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Recycling Organic Waste in the Face of Global Warming

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Abstract

Waste management remains a major environmental challenge. In landfills, garbage cans, or even landfill sites, organic waste decomposes, releasing methane (CH_4) and carbon dioxide (CO_2). These gases accumulate in the Earth's atmosphere and absorb infrared radiation emitted by the Earth's surface, thus contributing to the greenhouse effect responsible for global warming. According to the report of the 29th Conference of the Parties on Climate Change held in Baku, Azerbaijan, from November 11 to 22, 2024, reducing methane emissions into the atmosphere is one of the most promising ways to mitigate the increase in Earth's temperature in the short term. This involves the recovery of organic waste from agriculture, the agri-food industry, households, restaurants, gardens, animal husbandry, etc. This article highlights the challenges and techniques that can be used in converting organic waste into bioproducts that emit fewer greenhouse gases. It constitutes a scientific contribution to the mitigation of global warming, the fight against pollution, and the promotion of the circular economy and sustainable management of resources.

Keywords

Organic Waste, Global Warming, Recycling, Bioeconomy

1. Introduction

The global surface temperature is currently 1.1˚C higher than in the 1800s, before the Industrial Revolution. By 2030, it could increase by 1.5˚C (IPCC, 2014). Consequences include intense droughts, water shortages, severe wildfires, rising sea levels, floods, melting polar ice, catastrophic storms, and biodiversity decline. Global warming results from increasing concentrations of greenhouse gases (CO_2,

CH_4, etc.) in the Earth's atmosphere. These gases absorb infrared radiation emitted by the Earth's surface, contributing to the greenhouse effect, which is responsible for increasing global temperature. They are mainly produced during the combustion of fossil fuels (coal, oil, natural gas) and can also come from the decomposition of organic waste resulting from human activity (Lenton et al., 2023).

Organic waste represents 65% of the volume of waste generated by human activity. It comes from agriculture, the agri-food industry, catering, the wood-paper industry, gardens, animal breeding, and even households (Kait, 2022). Stored in landfills, it decomposes under the action of bacteria and fungi with emissions of methane (CH_4) and carbon dioxide (CO_2). These gases accumulate in the Earth's atmosphere and absorb infrared radiation emitted by the Earth's surface, thus contributing to the greenhouse effect responsible for global warming. The waste sector alone emits 20% of the methane present in the Earth's atmosphere (SQRD, 2025). According to the report of the 29th Conference of the Parties on Climate Change held in Baku (Azerbaijan) from 11 to 22 November 2024, reducing methane emissions into the atmosphere is one of the most promising ways to mitigate the increase in Earth's temperature in the short term (COP29, 2024). Sorting, recycling, or even transforming waste into lower-emitting bioproducts would help reduce its contribution to global warming by more than 80% (EDT, 2023).

Numerous green technologies aimed at transforming waste into bioproducts that emit fewer greenhouse gases have been developed in recent years. Organic waste can be used to produce green energy through anaerobic digestion or methanization processes. It can also be converted into compost, biofuels, organic acids, biodegradable plastics, bioflocculants, or even biopesticides (INTERACT-Africa, 2024). These bioproducts from the recycling of organic waste emit fewer greenhouse gases during their aerobic degradation or their use as bioenergy (EDT, 2023). The World Bank estimates that by 2050 we will produce 3.88 billion tons of waste per year, a 73% increase from 2020 (Kait, 2022).

2. Origin of Organic Waste

Organic waste is derived from materials of animal or plant origin. It comes from agriculture, livestock farming, households and restaurants, the food industry, green spaces, gardens, and even wood and paper.

2.1. Agricultural Waste

Agricultural waste is plant residue from agriculture that is not used for human or animal food. This includes hulls, straw, stems, inedible leaves, etc. All agricultural systems around the world generate waste. This waste can have a negative impact on both the environment and the climate. As it decomposes, it emits methane and carbon dioxide, which contribute to global warming. Furthermore, most agricultural waste is generally burned on plantations or in power plants. This combustion generates significant amounts of carbon dioxide and smog that pollute the ambient air (UNEP, 2021). The most common agricultural crops grown worldwide are sugarcane, corn, cereals, and rice (FAO, 2021). These crops generate more than 700 million tons of agricultural waste each year (Fritsch et al., 2017).

