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Review Article

COMPOSTING: AN ECO-FRIENDLY SOLUTION FOR ORGANIC WASTE MANAGEMENT TO MITIGATE THE EFFECTS OF CLIMATE CHANGE

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ABSTRACT

Composting is the process of converting organic waste into a nutrient-rich soil amendment. It is an eco-friendly and sustainable way to manage organic waste and it can have a number of benefits for the environment. Composting can help to reduce greenhouse gas emissions, improve soil quality, and conserve water. It can also help to reduce the amount of waste that goes to landfills, which can help to protect human health and the environment. The inputs of waste for composting can include food scraps, yard waste, and other organic materials. These materials are broken down by microorganisms in a process called decomposition. There are a lot of decomposition technologies as not limited to, aerobic decomposition which requires oxygen, so it is important to turn the compost pile regularly to ensure that there is enough oxygen present. The processes used in composting can vary depending on the scale of the operation. However, all composting methods involve the following steps: Collection of organic waste, followed by preparation of the waste (e.g., shredding and chopping), then mixing of the waste with other materials (e.g., soil, sand, and micro-organisms), turning of the compost pile, then, monitoring of the compost pile (e.g., moisture content, and temperature), and finally, harvest of the compost. The outputs of composting are a nutrient-rich soil amendment called compost. Compost can be used to improve soil quality, increase crop yields, and reduce the need for chemical fertilizers. Compost can also be used to create a more sustainable landscape by reducing the need for imported topsoil. This review will discuss the benefits of composting and how it can be used to mitigate the effects of climate change. It will also provide information on how to start composting and the different types of composting systems and factors affecting the compositing process that are available.

Keywords: Composting, Organic waste, Greenhouse gas emissions, Human health, Natural conservation.

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INTRODUCTION

Composting is the process of converting organic materials into a nutrient-rich soil amendment called compost. Composting can be done at home or on a commercial scale, and it is a great way to reduce waste, improve soil quality, and help mitigate the effects of climate change (Chen *et al*., 2011). The inputs for composting can vary depending on the type of composting system being used. However, most composting systems require a source of carbon and a source of nitrogen. Carbon-rich materials include leaves, grass clippings, and straw. Nitrogen-rich materials include manure, food scraps, and coffee grounds (Amlinger *et al*., 2008). Composting, which is the biological process at which hygienic transformation of organic wastes in a homogeneous and plant available material is an exothermic bio-oxidation, in which a diverse community of bacteria, archaea, and fungus biodegrade the organic substrate (De Bertoldi, *et al*., 1983). The garbage that breaks down most quickly is organic waste. The organic waste includes, not limited to the following: agricultural waste, market waste, and kitchen trash. This garbage could cause that several environmental issues especially increase the green houses gases that lead to climate change effect, if not managed properly (Lou and Nair, 2009). Composting is therefore the ideal low-cost choice to find a solution to this issue. All kinds of organic waste, including leftover fruits, vegetables, plants, and yard debris, can be broken down using the composting technique. The organic waste component can be utilized as plant nutrients, crop fertilizers, and for environmental control. However, as different forms of organic waste have varying percentages of nutrients, such as nitrogen, phosphorus, and potassium (N, P, and K), which are the common macro energetics found in fertilizers, numerous factors can affect the quality of compost products. There are a lot of factors affecting the compositing process and/or products as temperature, pH, moisture content, and the carbon nitrogen ratio (C: N) are the primary variables that influence how effectively compost is produced (Gonawala and Jardosh, 2018; Nozhevnikova *et al*., 2019).

There are two main types of composting: aerobic composting and anaerobic composting. Aerobic composting is the most common type of composting, and it requires oxygen. Anaerobic composting does not require oxygen, and it is often used to compost food scraps (Nakasaki *et al*., 2009). There are many benefits actors from composting process including: Reduces waste: Composting diverts organic waste from landfills, where it would release methane, a greenhouse gas that is 25 times more potent than carbon dioxide. Improves soil quality: Compost adds nutrients and organic matter to the soil, which can improve crop yields and reduce the need for chemical fertilizers. In addition, it can reduce the need for water: compost helps to retain moisture in the soil, which can reduce the need for irrigation. Besides, compost can help to suppress weeds by creating a thick layer of mulch that blocks sunlight. In addition, compost attracts beneficial insects, such as earthworms and ladybugs, which can help to improve soil health (Epstein, 2017).

