ISSN: 0973-4929, Vol. 19, No. (1) 2024, Pg. 35-45

Current World Environment

www.cwejournal.org

Composting of Agro-Phyto wastes: An Overview on Process, factors and Applications for Sustainability of Environment and Agriculture

TANVI TANEJA[1], MUKESH KUMAR[1], INDU SHARMA[2], RAJEEV KUMAR[3], ATUL SHARMA[1] and RAJ SINGH[1]*

[1]Department of Bio-Sciences and Technology, MMEC, Maharishi Markandeshwar, (Deemed to be University), Mullana, Ambala, Haryana.
[2]Department of Biotechnology, NIMS Institute of Allied Medical Science and Technology, NIMS University Rajasthan, Jaipur, Rajasthan, India
[3]Department of Bioscience and Bioengineering, Lovely Professional University Phagwara, Punjab. India.

Abstract

Composting is a naturally occurring process that turns organic waste materials like leaves, food scraps, and other organic wastes into a valuable manure that can improve the fertility and structure of the soil by introducing beneficial organisms, humus, and important plant nutrients. By breakdown, this process transforms the organic substance into inorganic and organic components. In recent years, composting received more attention due to pollution concerns. Loss of resources due to the continuous increase in wastes leads to environmental risks. The process of composting is of three types, i.e., aerobic, anaerobic and vermicomposting. Anaerobic composting occurs when there is no oxygen present, whereas aerobic composting occurs when oxygen is present. Vermicomposting is the breakdown of organic wastes by earthworms. The main purpose of composting is to stabilize waste used for land filling and mass reduction of solid waste. Its aim is to recycle the organic wastes to a natural product, i.e., manure. This study reviews the information on the conversion of organic wastes into a compost to reduce the environmental pollution. The use of central composting after separating organic and non-organic waste at source is one of the most innovative strategies especially in the fast-growing cities for the sustainability of environment.

Article History
Received: 06 October 2023
Accepted: 08 January 2024

Keywords
Composting; Environment Pollution; Manure; Recycling; Solid Waste.

CONTACT Raj Singh dr.rajsingh09@gmail.com Department of Bio-Sciences and Technology, MMEC, Maharishi Markandeshwar, (Deemed to be University), Mullana, Ambala, Haryana.

Doi: https://dx.doi.org/10.12944/CWE.19.1.4

Introduction

Landfill is the most traditional way for the disposal of solid wastes throughout the world, producing methane gas, which accounts for 30% of all atmospheric gases and extremely damaging leachates, which are the main environmental pollutants. Disposal of biodegradable organic wastes has become a major problem in cities, small towns and countries. For the cultivation of agricultural crops, the most feasible process is to recycle the organic matter and nutrients in agricultural fields. Composting is a vital technology for disposing the organic wastes economically.[1] It is a biochemical process, in which, aerobic and anaerobic microbes break down the organic material to create compost, a beneficial form of manure. Organic material is transformed into a nutrients' rich dark substance *via* a natural process. Composting turns the waste into nutrients back to the soil. Compost is useful in a variety of applications because of its higher biological activities and organic carbon content. Urban or rural vegetable and animal wastes converted by the composting process into a form that can be used to increase soil fertility. Compost is an essential part of agriculture because it contains essential macro- and micro-nutrients. Humus improves the soil's ability to conserve moisture while content of organic matter in soil also increases. Composting generates lot of heat, which can kill weed seeds and viruses.[2] Controlled breakdown of organic matter into a good compost retrieves the organic carbon. Composting defines the component of an effective management of resource plan. The waste management strategy that protects the environment and stops the production of organic wastes by converting or recycling waste materials potentially into a variety of products must be encouraged. Composting would support sustainable agriculture by making compost from organic wastes in an environment friendly manner.[3] Composting and sustainable agriculture are key components of a sustainable society. As a result, the sustainability concerns are a major force behind the development of composting technology. Controlling the composting process would better enable the related technologies more effective and commercially *via*ble, promoting agricultural and societal sustainability. The *via*ble waste management program followed in Africa during COVID-19 pandemics,[4] also the potentials for renovating polish towns and cities throughout the epidemic.[5]

Fresh organic matter should not be added to the soil because doing so, alters the ecosystem where the crop is growing.[6] If organic matter is not partially humified after being added to the soil, the microflora will breakdown it.[7,8] The microbes release the transitional metabolites that are incompatible with normal plant growth.[9] The drawbacks include the enhanced value of carbon to nitrogen ratio, ammonia production in the soil and competition for nitrogen between roots and microbes. Composting technique for achieving a constant product by biological oxidative transformation is comparable to that substance, which naturally takes place in soil.[3] Composting process is convenient, yield soil conditioner, saves money, reduces soil erosion and pollution, improves soil fertility, helps in promoting plant growth and providing higher crop yield, recycles the home waste and suppresses insect pests and plant diseases. As a result of streamlined assessment of food waste management and composting practice in Malaysia to reduce environmental contamination it was hoped that the local population will recognize the value of composting and food waste separation.[10]