2.2. Livestock Waste

Livestock waste consists of excrement, leftover fodder, spoiled feed, manure, slurry, animal carcasses, etc. This waste decomposes, releasing greenhouse gases including methane and carbon dioxide. According to a report by the Food and Agriculture Organization of the United Nations (FAO) published in 2023, livestock farming emits 12% of anthropogenic CO_2 (FAO, 2023). It accounts for 80% of greenhouse gas emissions from the global agricultural sector (Ordeco, 2025). The Belgian vegetarian association EVA estimates that avoiding farmed meat one day a week is equivalent to saving 170 kg of CO_2 per person per year (EVA, 2009). Waste management from livestock farms remains an environmental and economic problem in most industrialized countries.

2.3. Household and Restaurant Food Waste

Household and restaurant food waste represents a significant portion of organic waste, particularly in urban areas. It includes leftover meals, fruit, tuber, and vegetable peelings, spoiled food, uneaten food, expired products, food discarded at the end of restaurant service, meat cutting waste, and more. Its accumulation poses a problem for both the environment and the climate. It is a source of pollution, pest and pest proliferation, unpleasant odors, and greenhouse gas emissions.

2.4. Agro-Industrial Waste

Agro-industrial waste is residue resulting from the processing of agricultural products by agri-food industries. These include fruit and vegetable residues (peels, seeds, pulp), cereal by-products (wheat bran, rice, corn hulls, etc.), wastewater laden with organic matter, oil mill residues (cakes, fibers, peanut hulls, cotton, etc.), brewery waste (spent grains, yeast), etc. The growing world population has led to an increase in food needs and the increased development of agri-food industries. This generates enormous quantities of organic waste each year and constitutes a significant burden on the environment (Boulal et al., 2019).

2.5. Paper Waste

Paper waste is the residue resulting from the use of paper-based products. It represents a significant portion of municipal solid waste and comes from offices (printing paper, draft paper), schools (notebooks, paper), households (newspapers, cardboard boxes, wrapping paper, tissues, napkins), businesses (bills, flyers, paper bags, cardboard boxes), etc. Paper waste is an organic product that emits CO_2 during its decomposition.

2.6. Green Waste

Green waste comes from the maintenance of green spaces, gardens, parks, and agricultural activities. It includes garden waste, dead leaves, wilted flowers, grass clippings, straw, tree branches, tree trimmings, and more.

3. Greenhouse Gas Emissions from Organic Waste

The waste sector is responsible for around 20% of methane emissions worldwide. It is a very potent greenhouse gas with a global warming potential 25 times higher than that of CO_2 over a 100-year period (EPA, 2025). In landfills, the anaerobic decomposition of organic waste by bacteria and fungi is accompanied by emissions of CH_4 and CO_2. These greenhouse gases contribute significantly to climate change when they escape into the atmosphere. Furthermore, these emissions impair air quality and are associated with public health problems, such as asthma. Reducing methane emissions into the atmosphere is one of the most promising ways to mitigate global warming in the short term (COP29, 2024).

4. Organic Waste Recovery

4.1. Sorting and Separation of the Organic Fraction of Waste

Depending on the nature and composition of waste collected from urban landfills, agri-food industries, or households, it is necessary to separate the organic fraction of waste in order to recover it. In industrial settings, this separation is based on granulometric techniques (trommels), densimetric techniques (vibrating tables), magnetic techniques (magnetic or eddy current wheels), ballistic techniques, optical techniques, etc. (FNADE, 2011). Depending on the objectives to be achieved, manual sorting can also be performed. Furthermore, organic waste can be separated from other waste at the source (home, school, etc.) before collection and recycling.