Composting has the potential to mitigate climate change in several ways: Reduction of methane emissions, methane is a greenhouse gas that is 25 times more potent than carbon dioxide. Composting can reduce methane emissions by diverting organic waste from landfills, where it would decompose anaerobically and release methane. In addition, that, the composting helps to sequester carbon in the soil, which can help to reduce the amount of carbon dioxide in the atmosphere. Furthermore, compost can improve crop yields, which can reduce the need for land clearing, which can release carbon dioxide into the atmosphere (Rogger *et al*., 2011).

Hence, the composting is considered as an eco-friendly solution for organic waste management that can have a number of benefits, including reducing waste, improving soil quality, reducing the need for water, suppressing weeds, attracting beneficial insects, and mitigating climate change. The aim of this review is to discuss the benefits of composting and to provide an overview of the different composting methods available. The review will also discuss the potential of composting to mitigate the effects of climate change.

COMPOSTING TECHNOLOGIES

Decomposition

The process of decomposition is primarily aerobic. As a result, the type and degree of aeration are crucial. In order for organic waste to decompose, it must be exposed to oxygen (air), and CO_2, NH_3, water, and heat may result from this process. Any sort of organic waste can be treated with it as well; however, good composting requires the correct elements and circumstances. Composting material usually consists of moisture content between 60-70% and carbon to nitrogen ratio (C/N) of 30 to 1. Any major change prevents the process of deterioration. In general, wood and paper are significant sources of carbon, whereas food waste and sewage sludge are sources of nitrogen, ensuring a constant supply of oxygen. Forced or passive ventilation of waste is necessary (Gonawala and Jardosh, 2018). Aerobic micro-organisms further breakdown the intermediate molecules that aerobic composting may produce, such as organic acids. The resulting compost has a low risk of phytotoxicity due to the comparatively unstable organic materials that it contains. Proteins, lipids, and complex polysaccharides such as cellulose and hemicellulose are rapidly broken down by the heat produced. Consequently, the processing time is reduced. Furthermore, if the temperature is high enough, this process kills a lot of microorganisms that are plant or human pathogens, as well as weed seeds. Aerobic composting is thought to be more effective and helpful than anaerobic composting for agricultural productivity, despite the fact that more nutrients are lost from the materials (Misra, 2003).

The composted mass, however, forms microaerophilic and anaerobic micro-niches inside very minute particles, where anaerobic microbes thrive due to the insufficient oxygen supply. The original material's composition, the pretreatment method, the humidity level, and the composting process's aeration regime all play a significant role in determining the proportion of anaerobes in the overall number of microorganisms involved (Nozhevnikova *et al*., 2019). Anaerobic composting is the breakdown of organic wastes without the presence of oxygen, producing gases such as methane (CH_4), carbon dioxide (CO_2), nitrates (NH_3), and traces of other gases and organic acids. Animal manure and sewage sludge were traditionally composted using anaerobic composting, but recently certain municipal solid waste (MSW) and green waste have been more frequently processed in this manner (Misra, 2003; Gonawala and Jardosh, 2018).

The rate of synthesis and effectiveness of the exoenzymes produced by anaerobes may be even higher than those produced by aerobic bacteria, despite the fact that anaerobes only make up 1–10% of all microorganisms. Experimental evidence supports the presence of *Clostridium* species performing purely anaerobic fermentation of organic compounds in compost. For the same quantity of organic matter, anaerobes produce 10 times less heat than aerobes. Under anaerobic conditions, organic matter degrades in four stages: hydrolytic, enzymatic, acetogenic, and methanogenic. Hydrolytic degradation breaks down complex biopolymeric molecules into simpler oligosaccharides and monomers. Enzymatic degradation breaks down monomers into volatile fatty acids (VFAs), alcohols, carbon dioxide, and hydrogen. An extremely low oxidation-reduction potential (ORP) of −200–300 mV or lower is needed for the methanogenic step, which also calls for strictly anaerobic conditions. However, because methane is a flammable gas and its ignition could result in a fire, methane generation during composting is particularly undesirable. The anaerobic breakdown of organic materials ends at the stage of the synthesis of VFAs (which lower the pH of the medium), CO_2, and H_2 if the compost mass is periodically loosened or purged with air rather than reaching such a low ORP. The preservation of ammonium nitrogen and the lowering of the pH of the composted material may both benefit from the establishment of more suitable conditions for the life activity of anaerobic microorganisms; as a result, one of the best strategies to lower the cost of compost aeration and raise the overall energy efficiency of the composting process may be to enhance the contribution of anaerobic processes, which do not require an oxygen supply.