Application of Composting in Agricultural Soil

Compost treatments on the ground help to reduce organic matter and improve nutrient management. Adding compost in field replenishes nutrients removed through post-harvest burning of crop residue. Soil fertility and health are maintained and restored under by recycling process of organic waste. It is important to apply compost to agricultural land in a way that promotes sustainable growth To maximise agronomic benefits while assuring the protection of environment quality, management strategies must be devised.[11] Nitrogen availability is the primary factor in optimal agronomic usage but still more studies are needed to improve the use of nitrogen in productivity of organic manure, which can improve the soil properties, i.e., chemical, physical and biological, enhancing crop production. The amount of chemical fertilisers' replacement is determined by the compost's nutritional contents, which boosts the soil's ability to conserve and indirectly improves structure, due to the soil's ability to hold water, crop water requirements and irrigation frequency are lowered.

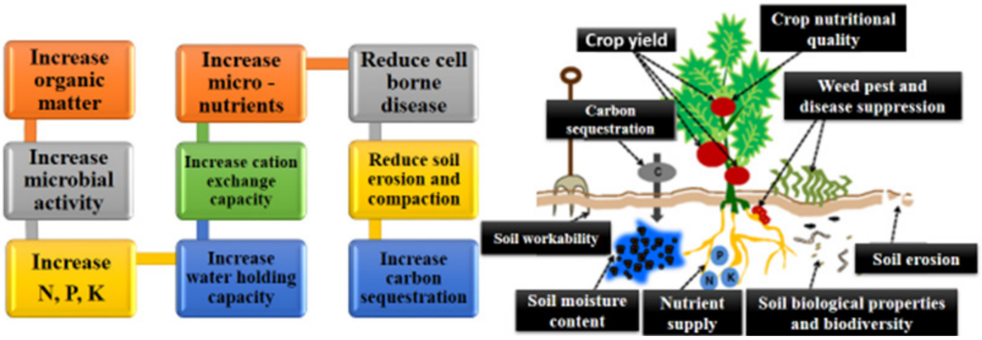

Fig. 1: (a) Benefit of compost in soil and (b) benefits of compost in plant

Composting Process

Composting has extensive antiquity and is regularly used to maintain the soil fertility by adding the organic matter back to the soil. However, the demand for waste treatment technologies that are eco-friendly has led to a recent spike in composting. Because home composting adheres to the values of round economy, it has a favourable economic and environmental impact on how household biodegradable waste is currently managed.[12] Waste management technique, which is acceptable to environment, is composting. Composting involves the aerobic process that turns biodegradable organic materials into a substance resembling humus by utilising naturally occurring microbes.[13] Pathogens are eliminated, nitrogen is transformed to stable organic form from the unstable ammonia, volume of waste is decreased and waste quality is improved during the process.[14] Because nitrogen in compost is more stable and slowly released, it also makes garbage easier to transport and handle and frequently enables larger application rates. The most well-known method for biological stabilisation of solid organic wastes is composting. This method converts the solid organic wastes into a material, which is safer and more stable or utilize as a mode of nutrition and soil conditioner in agricultural applications. In order to sanitise the waste by getting rid of pathogenic bacteria, organic materials must undergo an accelerated degradation process by microorganisms under regulated conditions in a process known as composting.[15] Many factors affect the composting process's efficiency, including as moisture content, oxygen availability, and temperature. Composting comes in two different types: anaerobic and aerobic.

Aerobic Composting

Composting process occurs in the presence of oxygen. Organic waste will break down quickly in the presence of oxygen and is not prone to release odour causing compounds. It requires accurate moisture monitoring and high maintenance and is good for large volume of compost. Microorganisms break down the organic material during this process, releasing carbon dioxide, ammonia, water, heat and humus, a stable organic product. Protein, fat and complex carbohydrates, such as cellulose and hemicellulose, are broken down.[9] Studied revealed the changes in variables such pH, temperature, moisture content, organic carbon and volatile solids during aerobic composting.[16,17]

Anaerobic Composting

Composting takes place anaerobically when very little or no oxygen is available. It can take years for compost to decompose. Organic materials are broken down by bacteria into odour substances like ammonia and methane gas.[16,17] In this method, anaerobic microorganisms predominate and generate intermediate compounds such as hydrogen sulphide, organic acids, methane, and others. These molecules build up in the absence of oxygen without being further metabolized. The mesophilic phase, the thermophilic phase, the maturing phase and the cooling phase are four stages of the composting process.[18]