4.2. Composting

The presence of organic matter in the soil is essential for maintaining soil fertility and reducing nutrient losses (Inckel et al., 2005). Compost is a humus-rich organic amendment that can act over the long term to improve the physical, chemical, and biological properties of the soil. It is obtained from the decomposition of organic waste under the action of microorganisms, worms, and insects. This organic waste includes crop residues, animal waste, food scraps, certain urban wastes, and suitable industrial waste. Compost provides temporary storage of nitrogen and carbon. When added to the soil, it gradually releases nitrogen for plants and is a good soil amendment (Paillat, 2008). Composting stabilizes waste to reduce pollution, reduce waste mass, produce an organic soil amendment, and reduce landfilling and burial of organic waste. In practice, the process of aerobic composting of organic waste is carried out in two successive stages, namely the fermentation stage and the maturation stage (AND, 2025).

1) Fermentation Stage

The fermentation stage most often begins 4 to 5 days after the compost pile is formed and can last 1 to 2 weeks. During fermentation, microorganisms multiply rapidly, which increases heat production. Fermentation is maximal when the temperature in the compost pile is 60˚C - 70˚C (Inckel et al., 2005). The compost fermentation stage can be subdivided into three phases: the mesophilic phase, the thermophilic phase, and the cooling phase. These phases are characterized by a specific temperature and microflora (AND, 2025).

- Mesophilic phase: Mesophilic microorganisms multiply rapidly by consuming available sugars and amino acids. Their optimal growth temperature is between 20˚C and 45˚C. During their activity, they produce heat, which inhibits their own metabolic activity. This heat production is linked to the decomposition of the hard and complex fibers of organic matter.

- Thermophilic phase: After the action of mesophilic microorganisms, thermophilic germs take over and continue the decomposition process. These microorganisms have an optimal growth temperature between 50˚C and 70˚C. During their metabolic activity, they raise the temperature of the compost to around 65˚C. The increased temperature of the compost kills pathogens and weed seeds.

- Cooling phase: The temperature decreases and becomes favorable for mesophilic microorganisms and fungi. The decomposition of organic matter occurs without significant heat release, so the temperature of the compost pile slowly decreases. The newly growing microorganisms transform the organic components of the compost into humus. The compost pile remains moist and warm in its center, and the temperature drops to around 30˚C (Inckel et al., 2005).

2) Maturation Stage

Maturation improves the quality of the compost. It is essential to obtain stabilized, humus-rich, and non-phytotoxic compost. During this phase, the most complex organic matter continues to decompose. Bacteria give way to fungi, protozoa, nematodes, and arthropods. The compost temperature gradually decreases until it reaches room temperature. The material turns dark brown to black. The compost maturation time varies depending on the type of waste. Rigid organic matter evolves more slowly, and labile organic matter evolves more quickly (La France & Duval, 2022).

4.3. Biopesticide Production

The use of chemical plant protection products has significantly reduced the arduousness of field work while enabling sufficient agricultural production at a lower cost. However, these synthetic products can cause environmental and health problems (Deravel et al., 2014). Biopesticides are alternatives to synthetic chemical pesticides. They possess antifungal, insecticidal, and antiparasitic properties. They can be produced from organic waste from agriculture (leaves, fruits, shells, seeds), the agri-food industry, or even households (pineapple peel, avocado kernel, etc.). One production technique involves grinding organic waste, dissolving the ground material in water to extract the active ingredients, and then removing the residue through filtration. Some organic wastes, such as coconut water, can be used as substrates for the production of *Bacillus thuringiensis*, a bacterium with insecticidal properties. Biopesticides are environmentally friendly, emit fewer greenhouse gases, and are distinguished by their specific mode of action, reduced toxicity to non-target organisms, short residual life, and better biodegradability. They do not persist for long in the environment and degrade quickly. After application, farmers can immediately enter the field or greenhouse to carry out other work (AAC, 2021). The use of local organic waste in the production of biopesticides makes them more accessible to farmers, especially in rural or low-income regions.