The best compost aeration mode must be chosen, and it must be strictly handled. In addition, one of the most efficient ways to preserve nitrogen in the finished compost without significantly slowing down the composting rate and, as a result, to raise the agronomic value of biofertilizers made from waste and the overall energy efficiency of the composting process, is to create a balance between active aerobic and anaerobic microorganisms in the compost mass through the use of various microbiological and technical procedures. Since anaerobic micro-zones populated by anaerobic bacteria emerge even under active aeration, composting is an aerobic-anaerobic process whether forced or natural aeration is used. Aerobic bacteria may use the latter's byproducts of living activity as substrates, and *vice versa*. There is not enough research on these processes. The stability of composting under shifting environmental circumstances is ensured by the aerobic and anaerobic bacteria present in the compost. Anaerobic fermentation and active oxidation alternate with anaerobic decomposition of organic materials, which may allow for enhanced composting and better ultimate product quality (Nozhevnikova *et al*., 2019).

The preparation of the mixture, the bio-oxidative phase, and the maturation phase are the three primary phases on which all composting systems are based. The fundamental difference between composting technologies is how the bio-oxidative phase is operated, and as a result, each one involves distinct technical and administrative decisions.

Passive composting in a windrow or pile

It includes forming the raw material mixture into a windrow or pile that is then frequently stirred to restore the porosity. Through the passive circulation of air through the pile, aeration is achieved. As a result, the pile or windrow must be small enough to permit passive air circulation. It is fairly inexpensive and suggested for small farms without significant space issues (Pergola *et al*., 2017). In windrow composting, the mixture of raw materials is arranged in long, narrow piles, or windrows, that are periodically mechanically moved to aerate the piles. Consistent oxygenation is not always achieved when turning alone. Within an hour of turning, oxygen levels in a pile frequently drop significantly, which, in turn, lowers microbial activity. This necessitates regular pile turns, which causes technical and financial issues. In addition, pile size is a crucial factor because it becomes challenging to aerate piles that are higher than 3 m (Domínguez *et al*., 1997).

Aerated static pile

This method uses blowers to blow air into the pile using positive pressure to supply oxygen and cooling; it is helpful primarily for the speed at which composting takes place and for the small amount of area required. Blowers can be operated intermittently or continuously. For this method of composting, a base layer of porous material (such as wood chips or straw) is needed to disperse air uniformly as it enters or exits the aeration pipes, and a top layer (such as finished compost or sawdust) is needed to absorb odors, keep flies away, and hold onto moisture, ammonia, and heat (Pergola *et al*., 2017). The pile's lower layers tend to cool and dry with this procedure while remaining warm and wet on top. Bottom blowing and bottom suction aeration are alternated in alternative ventilation systems. The alternate air flow causes the warmth and moisture to be uniformly distributed throughout the pile (Domínguez *et al*., 1997).

Depending on the porosity of the pile-building material, the weather, and the equipment's length, the piles' initial height should be between 150 and 245 cm. In the winter, having more height is useful since it keeps the heat inside. The pile may need to be topped off with 15 cm of finished compost or a bulking agent. The final compost layer prevents the pile's surface from drying out, insulates it from heat loss, deters flies, and filters ammonia and any potential odors that may be produced inside the pile. Aerated static piles often have two different shapes: individual piles and extended piles. Individual piles are long triangular piles with a width that is roughly twice as large as their height (approximately 300–490 cm, not including the cover). Under the pile's ridge, the aeration pipe runs lengthwise. A single large batch of material or several batches with roughly the same recipe and age are stored in each pile (e.g., within three days). Where raw materials are available for composting intermittently rather than continually, individual piles are practical. The choice and initial mixing of raw materials are essential to preventing poor air distribution and uneven composting because the pile does not receive additional turnings. In addition, the pile needs a sound foundation to function properly.