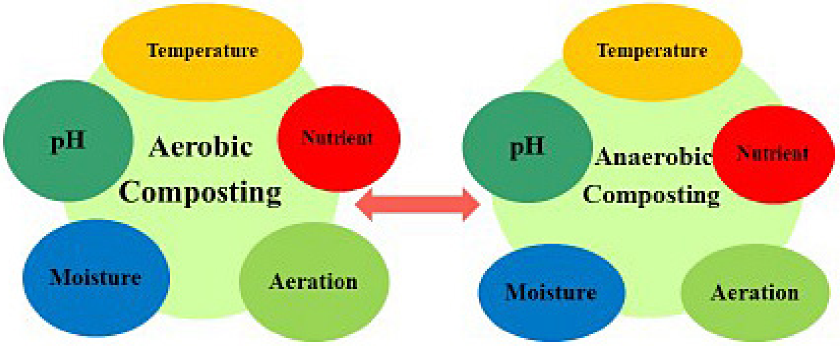

Fig. 2: Factors affecting aerobic and anaerobic composting

Important Parameters of Composting Process

In composting process to get good quality compost or early maturation, some parameters are important. Several factors affect the rate of effective composting, including moisture content, temperature, carbon to nitrogen ratio, pH value, oxygen (aeration) and time.[19]

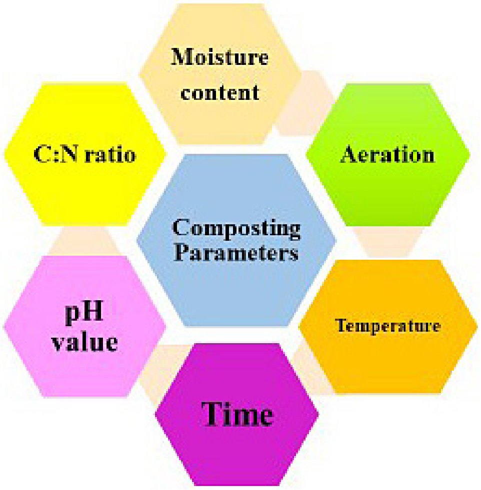

Fig. 3: Parameters of composting

Moisture Content

The trash should have a moisture content between 50 and 55 percent. Less moisture will cause the bacteria to die, whereas, greater moisture will provide anaerobic conditions that will render the inoculated microbes useless in the composting process and cause the production of odorous greenhouse gases. The higher moisture content (>75%) is not suitable for composting heaps because it cools the heap, which lowers temperature and reduces biomass and microbial activity. For microbial stabilisation to work effectively, the solid waste must include enough moisture. For microbial processes, water is necessary.[20] For microbial stabilisation to be as effective as possible, the solid waste must include enough moisture. Microbial processes both need and create water. The loss of water *via* evaporation as the composting process develops is a significant component of the process. As a result of microbial heat generation, moisture is eliminated by evaporation (evaporative cooling), which also impacts porosity and gas diffusivity. In terms of water dislodging air in apertures, promoting clumping and lowering the structural strength of the material, humidity and airing are related. The ideal moisture level for composting varies and are primarily influenced by physical state and particle size.[21]

Temperature

The composting of organic waste occurs between the mesophilic and thermophilic temperature profiles. In a thermophilic environment, decomposition begins and within a few days, temperature increases 65 to 70°C due to exothermic biological activity of aerobic bacteria. Throughout the process, this temperature must be maintained. The four stages of the composting process are as follows: (1) the first, mesophilic phase (10–42 ◦C), in which the temperature rises quickly and starts the decomposition of organic matter; (2) the thermophilic phase (45–70 ◦C), which is characterized by high temperatures that persist for a long time because of the extensive metabolic activities carried out by endogenous microorganisms; (3) the middle, mesophilic phase (65–50 ◦C), in which the temperature drops and allows the re-establishment of the heat-resistant microbes; and (4) the finishing phase (50–23 ◦C), in which the organic matter and biological heat production stabilize.[22] Due to the natural insulation that solid urban trash provides, heat is trapped inside the heap and released due to the respiration of microorganisms that break down organic waste. However, an excessively high temperature prevents majority of the present microorganisms from growing, which delays the breakdown of organic waste. Few species of thermophilic sporogenous bacteria have metabolic activity over 70°C temperature.[23,24]

Carbon to Nitrogen Ratio (C/N ratio)

For rapid composting, the ratio of nitrogen and carbon is maintained 50. When the C: N ratio increases suddenly, the decomposition rate decreases. If the carbon to nitrogen ratio increases, nitrogenous material like cow dung, necessary to add to maintain its proper level. When the biological process comes to a conclusion, the carbon to nitrogen ratio should drop to about 15. The ideal Carbon(C) – Nitrogen (N) ratio, should be below 30:1 at the start of the composting process and should be reduced to 20:1 at the end. When an organism is growing aerobically, between 25 and 35 units of carbon are used for every unity of nitrogen.[17]