4.4. Biofuel Production

4.4.1. Bioethanol

An alternative to fossil fuels could be bioethanol derived from organic waste rich in fermentable sugars. This waste includes sugarcane bagasse, cereal straw, rice hulls, etc. The sugars they contain are converted into ethanol by the action of microorganisms (Macqueron, 2009). This process is called alcoholic fermentation. The microorganisms responsible for the alcoholic fermentation of sugars are mainly yeasts of the genera Saccharomyces (*S. cerevisiae*, *S. uvarum* or *carlsbergensis*, *S. bayanus*), Schizosaccharomyces (*S. pombe*), and *Kluyveromyces* (*K. fragilis*). Bacterial species such as *Zymomonas mobilis* are also found (Ballerini, 2002). Bioethanol can be used as a fuel for engines. It can also be used as a disinfectant, antiseptic, or solvent for the chemical, pharmaceutical, and cosmetic industries (Onyekwelu, 2019). The renewed interest in bioethanol production today is linked to the international community's desire to promote renewable energy sources. Bioethanol offers a more sustainable and environmentally friendly energy source (Ballerini, 2002). Global bioethanol production has increased significantly in recent years to reach 65 billion liters per year; this is to meet the growing demand for biofuel (Macqueron, 2009).

4.4.2. Biodiesel

Today, industrialization and motorization are constantly increasing, requiring more and more fuel (Bettahar et al., 2016). This increases the production of greenhouse gases due to the use of fossil fuels. An environmentally friendly alternative to fossil fuels is to produce biodiesel by converting biodegradable waste oils and fats into alkyl esters through transesterification. This is a chemical process in which a vegetable or animal oil is mixed with an alcohol in the presence of a catalyst. One technique involves heating vegetable oil in the presence of methanol and potassium hydroxide. The heat and potassium hydroxide release the fatty acids from glycerol and allow a methanol molecule to attach to each fatty acid to form methyl esters, a form of biodiesel (Vessey, 2025). Waste fats and oils used in the production of biodiesel can include cooking oils, animal fat, residual vegetable oil, lipid-rich agri-food residues, etc. By replacing fossil fuels, biodiesel contributes to the reduction of greenhouse gas emissions into the atmosphere.

4.4.3. Biobutanol

Acetone-butanol-ethanol (ABE) fermentation is gaining renewed interest due to the environmental problems caused by fossil fuels. It is increasingly being studied for the production of butanol, a promising biofuel (Baral & Shah, 2014). Acetone-butanol-ethanol fermentation is an anaerobic process that occurs in two stages: acidogenesis and solvogenesis. During acidogenesis, bacteria ferment sugars, producing organic acids such as acetic acid and butyric acid. These acids are then converted to acetone, n-butanol, and ethanol during solvogenesis. ABE fermentation requires anaerobic conditions, a temperature of approximately 35˚C - 37˚C, and a pH of approximately 5. Bacteria of the genus *Clostridium*, particularly *Clostridium acetobutylicum*, are the main microorganisms used (Tapias et al., 2024).

4.5. Biogas Production: Methanization

Also known as anaerobic digestion, methanization is the anaerobic degradation of organic waste by microorganisms under controlled conditions. It takes place in a digester and results in the formation of biogas and digestate. It can be carried out on agricultural, industrial, and household organic waste, or on liquid effluents such as sewage sludge, livestock effluent, agri-food effluent, etc. (CDE, 2025). The biogas formed is a water-saturated gaseous mixture consisting of approximately 50% to 70% methane (CH_4), 20% to 50% carbon dioxide (CO_2), and a few trace gases (NH_3, N_2, H_2S) (Bastide, 2014). This methane-rich biogas can be used as energy (electricity, heat, biofuel, etc.) or purified for direct injection into the natural gas distribution network (FNADE, 2011). The advantage of methanization is the reduction of greenhouse gas emissions because it replaces the use of fossil fuels (Bastide, 2014). It takes place in four stages, namely hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Orellana & Ricardo, 2019).