For static pile composting, there are two options to supply the air: a suction system that draws air through the pile, or a pressure system that forces air into the pile through a blower. Air is drawn into the pile by suction from the pile's outside surface, where it is collected in the aeration pipe. If odors develop during the composting process, the exhaust air may be easily filtered because it is contained in the discharge pipe. The exhaust air leaves the compost pile over the entire pile surface when positive pressure aeration is used. As a result, gathering air for odor control is challenging. A thicker outer layer of compost might be used in areas where improved odor control is desired. In large part due to the absence of an odor filter, pressure aeration produces more airflow than suction aeration. Greater airflow is produced at the same blower power due to the lower pressure loss. As a result, pressure systems are favored when temperature control is the primary goal since they can be more successful at cooling the pile (Fig. 1).

In-vessel composting

Composting techniques referred to as "in-vessel" limit the composting materials inside a structure, container, or vessel. The composting process is sped up using a variety of forced aeration and mechanical turning techniques in in-vessel procedures. Many approaches combine strategies from the wind-row and aerated pile approaches in an effort to address the shortcomings and maximize the benefits of each approach. There are numerous in-vessel techniques using various arrangements of vessels, aeration equipment, and turning motors. The techniques covered here have either been put to use or have been suggested for farm composting.

Vermicomposting

Vermicomposting is the practice of composting organic waste using earthworms. Earthworms can eat nearly any type of organic material, and they can devour as much food as their body weight each day, for example, 1 kg of worms can eat 1 kg of leftovers each day. The worms' excreta (castings) are abundant in nitrate as well as usable forms of P, K, Ca, and Mg. Earthworms move dirt, which encourages the growth of bacteria and actinomycetes. Worm presence makes actinomycetes thrive, and their concentration in worm casts is more than six times that of the original soil (Misra, 2003).

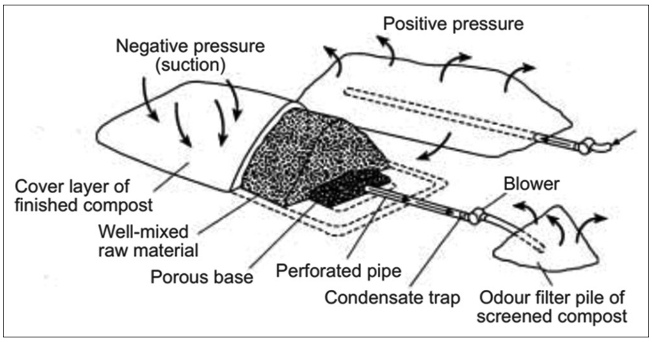

Fig. 1: Aerated static pile (Misra, 2003)

It is a promising method that has demonstrated its potential in a number of difficult fields, including the expansion of food production, trash recycling, and solid waste management, among others. By not treating organic waste, it helps to reduce environmental pollution and resource consumption. Vermicompost strengthens the soil's ability to retain water while also improving the texture of the soil. It may have a low NPK content, but it also includes vital nutrients that are absent from inorganic fertilizers, such as calcium, magnesium, manganese, copper, iron, and zinc. In addition, it has microbes that support plant health and resilience to pests and diseases. Given the numerous resources available in farms, vermicomposting can aid in preserving soil and promote environmental protection.

Mealworm composting

One of the major problems farmers face is managing crop residue, which includes rice straw (RS), rice husk (RH), and corn straw (CS). This is mainly because there is no established value chain for trash collection. The majority of these crop wastes are burned or discarded improperly, which disturbs the ecosystem and causes pollution. This results in the squandering of agricultural resources in addition to contributing to ecological devastation.

Yellow mealworms, or mealworms as they are referred to here, are the larvae of the beetle *Tenebrio molitor*. They are a member of the family *Tenebrionidae*, a family of beetles that are known as the "darkling beetle" in common name. The cultivation of mealworms has gained popularity in China, the USA, and Europe. Mealworms have recently been discovered to have strong digestive systems. It has been discovered through recent research on agricultural residues and wastes that mealworms have the capacity to live on and biodegrade raw lignin, including LCWs such as wheat straw (WS) and rice straw (RS), up to 41-49%. Results have demonstrated the viability of using LCWs as supplemental feedstocks to produce mealworm biomass using a high-value-added product method. However, mealworms consume amounts of waste that is around 2–3 times more than the biomass they generate. Mealworm farming operations are required to handle or treat millions of tons of frass waste, and only a small portion of the excrement is now used properly; the remainder could be hazardous to the environment, but through the use of this waste as a readily available organic fertilizer, proper use of frass might significantly improve rural incomes.