Aeration

Aeration process occurs only when oxygen is available. Aeration will be sufficient if the heap is turned frequently. Turning windrows is essential for providing optimum aeration. Aerobic type composting needed a significant amount of oxygen at the beginning. Oxygen is provided through gas exchange while carbon dioxide, heat, and water vapour are removed.16 Because aerobic respiration produces heat at a pace suitable for self-heating, providing oxygen is important. The quantity of oxygen or carbon dioxide was thought to constitute feedback variables by some researchers. The rate of degradation should be able to be determined by measuring carbon dioxide or oxygen at a known flow rate.[25]

pH value

The pH values of the biodegradable components should also be ascertained. There should be a range of 6 to 8. Otherwise, biological activity will slow down dramatically. The pH >8 indicates that lime or bleaching powder is being used by municipal authorities at collection or storage stations Since this activity harms the biological process, it should be discouraged. To control odours and flies, it is advisable to use SANITREAT and/or HERBOCEL instead. By limiting the nutrients that the bacteria may access, pH of the compost pile can have an immediate impact on the microbial community. For majority of bacteria to grow in a compost pile, the pH range must be between 6.0 and 7.5. The pH level of compost is considered a sign of stabilisation and decomposition processes. the pH value changes during composting in a predictable way, i.e., it initially dips somewhat before rising quickly to about 8.5 due to ammonification.[26] As the compost stabilises, the pH value falls to 7.5-8.0.

Composting Period

Overall decomposition time of organic matter is affected by the number of variables, including temperature, oxygen availability, particle size, moisture content and the nature of the contaminants, e.g., the active composting duration for dairy cattle waste is typically 10-14 weeks. After this stage, there is a cure period of 3-4 weeks.

Methods of Composting

Pit Method

A reasonable length, width and depth for the pit are between 1.5 and 2.0 meters. It is necessary to fill the pit layer by layer and to spray enough water over the fill material to moisten it. As you fill the hole, you must prevent compacting. Three times throughout the composting process, the felt pit must be flipped. After 15 days, the first turn is to be completed, followed by 15, 15 and 30 days. The mixture is completely mixed and watered down, and the pit is added after each turning.[27]

Heap Method

The Indore pile is 2 m wide, 1.5 m tall, and 2 m long. The sides taper to retain a top that is about 0.5 m wider than the base. Occasionally, a little bund may be constructed around the pile to shield it from the wind, which could cause the heap to dry out. A layer of carbonaceous material, such as leaves, hay straw, sawdust, or wood chips, is usually applied to the heap first, followed by a layer of nitrogenous material, such as trash, dried or fresh manure, weeds, or residual garden plant material, which is applied in a layer of 10 cm. You can combine any material in the pile. Wind and rain are not well protected.[28] The heap method needs a lot of water. Hence, it is not suitable for locations adjacent to those with limited rainfall. Violent aerobic decomposition is applied to the material, which clearly speeds up the composting process but results in large losses of nitrogen and organic materials. The carbon to nitrogen ratio should be kept between 30 and 40 to stop these losses.

Bangalore Method

The Indian Bangalore composting method was developed at Bangalore in India. Pits of 1 m depth are excavated. The amount of available area and the kind of material to be decomposed determine the width and length of the trenches or pits. The indoor technique is followed when choosing the location for one pit. To avoid water logging, the ditches should have sloping sides and a 50 cm slope on the floor. Once the pit is filled, a layer of trash between 15 and 20 centimetres deep is put over it.[22] The pit is filled with night soil and organic waste in alternate layers. The materials are left in the pit for 90 days without being turned or watered. As the volume of the biomass reduces at this stage, the material settles. The substance decomposes anaerobically incredibly slowly. The process takes roughly 180-240 days to complete. Compost can be used for soil conditioning, house plants, vegetable gardens, flower gardens, trees, shrubs and lawn dressing.

Applications of Compost

Increasing Soil Fertility, Crop Yield, Controlling Erosion and Amending the Soil

Composting is a safe way to manage degradable organic waste. Composting is a practical substitute for burning garbage or disposing of it next to waterways or roadways. Various beneficial products are made from these composted waste. Compost can also be supplemented with synthetic fertilizer to promote plant development. An advice applying the two together in the proper ratio because research suggests synthetic fertiliser may be more beneficial than compost in promoting plant development.[29] Composts also harbour bacteria that promote plant development, improving soil fertility and plant development. As a result of erosion, the soil loses some of its fertility. Significant losses of nitrogen, phosphate and potassium are brought on by erosion. There are rumours that organic surface-applied nutrients are particularly good at stopping erosion. The soil's aggregate stability, soil structure and ability to store water are all improved by compost.[30] This is brought on by the existence of humus, a stable by-product of considerable organic matter decomposition that sticks to the soil and functions as a sort of glue to bind the different soil constituents together.[31]

Bioremediation, Disease Biocontrol and Secure Waste Management

Compost has a biological control over plant diseases. Compost bacteria use a variety of mechanism to combat their dangerous competitors. These consist of nutritional competition, parasitism, predatory behaviour, the development of antibiotics and lytics, as well as other extracellular enzymes or chemicals.[32] For instance, it has been shown that *Bacillus* sp. in compost can prevent plant wilt and damping-off diseases.