4.5.1. Hydrolysis

The hydrolysis of organic matter is carried out by strict or facultative anaerobic eubacteria. The main species belong to the genera *Clostridium*, *Bacillus*, *Ruminococcus*, *Enterobacteroides*, *Propionibacterium*, and *Butyrivibrio*. These microorganisms produce hydrolytic enzymes that degrade macromolecules (proteins, lipids, polysaccharides) in organic matter, releasing simple molecules such as fatty acids, mono- and disaccharides, peptides, and amino acids (Bennama, 2016). Once solubilized, organic substances are available for assimilation by acidogenic bacteria (Lacour, 2012).

4.5.2. Acidogenesis

Acidogenesis is carried out by so-called fermentative bacteria. These microorganisms mainly belong to the genus *Clostridium*. They also include bacteria of the genera *Bacteroides*, *Bacillus*, *Pelobacter*, *Acetobacterium*, *Ulyobacter*, and the *Enterobacteriaceae*family. During acidogenesis, the simple molecules released during the hydrolysis stage are converted into volatile fatty acids (acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate), alcohols, hydrogen sulfide (H_2S), carbon dioxide (CO_2), and hydrogen (H_2) (TI, 2025). Acidogenesis is the fastest stage of the methanization process. This is a decisive step in the methanization process because the accumulation of volatile fatty acids can lead to a drop in the pH of the medium and inhibit the entire methanization process (Lacour, 2012).

4.5.3. Acetogenesis

Acetogenesis is the synthesis of acetate through aerobic oxidation of ethanol, fermentation of hexoses, or autotrophically from CO_2 and H_2. During acetogenesis, the metabolic intermediates of acidogenesis are transformed into acetic acid, hydrogen, and carbon dioxide. These molecules are the precursors for methane formation. Acetogenic bacteria involved in methanation can be subdivided into three groups. The first group is called syntrophic bacteria. These are microorganisms of the genera *Syntrophobacter*, *Syntrophomonas*, *Syntrophus*, etc. They oxidize alcohols and volatile fatty acids into acetic acid, hydrogen, and carbon dioxide. The second group is called homoacetogenic bacteria. These bacteria belong to the genera *Acetobacterium*, *Clostridium*, *Eubacterium*, etc. They are capable of producing acetic acid from CO_2 and H_2 via the Wood-Ljungdahl pathway (Lacour, 2012). The third group corresponds to sulfate-reducing bacteria. These bacteria belong to the genera *Desulfovibrio*, *Desulfobacter*, *Desulfotomaculum*, etc. They use sulfate (SO_4^{2-}) as the final electron acceptor to produce hydrogen sulfide (H_2S). Sulfate-reducing bacteria are not strictly acetogenic; in the absence of sulfate, some can use pathways similar to acetogenesis to survive (Moletta, 2015).

4.5.4. Methanogenesis

Methanogenesis is the final stage of the methanization process. It is a form of anaerobic respiration that results in the production of methane in certain microorganisms belonging to the archaea group. Among the methanogenic archaea, a distinction is made between acetoclasts and hydrogenotrophs. Acetoclasts are the key microorganisms in methanogenesis. They convert acetic acid into methane and carbon dioxide. These are microorganisms of the genera Methanosarcina, Methanosaeta, etc. Acetoclasts grow slowly and are very sensitive to pH, temperature, and toxic substances (NH^{4+}, heavy metals). Hydrogenotrophs, on the other hand, have a complementary action to acetoclasts. They produce methane using hydrogen (H_2) as an electron donor and carbon dioxide (CO_2) as an acceptor. They belong to the genera Methanobacterium and Methanococcus or Methanospirillum. The biogas obtained after methanogenesis is composed of approximately 60% CH_4, 40% CO_2, and traces of H_2S, NH_3, and H_2. This stage takes between one and two weeks (Jouany & Thivend, 2008; Moletta, 2015). It should be noted that biogas can be described as "biomethane" when it has been freed from its impurities and undesirable components, namely, mainly carbon dioxide, hydrogen sulfide, and water (CDE, 2025).