Comparing composting technology to alternative treatment methods for various biowaste products from the municipal and industrial sectors, it is quite effective. Due to its superiority over landfills and its capacity to manage odorous emissions, contribute to the mitigation of greenhouse gas emissions, reduce waste volume, and recycle nutrients as fertilizer, it has drawn increased attention. However, due to its slow decomposition rate, the lignocellulosic component of raw LCWs is difficult to compost. The greatest challenges to LCW biodegradation are caused by the resistant structural characteristics of lignocellulose; usually, lignin sheaths cellulose. The aerobic decomposition of LCWs is prevented or slowed down by the presence of cellulose and hemicellulose, among other factors. Mealworms' improved digestion makes it possible to skip LCW pretreatment before composting due to the partial lignocellulose decomposition in mealworm frass. In addition, the frass contains lignocellulose-decomposing bacteria from the mealworm stomach, which may help speeding up the composting process without the use of additional microbial agents (He *et al*., 2021).

FACTORS THAT AFFECT COMPOSTING PROCESS

Temperature

In general, one of the factors that ensure that the composting process may proceed more effectively is the temperature. These characteristics appear to have an impact on the composition and density of microbes in the compost mass in addition to the metabolic activity of microorganisms. For optimum activity, micro-organisms require a specific temperature range. At certain temperatures, bacteria and weed seeds are eliminated while composting proceeds quickly. The pile's center can reach a temperature of at least 140°F (60°C) due to microbial activity (Fig. 2). Anaerobic conditions – or rotting – occur if the temperature does not rise (Wang *et al.*, 2022). Various phases of composing may have temperature dynamics and microbial composition. The temperature regime, which is created by self-heating brought on by microbial activity, is a sign of how much benefit the composting process is. According to traditional view, the process can be divided into four temperature steps: mesophilic (40°C), thermophilic (60°C), cooling (40°C), and maturation (until a difference of not more than 10°C between the average mass temperature and the ambient temperature occurs). The microbial processes are thought to be accelerated by 2–3 times for every 10°C of temperature increase in the region of 10°C–50°C (Nozhevnikova *et al.*, 2019).

The "active" phase of decomposition: As the microbial population multiplies and starts to break down the material that breaks down the quickest, heat from the microbial activity builds up inside the pile, and the temperature rises steadily, moving from the mesophilic range (25–45°C) to the thermophilic range (more than 45°C). Because they eliminate more pathogens, weed seeds, and fly larvae in the composting materials, thermophilic temperatures (55 C and above) are preferred. Compost managers employ aeration and mixing to keep the temperature below 65°C because this temperature kills many types of bacteria and slows the process of decomposition. In the cooling stage, the temperature of the compost progressively drops as the supply of high-energy molecules runs out, and mesophilic bacteria begin to grow. The pile is once again dominated by mesophilic microbes, maturation "curing" phase: Even though it is occurring at a lower temperature than the preceding phases, there are still a lot of naturally occurring reactions taking place during this phase. Material humification is one of the characteristics of this step, and it offers the compost that is created a fascinating value. It is important to note that there are various composting techniques that can be used, and the choice of technique depends on factors such as capital cost, labor cost, time, and land availability. These techniques include static aerated pile composting, turned composting, passive composting, and all varieties of in-vessel composting, all these methods will be discussed later (Sayara *et al.*, 2020).