Heavy metal-contaminated soil can be treated with compost. Compost has broken down both chlorinated and non-chlorinated hydrocarbons, solvents, heavy metals, herbicides, petroleum chemicals, explosives and wood preservatives in soil. By absorbing or decomposing these elements, compost can lessen the toxicity of some chemical contaminants.[33] By precipitation, adsorption complexation and redox reactions and access to heavy metals may be restricted. Composting is a safe way to manage degradable organic waste. Composting is a practical substitute for burning garbage or disposing of it next to waterways or roadways. Various beneficial products are made from these composted wastes.

Advantages of Composting

Historically, green waste has either been burned or dumped in landfills, which is a bad practice because it releases a lot of greenhouse gases and consumes valuable farmland. The use and disposal of organic wastes through composting has drawn increased attention as a sustainable method. Composting turns organic waste into valuable products, assisting in the sustainable management of vast amounts of organic waste. Veterinary medicines and other relatively persistent organic chemicals have been found to be reduced by composting. Compost, the end-result of composting, has also been discovered to offer several advantages.[14] Recent research has shown that commercial inorganic fertilizers cannot compete with the quality of compost made from organic wastes. Composts can take the role of soil conditioners in order to encourage humus production, it is an advantage that cannot be created artificially. The humic-like portion of composts enhances plant health and growth while also acting as a biocontrol agent against certain fungi and other soil-borne phytopathogens. Pathogenic organisms in garbage have been eliminated as a result of temperature build up during composting.

Composting's Microbiota

The biochemical process of composting is carried out by several swarms of different worms and microbes. It is an aerobic thermophilic process known as solid-state anaerobic fermentation, organisms like *Clostridium* have been connected to the process even though the hydrolysis of organic matter into humus during composting is regarded as oxygen-demanding process.[34] Different microbial groups' physiological activity can be connected to the nutritional potential of compost and how it affects agricultural output. Plant diseases caused by soil-borne pathogens can be biologically controlled by compost's microbial communities, much as how mammals' natural microbiota fights off infections. Plant diseases are prevented from developing by these microbial consortia in compost because they produce heat, outcompete pathogens, and change the survival of soil-borne pathogens. They can also produce a variety of antimicrobial compounds. Several commercial inoculant formulations, such Microbial Activator Super LDD 1 and Effective Microorganism (EM), are available for the agronomic enhancement of the final product because of the critical roles that microorganisms play in the composting process. According to several authors, composting occurs in three distinct stages. Mesophiles are the most prevalent organisms at the start of the composting process. The compost's easily degradable soluble components are broken down during this stage of moderate temperature fermentation. These species' metabolic processes produce heat, which causes a rapid increase in temperature. With the mesophiles being replaced by thermophilic microbes as a result of the temperature increase, the process of composting moves into its high-temperature phase. when the thermophiles may break down polysaccharides, proteins and lipids.[35] The mortality of soil-borne diseases and weed seeds is another key consequence of this higher temperature. Despite that compost is typically regarded as an environment friendly technology, it can introduce extremely harmful organisms into the soil. Infections with the cytotoxin-producing serotype *Escherichia coli* O157:H7 can spread through contaminated compost or irrigation water, which can result in outbreaks. However, the growth of various test pathogens was found to be effectively suppressed by the native microflora of a completed compost material.

Major Elements in Compost

Before the compost may be deemed beneficial, it must include specific ingredients in proper ratio to supply plants with adequate nutrients. Even if these components might not be necessary if the compost is destined for landfills.

Nitrogen

One of the most crucial elements is nitrogen in plant growth. When there is a shortage of nitrogen, plant growth and development are inhibited. Nitrogen, a major component of chlorophyll, is what gives plants their characteristic green colour. Compost, according to research, provides the perfect amount of nitrogen for plant growth. High nitrogen concentration is not commonly found in compost fertilizer because nutrients are gradually released through mineralization. Rapid growth, beautiful green colour and a compromised root system are all signs that the plants have too much nitrogen due to over application of fertilizer.[36] In extreme cases, an excess of nitrogen can cause the plant to eventually perish by causing the tissue in its leaves to burn. In the absence of nitrogen, plants turn yellow, develop more slowly, produce less protein and lose their green hue.