4.6. Biochar Production

As plant waste decomposes, it releases the carbon stored during photosynthesis in the form of CO_2. When transformed into biochar, the CO_2 is sequestered within the material (Carbo, 2025). Biochar is a form of charcoal produced by the pyrolysis of organic matter such as wood by-products, agricultural residues, solid manure, green waste, or food waste (Novethic, 2025). Also known as carbonization, pyrolysis is a technique that involves heating biomass between 350˚C and 650˚C in the absence of oxygen (Carbo, 2025). This process transforms the biomass into a stable carbon material. Biochar could have beneficial properties in agriculture and sustainable soil management. As a soil amendment, biochar improves water retention, fertility, and carbon sequestration, thus contributing to the fight against climate change (Novethic, 2025). Furthermore, it is a porous material that can adsorb pollutants present in water. It can be used to make drinking water or filter sewage treatment plant sludge. It can also be used to treat manure and bedding, and to enhance the efficiency of compost (better digestibility, mass gain, nutrient supply). Pyrolysis also leads to the production of a synthetic gas (syngas) and a bio-oil rich in organic compounds (Carbo, 2025).

4.7. Production of Recycled Paper and Biodegradable Plastics

Recycled paper is produced by transforming waste paper (newspapers, cardboard, used sheets) into new, usable products. After collection, the waste paper is sorted and then shredded. The shredded material is dissolved in water, de-anchored, and freed from impurities (staples, plastics, etc.). The resulting pulp is then purified, bleached, spread into sheets, pressed, dried, and rolled. The production of biodegradable plastics is an ecological solution for preserving the environment. Non-biodegradable polymers such as polyethylene, polypropylene, and polyvinyl chloride contribute significantly to plastic pollution and accumulate over time (Tanunchai et al., 2023). Raw materials used in the manufacture of bioplastic include starch (e.g., from corn, cassava, potato waste), cellulose (fruit residues, cane bagasse, leaves), proteins (soybean skins, whey), sugars (fruit skins, pulps), cotton, etc. (Moses, 2023).

4.8. Production of Organic Acids

Acetic acid (vinegar) can be produced by aerobic fermentation of sugar-containing waste by bacteria of the genus Acetobacter. Lactic acid is produced by anaerobic fermentation of lactose and starch contained in organic waste by lactic acid bacteria. Citric acid can be produced by fermentation of fruit pulp and sugarcane waste by *Aspergillus niger*. Butyric acid is produced by anaerobic fermentation of fermentable fatty acids. These acids can be used in the food industry, biodegradable plastics manufacturing, chemical industries, etc. The microbial production of organic acids has become a rapidly developing field due to their increasing global market (Lu et al., 2019).

4.9. Animal Feed

The costs associated with animal nutrition during livestock farming can be reduced by using organic waste from fields, households, or even agro-industry. This waste includes, among other things, grain residues, fruit pulp, tuber peelings, spent grains, oilcakes, restaurant waste, etc. Brewing waste such as spent grains, for example, can be used to feed pigs and chickens. Subsequently, the excrement, effluent, and leftover fodder generated during livestock farming can be recycled through processes such as methanization, biofuel production, biochar production, etc. The objectives are to avoid food waste and reduce the presence of organic waste in landfills and in nature. This limits the proportion of greenhouse gases produced by their decomposition.

4.10. Spreading on Agricultural Land

Direct spreading of organic waste on agricultural land is a common practice aimed at improving soil fertility and recovering organic matter from agricultural, household, livestock, agro-industrial activities, etc. This organic waste can include manure, slurry, crop residues, kitchen waste, etc. The objective is to provide nitrogen (N), phosphorus (P), potassium (K), and trace elements essential for plant growth. Spreading must be done in an aerated manner and outside the rainy season to limit the formation of greenhouse gases.

4.11. Production of Plant Extracts of Interest

Plant waste consists of active metabolites with diverse biological properties. After processing and grinding, they can be extracted by maceration, decoction, infusion, etc. Extraction solvents include water, ethanol, palm wine, methanol, etc. The resulting crude extracts can be used in pharmaceuticals, cosmetics, animal nutrition, crop protection, etc. Furthermore, substances of interest such as proteins, cellulose, essential oils, and carotenoids can also be isolated from plant waste using chromatographic methods.