It was demonstrated that the composting temperature increases to 70°C and above as a result of the active degradation of the organic matter of swine manure mixed with sawdust during the thermophilic stage. There have been reports of sewage sludge and animal waste, including animal bones, degrading quickly under high-temperature composting (up to 110°C). The hypothesis that these isolates belong to a new genus of the family *Bacillaceae*, order *Bacillales*, class *Bacilli*, and phylum *Firmicutes* was supported by the discovery of two novel thermophilic bacteria, designated YMO81(T), and phylogenetic analysis. Because these temperatures are higher than the ideal temperatures for the compost's inhabitants, which are moderately thermophilic microorganisms, protozoa, and invertebrates, it should be noted that the intense self-heating of compost to 65-85°C is typically accompanied by a decrease in the rate of organic substrate biodegradation. Many different microorganisms, principally members of the four bacterial phyla *Firmicutes, Proteobacteria, Bacteroidetes, and Actinobacteria*, participate in the composting process under varying temperature conditions. These make up 85% of all the microorganisms that have been found and categorized in the compost samples analyzed. Mesophilic bacteria and fungi carry out the first stage of mesophilic composting; as the compost temperature rises, thermophiles take their place. The early phases of composting are when members of the huge family *Enterobacterales* (Proteobacteria) become active. These facultative anaerobes live in soil, the gastrointestinal tracts of humans and animals, and the environment. Moderately thermophilic *Lactobacillales (Firmicutes*) bacteria are active at the start of the heating stage of the compost as well as after repeated loosening of the compost material at the beginning of the cooling cycle. Various *bacilli* of the genus *Bacillus (Firmicutes*) may make up more than 80% of all bacteria at the thermophilic stage of composting (45–60°C). The three species of *Bacillus* that are most frequently found are *B. subtilis, B. licheniformis, and B. circulans*. Thermus species are involved in the breakdown of different macromolecules and can grow between 65 and 82°C. Bacteria from the genera *Thermobifida* and *Bacillus* and tiny fungi from the genera *Thermomyces* and *Aspergillus* are the most prevalent members of the stabilized compost layers. *Actinomycetes (Actinomycetales*) and bacteria from the genera of the families *Enterobacteriales* and *Pseudomonadales*, which promote more thorough decomposition of leftover organic material, become active at the third stage (cooling) and at the compost maturation stage.

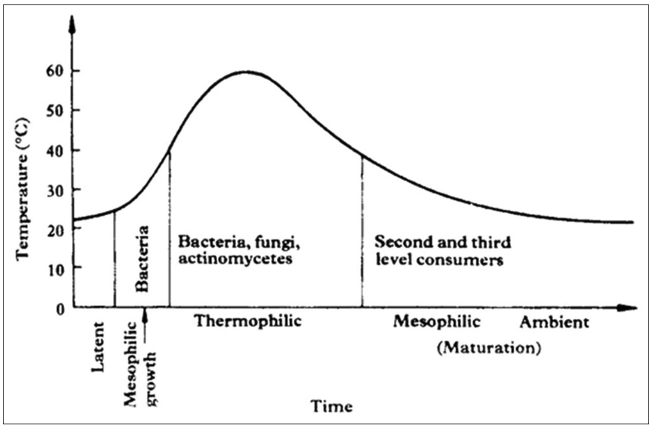

Fig. 2: Patterns of temperature and microbial growth in compost piles (Antil *et al.*, 2014)

Microscopic fungi (*micromycetes*), whose activity and growth are greatly controlled by temperature, play an important part in the composting process. When the temperature rises to 55°C, many *micromycetes* become inactive; however, when the temperature drops, they begin to reactivate and spread throughout the composted mass from the colder regions. The lignin breakdown process is carried out by a variety of thermophilic *micromycetes (Ascomycota*) and *thermophilic Actinobacteria*, which are active during the second stage of composting at temperatures between 40 and 50°C. It was found that as the temperature rises, the number of minute fungi in the compost reduces until they are essentially undetectable at 64°C. At high temperatures, the exoenzymes secreted by *Thermomyces lanuginosus*, known as hemicellulase, ligninases, and cellulases, play a significant role in the lignocellulose and hemicellulose breakdown processes. The concentration of nutrients and the amount of accessible nitrogen is two more factors that limit fungal development in addition to temperature. Due to their physiological potential and hyphal development, filamentous fungi are regarded as the most significant group for composting processes. Macromolecular substrates are degraded by numerous filamentous fungi (in particular, carbohydrates). While white-rot ascomycetes, *Trichoderma reesi*, *Trichoderma lignorum*, and *Chaetomium cellulolyticum* produce cellulase, filamentous fungi of the genera *Mucor, Rhizopus, and Aspergillus* produce amylases. The fundamental advantage that filamentous fungi have over unicellular microbes when colonizing solid substrates and utilizing available resources is hyphal development. Only a small subset of higher fungi can break down lignin, which has the highest resistance to enzymes. In addition, viruses and minute eukaryotes (protozoa) may be present in the compost material. Numerous obligatory ultramicroscopic parasites infect plants, animals, and people with disease. The amount of pathogenic viruses in the contaminated material drastically drops during the thermophilic stage of the composting process if it is subjected to composting (Nozhevnikova *et al.*, 2019).

