oxygen to microorganisms and promote the degradation of organic matter. Dehydrogenase activity is the easiest, fastest, and cheapest way to assess the stability and maturity of compost in ATP content and microbial bio-mass process (Tiquia, 2005). Composting alters the bioavailability of copper and phosphorus due to the decomposition of organic matter (microbial activity % and Humic acid/Fulvic acid ratio). C/N ratio of 22 allowed for successfully immobilizing copper, zinc, and phosphorus in compost (Wang et al., 2019). Aerobic composting is a decomposition process in which organic substrates break down in the presence of oxygen, producing carbon dioxide. Composting works best with a C/N ratio of 30–40% and a moisture of 50–65%, while new research suggests that C/N ratios as low as 20% may also be useful (Firdaus et al., 2018).

According to Schroeder et al. (2020), dried food waste with lower moisture content than ideal poses a significant issue; however, it is possible to compose this type of dry organic material by mixing it with other organic waste. For instance, combining yard waste high in nitrogen and moisture with raw food waste low in carbon can result in a healthful compost pile. Overall, Low humidity food waste, besides preserving nutrients, allows for the potential to produce a beneficial practical microbial photo-beneficial cum that may provide more advantages. Thus, managing dry organic waste is much easier than wet, and It can generate high-value products such as bio compost, biogas, and bioethanol (Loizidou, 2015). Table 2 Summarizes the optimum values of the various parameters of the composting processes.

Additionally, dehydrated food waste can be used as animal feed in nations where it is legal to feed animals with food waste. However, it must be processed very carefully before being fed. For example, the United States must heat food waste at 100ºC for 30 minutes. Also, in Japan, food waste processed for use in animal feed is referred to as "ecofeed." Preferably, raw materials containing uncooked meat should be heated at 70°C for 30 minutes or 80°C for 3 minutes before being used to make "ecofeed." Because of the drying process, Ecofeed can be preserved for a longer time (Georganas et al., 2020). Compared to turning wet food waste into dry pig feed, dry feed poses fewer environmental and health risks. However, the higher fossil fuel inputs required to dehydrate municipal food wastes represent a large percentage of the difference between wet and dry diets shown in Figure 7. Dehydrating food wastes to produce dry feed involves gas and electricity due to their high-water content, which ranges from 65 to 80%. The finding indicated that food waste should always be fed as wet feed. Because these two approaches, wet and dry, are appropriate for various pig production systems (Salemdeeb et al., 2017b). Table 3 summarizes the components of dried food waste used as a feedstock for composting.

Table 2
Summarizes the optimal values of the various parameters to be carried out after composting process

Parameter	Optimum values	References
pH	Between 5.5–7.3	Kannah et al. (2020)
Electrical conductivity (EC)	2.89 ds/m	Khan and Ishaq (2011)
Total of C	46.8%	Jiménez and García (1992)
Total of N	0.4–3.5%	Harrison (2008)
Total of S	0.25–0.8%	Bahtiar et al. (2017)
Moisture content	50–65%	Firdaus et al. (2018)
C: N	25–30:1	Firdaus et al. (2018)

Table 3
Summarizes the components of dried food waste used as a feedstock for composting

Components	wt.%, dry basis
pH	4.7–5.1
electrical conductivity	4.83–7.64
Carbon	48.3
Nitrogen	3.26
C: N	14.8
Sulfur	0.23

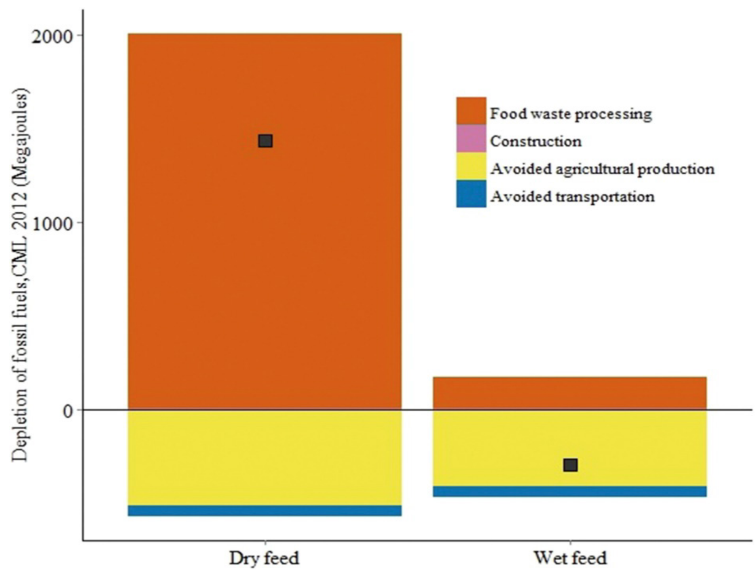

Figure 7. Manufacturing wet and dry feed using fossil fuel energy (MJ) (Salemdeeb et al., 2017)