Phosphorus

Phosphorus is a component in the intricate nucleic acid structure of plants, which controls the creation of proteins. Thus, phosphorus plays a crucial role in the complicated energy transformations in plants as well as the division of cells that results in the production of new tissue.[36] Root growth, winter hardiness, tilling and plant maturity are all hastened when phosphorus is supplied to soil low in phosphorus. Lack of phosphorus can result in stunted growth, subpar seed and fruit production, delayed maturity and mature leaves that do not turn the characteristic dark blue to blue-green of plants. The ideal phosphorus concentration required for plant growth has reportedly been found in compost. Potassium: Potassium is needed by the plant for the formation of sugar. Furthermore, it is essential for the plant's resistance to disease and ability to withstand challenging environmental circumstances like cold and drought. A lack of potassium in plants can result in the browning and blistering of older leaves' tips, which gradually extends to the entire leaf. Weak stalks could also be caused by a shortage of potassium. Composts are effective sources of the essential phosphorus for plant growth.[36] Potassium is a necessary element for healthy development of the plants. It promotes chlorophyll, carotene, plant growth and vigour.[37]

Compost Quality

The amount of moisture, nutrients, heavy metals, pathogens, stability, and product consistency over time, particle size distribution, self-heating test, humification ratio and enzymatic activity are used to calculate the value of compost.

Compost Marketing

A marketing or distribution strategy for compost is essential for a composting operation to be successful. The items must be of consistently excellent quality in order to create long-term markets. Planning, understanding of end consumers, adhering to fundamental marketing concepts, overcoming potential regulatory obstacles and overcoming product stigma are further crucial marketing considerations. The qualities of compost that end users want vary depending on the intended uses, however, the majority of compost users prioritise the qualities such as the superior (moisture, odour, size of particle, strength, nutrient application, product regularity and phototoxic compounds including the contaminants), value (shows more *via*bility then another compost while superior quality and good performance can justify a higher price), appearance (constant consistency, comparatively dehydrated and poor in colour), information (nutrients and pH analysis and application rates and procedures) and steadfast source. Despite their benefits, farmers are still not adopting organo-mineral fertilizers in an acceptable manner, which may be caused by their accessibility issues and a sluggish market.[38]

Potential for Future Development

Composting has historically required a lot of labour but technological developments have speed up the method. They claimed that using chemicals, like polyethylene glycol and jaggery, speeds up the process of composting and yields compost of superior grade. Nonetheless, based on their reports, the additives that are now in use are not efficient in terms of cost. However, they did assert that the upgrades were not economical. Therefore, more research should concentrate on locating cost-effective enhancements. To improve the effectiveness of composting process, it is recommended to employ low-cost pre-treatment procedures, resistant substrates and a microbial inoculum, some genetically modified strains are used to accelerate the bioconversion of organic materials. The government should build programs and initiatives that are in charge of lending money and giving subsidies for composting facilities in order to promote composting as a waste substitute.[4] This will make composting sustainable and lead to the creation of jobs for the local community. In contrast to conventional soil additions and fertilizers, this will foster a positive market and promote the use of composts.

The capacity of microorganisms to transform contaminants, both organic and inorganic, into odourless, non-toxic chemicals is the foundation of biological air remediation. Still, research on novel media and reactor structures, simulations of the removal of gas component and analysis of microbial structure are still being conducted. Bioreactors are popular techniques for biological air purification. The bioreactors used in agricultural applications, where pollutant concentrations are low, must be simple, manageable, and have lower investment and running expenses than those used in the industrial sector. Toxic VOC emissions from industrial sources can be reduced using bioreactors. Dynamic olfactometry is the most used technique for figuring out scent concentration, quality, and intensity.[39] According to a study on odour assessment methods, dilution olfactometry is the most often used methodology worldwide. However, it has been asserted that the process takes a long time, is expensive, labour-intensive, prone to human error and causes delay between sample and measurement. Furthermore, this technique does not identify the molecules creating the aroma. Consequently, a variety of smell treatment and control techniques have been developed and are now widely accessible. Some of these technologies, like carbon adsorption and chemical scrubbers, have reportedly been in use for a long time, while others like bio filters, have only lately become widely used in composting facilities. Dielectric barrier discharge (DBD) reactors masking chemicals and electronic noses are further approaches that have been suggested.

Conclusion

Composting is the process of decomposition of organic waste because it enables the production of useful products from materials that would otherwise be discarded in the environment. Composting reduces the requirement for landfill area, surface and groundwater contamination, production of methane and air pollution. Additionally, it provides more flexible total waste management, enhances material recycling and is comparatively low-cost to implement and operate. Composts can take the role of soil conditioners in order to encourage humus production, which is a benefit that cannot be artificially produced.