Carbon/nitrogen ratio

In the degradation process, it is known that microorganisms like bacteria or fungi use around 30 parts cellulose for every part of nitrogen. The ratios of C and N in composting materials are crucial. For microbes, carbon serves as both an energy source and an elemental component, and nitrogen is necessary for the creation of amino acids, proteins, and nucleic acids. The microbes in aerobic fermentation consume 15 to 30 times more carbon than nitrogen during the active phases. It was established that a higher initial C/N ratio results in a longer composting time. Compost made from shrubs and wood takes longer to mature (18 months) than compost made from household waste (with an initial C/N of 30), which takes only 7 months. This is because recalcitrant carbon is more difficult to break down. One of the key elements influencing the composting process as well as the characteristics of the finished product is the carbon to nitrogen (C/N) ratio. According to reports, the ideal C/N ratios for composting the majority of materials range from 25 to 30. According to the research, a C/N ratio of roughly 30 is optimum for ensuring carbon energy intake while promoting rapid microbial development (Azim *et al*., 2018).

Aeration

Large amounts of oxygen are needed for aerobic composting, especially in the beginning. Since aeration is the source of oxygen, aerobic composting requires it. Where there is insufficient oxygen available, the growth of aerobic microorganisms is constrained, which slows down decomposition. Aeration also eliminates trapped gases, water vapor, and excessive heat from the pile. In hot areas where there is a greater chance of overheating and fire, heat removal is especially crucial. As a result, effective aeration is necessary for composting. It can be done by regulating the physical quality of the materials (particle size and moisture content), the size of the pile, the amount of ventilation, and the turning frequency (Misra, 2003).

Moisture

As microorganisms need water, like other living things, to move nutrients and energy components across the cell membrane, moisture is a property that is directly associated with them. It can be challenging to maintain ideal moisture levels while composting, especially if the process is taking place outdoors. Practically, this issue is frequently resolved by keeping an eye on the temperature, which provides good information on when it is ideal to turn, moisten, and/or ventilate the pile. Low initial moisture values (less than 30%) can cause compost to rapidly dehydrate, pausing the biological process, and resulting in compost that is physically stable but biologically unstable. In contrast, compost becomes anaerobic when the relative humidity is high (greater than 80%). Determining the ideal moisture values for the composting process is crucial. Composting materials should maintain a moisture content of 40–65%. In practice, it is advisable to start the pile with a moisture content of 50–60%, finishing at about 30% (Misra, 2003).

The release of metabolic water by microorganisms that decompose organic waste in the presence of oxygen causes the water content to rise during composting. Under the combined effects of the temperature increase and forced ventilation, the water content reduces and is lost as water vapor. In addition, the ideal moisture content changes and largely depends on how the compost's physical composition and particle size change. As a result, moisture and aeration are interlinked. There is no optimal moisture for composting materials that can be used everywhere. This is because each material has specific physical, chemical, and biological properties that influence how moisture and its corollary components, including water availability, particle size, porosity, and permeability, relate to one another. However, additional trace element analysis and physical characteristics are necessary to determine the compost's quality from municipal solid wastes (Azim *et al*., 2018).

Microbial activity

Moisture content has a significant impact on microbial activity; under dry conditions, activity declines, and under waterlogged conditions, aerobic activity declines as a result of the reduced air supply. On a bulk basis, 40–60% water content is the suggested maximum. The distinct stages of the composting process are determined by the microorganisms' development in relation to the mass' temperature. Early in the composting process, bacteria predominate; fungi are present throughout, but they only become dominant at water levels below 35% and when temperatures are higher than 60°C. Actinomycetes, which predominate during stabilization and curing, can break down tough polymers alongside fungus (Antil *et al*., 2014).