Trench Composting of Dehydrated Food Waste

Trenching is a means to handle organic waste directly in the garden by burying it. It is a good way for plant roots to deposit nutrients in the soil. It also promotes the growth of deep root systems that provide water. Trenching for the plants generates nutrient-rich low-floor areas. The composting process is slower than in a managed backyard scenario, but more nitrogen is maintained throughout the process. For decomposing organic waste, trench compost relies only on the soil's decomposition of microorganisms and bugs. Since the substance is buried, it derives its water and oxygen from the earth underneath it. Additionally, the soil particles cling to decaying nitrogen, preventing it from escaping as methane and unpleasant odors (Compost Education Centre, 2010). Since the composting process is anaerobic, the lack of oxygen makes it unsuitable for high-humidity organic waste, leading to pathogens in the final product. In this case, trench compost is a good option for dry waste. A trench system attracts a maximum of 54°C in 15 days, lasts for five days until day 21, and then begins settling. This procedure takes around 30 days. Composting of trenches is comparable to pit compost. Composting in a pit necessitates the excavation of a hole or trench. This technique is effective at concealing decomposing organic materials. It is particularly beneficial against thermite attacks since most species dwell above ground level (Teresita et al., 2021).

The application of trench compost improves the soil quality and air retention, nutrients, and moisture, leading to healthy and flourishing plants (Brock et al., 2021). The disturbance and heterogeneity generated by human activities are substantially different in urban soil. By adding organic waste, significant increases in soil organic carbon have been identified, and soil physical and chemical characteristics improved and produced large amounts of organic carbon. In improving product quality and storage life after harvesting and eliminating product waste, the mechanical properties of garden produce play a significant role. The recent movement towards producing high-quality products and enhancing soil quality has been gradually using organic fertilizers (Jahanbakhshi & Kheiralipour, 2019). According to previous research, dehydrated food waste should be composted before being used as an organic fertilizer in the soil. Trench compost was recommended for dehydrated organic waste when comparing composting processes.

CONCLUSION

The use of food wastes as biofertilizers is a potential environmental solution to the current global food-waste disposal problem. The researchers concluded that dehydration of food waste is important and has a positive effect on reducing food waste during the management period. Sun-drying is the most cost-effective drying method, but it is not frequently recommended for food waste management due to some drawbacks, such as the inability to control sunray temperature and end-product quality. Thermal drying is an alternative method for sun-drying, which can dry food waste with high quality quickly. Thermal dryers, such as the GAIA GC-300 dryer and cabinet dryer fitted with a standard tray, provide a non-biological alternative to food waste dehydrators that effectively reduce the volume of waste generated. According to previous researchers, dry food waste can be used as a raw material for composting because it is high in nutrients and comparable to wet food waste. Dehydrated food waste contains 48.3% carbon, 3.26% nitrogen, 0.23% sulfur, 14.8% of carbon-nitrogen ratio, and it is slightly acidic (4.7–5.1) with high levels of electrical conductivity (EC) (4.83–7.64 mS cm^{-1}). Nevertheless, using dried food waste with a lower moisture content than the ideal moisture of 50–65 in the composting process has a significant problem; however, this type of dry organic material can be composted by mixing it with other organic waste. For instance, combining yard waste high in nitrogen and low moisture with raw food waste low in carbon and high moisture can result in a healthful compost pile. Adjusting the moisture level before composting might help minimize greenhouse gas emissions and the environmental impact; the result of two different humidity levels of 44 and 66% throughout the composting process was shown. The total estimated methane output was 35 g CH_4-C kg^{-1} initial C, which was reduced to 0.04 g CH_4-C kg^{-1} initial C. As a result, the review recommended that food waste be dried to an adequate moisture level before composting to reduce greenhouse gas emissions, odor, and leachate.

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