4.12. Use of Animal Waste

Animal fat can be used in the oleochemical sector to make soaps, lubricants, paints, and cosmetics. Beef and pork fats are the most commonly used in soap making. Pig by-products are used in medicine: cartilage is used to treat osteoarthritis, while mucus is used to make heparin (Ordeco, 2025). Animal meal (feather meal, meat meal) is used in organic farming as a nitrogen amendment. It is rich in nitrogen, which is readily available and readily assimilated by plants.

4.13. Bioflocculants

Bioflocculants are natural polymers produced by microorganisms that can agglomerate suspended particles in water (Li et al., 2009). They are an environmentally friendly alternative to chemical flocculants such as aluminum or iron salts. Organic wastes that can be used in the production of bioflocculants include potato or banana peels, sugarcane residues, food scraps, manure, etc. These wastes provide sugars, fatty acids, and other nutrients to the microorganisms that produce bioflocculants. The microorganisms commonly used are *Bacillus subtilis*, *Aspergillus niger*, *Pseudomonas* sp., etc. The production process begins with enzymatic or thermal hydrolysis of the organic waste to release fermentable compounds. The reaction medium is then inoculated with the microbial strain. After incubation under defined conditions, the bioflocculant is recovered by centrifugation and precipitation. Bioflocculants are commonly applied to wastewater treatment, especially in heavy metal wastewater treatment, because they are safe to use in the environment (Lu et al., 2014).

4.14. Brick Making

Brick making from organic waste involves incorporating biodegradable materials into clay or other binders to form more durable or insulating bricks. These wastes include sugarcane bagasse, peanut shells, cow dung, etc. After drying, grinding, and sieving, the waste is mixed with clay and formed into molds. The bricks are then air-dried or sun-dried for several days. Additional kiln firing may be performed to further solidify the bricks.

4.15. Biorefineries

Biorefineries are industrial facilities where biomass (organic waste, agricultural residues, wood waste, algae, etc.) is transformed into value-added products such as biofuels (biogas, bioethanol, biodiesel), biochar, biodegradable plastics, chemicals (solvents, acids, plastics), energy (heat, electricity), food or cosmetic products, fertilizers, or organic amendments. Their objectives are to reduce dependence on fossil fuels, fully recover biomass, minimize waste, and promote the circular economy. By incorporating many different processes into one refinery under one roof, power, energy, utilities, and maintenance costs can be shared and conserved (Fernando, 2006). **Table 1** below compares some key organic waste recovery processes.

Table 1. Comparison of organic waste recovery techniques.

Processes	Comparison criteria			
	Type of waste accepted	Technical complexity	Installation cost	Environmental impact
Composting	Green waste, food waste, manure	Low (simple process)	Low to moderate	Waste reduction, soil improvement
Methanization	Wet organic waste, sludge, livestock effluents	Medium to high (requires precise control)	High	Reduction of greenhouse gas emissions, production of renewable energy
Pyrolysis	Dry biomass, wood waste, organic plastics	High (advanced technology, temperature, and atmosphere control)	Very high	Carbon fixation (biochar) and energy production require rigorous emissions management.
Biofuels (e.g., biodiesel, bioethanol)	Organic waste rich in lipids and sugars	High (advanced technology, requires pretreatment)	High	Replaces fossil fuels and reduces greenhouse gas emissions.

5. Conclusion

Organic waste recovery represents a strategic response to contemporary environmental challenges, particularly global warming. The objective of this review article was to highlight the various methods for recovering and transforming organic waste into other useful bioproducts. By promoting its transformation into compost, biogas, biofertilizers, or bio-sourced materials, recovering organic waste helps reduce its harmful impact on the environment, decrease dependence on fossil fuels and chemical agricultural inputs, and reduce greenhouse gas emissions. Organic waste recovery is part of a circular economy and sustainable resource management approach. However, its effectiveness depends on the implementation of coherent policies, appropriate infrastructure, and increased awareness among local stakeholders. Investing in organic waste recovery means acting both for the health of ecosystems and for the resilience of regions in the face of climate change.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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