Acknowledgement

In this study, authors are thankful to Dr. Anil Kumar Sharma, Professor and Head Department of Bio-Sciences and Technology, Maharishi Markandeshwar (Deemed to be University), Mullana–Ambala, Haryana, India to provide the necessary facilities, in this investigation and Dr. R.K. Behl, Department of Agriculture, Maharishi Markandeshwar (Deemed to be University), Mullana–Ambala, Haryana, India, for their valuable suggestions and edited the manuscript.

Funding

No sources of funding.

Conflict of Interests

The authors declare no conflict of interest.

References

1. Abdel-Shafy H. I, Mansour M. S. Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum* 2018; 27 1275-1290.
2. Waqas M, Hashim S, Humphries U. W, Ahmad S, Noor R, Shoaib M, Lin H. A. Composting Processes for Agricultural Waste Management: A Comprehensive Review. *Processes* 2023; 11 731.
3. Singh V. K, Solanki P, Ghosh A, Pal A. Solid waste management and policies toward sustainable agriculture. In *Handbook of solid waste management: sustainability through circular economy* 2022; 523-544.
4. Adusei-Gyamfi J, Boateng K. S, Sulemana A, Hogarh J. N. Post COVID-19 recovery: Challenges and opportunities for solid waste management in *Africa Environ Chall* 2022 ;9 1-14.
5. Majewska A, Denis M, Jarecka-Bidzińska E, Jaroszewicz J, Krupowicz W. Pandemic resilient cities: possibilities of repairing polish towns and cities during COVID-19 pandemic. *Land Use Policy* 2022; 113 105904.
6. Rimpi, Kumar M, Sharma A, Kumar R, Singh R. An Overview on Paddy Crop Residue Decomposition: A Biochemical Analysis of the Process. *Bulletin of Pure and Applied Sciences-Botany,* 2023; 42B(1):27-35.
7. Singh R, Upadhyay S.K, Upadhyay T.K, Singh B.J, Rani A. Singh C. Association analyses among fungi colonizing wheat crop residues during decomposition for sustainable and environment-friendly management of renewable natural resources. *Biointerface Res. Appl. Chem.* 2021; 11(5), 13754–13764. https://doi.org/10.33263/BRIAC115.1375413764
8. Taneja T, Kumar M, Sharma I, Sharma A, Singh R. The Role of Mycobiota in the Process of Composting of Biomass and Assessment. *Bulletin of Pure and Applied Sciences-Botany,* 2023; 42B (1):19-26.
9. Singh R, Singh B.J, Mukherjee T.K, Kumar V, Upadhyay S.K. Biochemical Changes during Solid State Fermentation of Wheat Crop Residues by *Aspergillus flavus* (Link) and *Aspergillus niger* (van Tieghem). *Biointerface*

Res. Appl. Chem. 2023; 13(3):1-14.

10. Hashim A. A, Kadir A. A, Ibrahim M. H, Halim S, Sarani N. A, Hassan M. I. H, Hamid N. J. A, Hashar N. N. H, Hissham N. F. N. Overview on food waste management and composting practice in Malaysia. In: *AIP Conf Proc* 2021; 2339 020181.
11. Sayara T, Basheer-Salimia R, Hawamde F, Sánchez A. Recycling of organic wastes through composting: Process performance and compost application in agriculture. *Agronomy* 2020; 10 1838.
12. Sulewski P, Kais K, Gołaś M, Rawa G, Urbańska K, Wąs A. Home bio-waste composting for the circular economy. *Energies* 2021; 14 6164.
13. Singh R, Upadhyay S.K, Rani A, Kumar P, Kumar A, Singh C. Lignin biodegradation in nature and significance. *Vegetos,* 2018; 31(4):39-44.
14. Palaniveloo K, Amran M. A, Norhashim N. A, Mohamad-Fauzi N, Peng-Hui F, Hui-Wen L, Razak S. A. Food waste composting and microbial community structure profiling. *Processes* 2020; 8 723.
15. Vyas P, Sharma S, Gupta J. Vermicomposting with microbial amendment: implications for bioremediation of industrial and agricultural waste. *BioTechnologia* 2022; 103 203.
16. Mehta C. M, Sirari K. Comparative study of aerobic and anaerobic composting for better understanding of organic waste management: A mini review. *Plant Arch* 2018; 18 44-48.
17. Tang R, Liu Y, Ma R, Zhang L, Li Y, Li G, Yuan J. Effect of moisture content, aeration rate, and C/N on maturity and gaseous emissions during kitchen waste rapid composting. *J Environ Manage* 2023; 326 116662.
18. Liu Y, Zhang Y, Wang M, Wang L, Zheng W, Zeng Q, Wang K. Comparison of the basic processes of aerobic, anaerobic, and aerobic-anaerobic coupling composting of Chinese medicinal herbal residues. *Bioresour Technol* 2023; 379 128996.
19. Goswami S. B, Mondal R, Mandi S. K. Crop residue management options in rice–rice system: a review. *Arch Agron Soil Sci* 2020; 66 1218-1234.
20. Ghosh S and Rai S.K. *Boerhaavia diffusa*: One plant with many functions. *Int. J. Green Pharm* 2018; 12 442-448.
21. Sharma S, Hussain M. S, Agarwal N. B, Bhurani D, Khan M. A, Ahmad Ansari M. A. Efficacy of sirolimus for treatment of autoimmune lymphoproliferative syndrome: a systematic review of open label clinical studies. *Expert Opinion on Orphan Drugs* 2021; 9(7-10)219-226.
22. Papale M, Romano I, Finore I, Lo Giudice A, Piccolo A, Cangemi S, Di Meo V, Nicolaus B, Poli A. Prokaryotic diversity of the composting thermophilic phase: the case of ground coffee compost. *Microorganisms.* 2021; 9(2):218.
23. Iyer M, Tiwari S, Renu K, Pasha M. Y, Pandit S, Singh, B, Vellingiri B. Environmental survival of SARS-CoV-2–a solid waste perspective. *Environ Res* 2021; 197:111015.
24. Prakash P, Radha, Kumar, M, Pundir, A, Puri, S, Prakash S. Documentation of commonly used ethnoveterinary medicines from wild plants of high mountains in shimla district, himachal pradesh, india. *Horticulturae* 2021; 7 351
25. Oshins C, Michel F, Louis P, Richard T. L, Rynk R. The composting process. In *The Composting Handbook* 2022; 51-101.
26. Ge M, Shen Y, Ding J, Meng H, Zhou H, Zhou J, Liu J. New insight into the impact of moisture content and pH on dissolved organic matter and microbial dynamics during cattle manure composting. *Bioresour Technol* 2022; 344 126236
27. Sumiyati S, Lantip D. S, Huboyo H. S, Ramadan B. S, Hadiwidodo M, Samadikun, B. P, Yumaroh S. Pit Composting Methods for Community Based Waste Treatment (A Case Study in Ngadimulyo Village). *J Phys Conf Ser* 2020; 2-8.
28. Paul N, Giri U, Roy G. Composting. *In Organic Fertilizers-History, Production and Applications* 2019. IntechOpen
29. Pampuro N, Bertora C, Sacco D, Dinuccio E, Grignani C, Balsari P, Cavallo E, Bernal M. P. Fertilizer value and greenhouse gas emissions from solid fraction pig slurry compost pellets. *J Agric Sci* 2017; 155 1646–1658.
30. Gonawala S. S, Jardosh H. Organic Waste in Composting: A brief review. *Int. J curr eng Technol* 2018; 8 36-38.
31. Epelde L, Jauregi L, Urra J, Ibarretxe L, Romo J, Goikoetxea I, Garbisu C. Characterization

of composted organic amendments for agricultural use. *Front sustain food syst* 2018; 2 1-12.

32. Olanrewaju O. S, Glick B. R, Babalola O. O. Mechanisms of action of plant growth promoting bacteria. *World J Microbiol Biotechnol* 2017; 33 197.
33. Huang J, Yu Z, Gao H, Yan X, Chang J, Wang C, Zhang L. Chemical structures and characteristics of animal manures and composts during composting and assessment of maturity indices. *PloS one* 2017; 12:e0178110.
34. Nemet F, Perić K, Lončarić Z. Microbiological activities in the composting process–A review. *COLUMELLA– J Agric Environ Sci* 2021; 8 41-53.
35. Galitskaya P, Biktasheva L, Saveliev A, Grigoryeva T, Boulygina E, Selivanovskaya S. Fungal and bacterial successions in the process of co-composting of organic wastes as revealed by 454 pyrosequencing. *PloS one* 2017; 12:e0186051.
36. Han Y, White P. J, Cheng L. Mechanisms for improving phosphorus utilization efficiency in plants. *Annals of botany* 2022; 129 247-258.
37. Razaq M, Zhang P, Shen, H. L. Influence of nitrogen and phosphorous on the growth and root morphology of Acer mono. PLoS ONE 2017; 12 e0171321.
38. Bouhia Y, Hafidi M, Ouhdouch Y, Boukhari M. E. M. E, Mphatso C, Zeroual Y, Lyamlouli K. Conversion of waste into organo-mineral fertilizers: current technological trends and prospects. *Rev Environ Sci Biotechnol* 2022; 21 425-446.
39. Bala S, Garg D, Thirumalesh B.V, Sharma M, Sridhar K, Inbaraj B. S, Tripathi M. Recent strategies for bioremediation of emerging pollutants: a review for a green and sustainable environment. Toxics 2022; 10 484.