Lignin content

One of the key components of plant cell walls is lignin, which has a chemical composition that makes it extremely resistant to microbial deterioration. There are two consequences for lignin's structure. One is that the bioavailability of the other cell-wall components is decreased by lignin, resulting in a lower real C: N ratio (i.e., ratio of biodegradable C to N) than the one typically reported. The other is that lignin improves porosity, which makes the environment favorable for aerobic composting. As a result, while the addition of lignin-decomposing fungus may in some situations enhance accessible C, accelerate composting, and minimize N loss, in others it may lead to a higher real C: N ratio and poor porosity, both of which lengthen the composting process (Misra, 2003).

pH

The pH is a useful indicator of how composting is progressing through its many stages. Due to the creation of organic acids at the start of the composting process, the pH slightly decreased. The pH quickly increased during the cooling and maturation stages after lowering due to the use of these acids as substrates by other aerobic bacteria, and it eventually reached a value near neutral. The pH trend could be used to track the maturation and stabilization of compost (Antil *et al*., 2014). Due to the release of organic acids during the breakdown of simple organic substrates and the volatilization of the initial ammonia, the pH may fall during the first stage of composting. After then, mineralization and the removal of easily degradable organic components caused the pH to rise. Due to the H+ ions generated during nitrification, composting may potentially end with an acidic pH. As seen in the instance of compost formed from waste wood and paper, the raw materials and any additions to the initial mixture actually have a substantial impact on pH variations. It also depends on the circumstances of the composting's airflow, for example, effective ventilation allows for good organic material breakdown and causes the final pH to rise. Temperature influences pH evolution, encouraging the volatilization of ammonia.

Early in the thermophile phase, flora creates a lot of CO_2 and organic acids during the acid-genesis phase (I). With increasing pH, bacterial hydrolysis of protein and organic nitrogen produces ammonia. The pH is stabilized during the alkalization phase (II). Nitrogen is utilized by bacteria to create new humic chemicals, whereas ammonia is lost by volatilization (particularly at pH levels above 8). Stable Phase (IV): The compost is maturing, and the pH is close to neutral. This stability is a result of the humus buffer's influence and sluggish reactions. Effects of low C/N ratios under various C/N ratios on naturally aerated composting of high lignocellulosic materials, particulary coir pith are examined. Regarding pH evolution, all compost piles initially have higher pH levels, especially during the thermophilic phase. It was probably caused by the metabolic breakdown of organic acids and the ammonification processes that occur during the breakdown of organic substances. The pH values of all piles dramatically decreased after the 14th day, which is probably due to the synthesis of phenolic compounds and organic acids during the biodegradation of lignocellulose in the compost piles (Li *et al*., 2013; Azim *et al*., 2018).

Conductivity

The conductivity is a measure of the salts that have dissolved in the compost. This measurement is important since it indicates how salty the compost is, and too salty compost is probably unhealthy for plants. Because organic acids and soluble salts are released during the breakdown of organic matter, the amount of soluble salts in the water extracts rises as compost ages, showing the stability of the compost (Antil *et al*., 2014).

Table 1: Screening the benefits and limitations of compost (biological fertilizers)

Benefits	Limitations
Biological fertilizers can mobilize nutrients that favor the development of biological activities in soils	Compost products have highly variable concentrations of nutrients. In addition, implementation costs are higher than those of certain chemical fertilizers
Maintenance of plant health is enhanced by the addition of balanced nutrients	Extensive and long-term application may result in accumulation of salts, nutrients, and heavy metals that could cause adverse effects on plant growth, development of organisms of the soil, water quality, and human health
Food supply is provided and growth of microorganisms and beneficial soil worms is impelled	Large volumes are required for land application due to low contents of special nutrients, in comparison with chemical fertilizers
As a result of the good structure provided to the soil, root growth is promoted.	Main macronutrients may not be available in sufficient quantities for growth and development of plants
The content of organic matter in soil is higher than normal levels	Nutritional deficiencies could exist, caused by the low transfer of micro-and macro-nutrients
Promotes the development of mycorrhiza associations, which increases the availability of phosphorus (P) on the soil	
Help to eliminate plantar diseases and provide continuous supply of micronutrients to the soil	
Contribute to the maintenance of stable nitrogen (N) andphosphorus (P) concentrations	
Improvements on the capacity of nutrients' exchange in the soil	

CONCLUSION

Composting is a natural process that can be used to convert organic materials into a nutrient-rich soil amendment called compost. Composting can be done at home or on a commercial scale, and it is a great way to reduce waste, improve soil quality, and help mitigate the effects of climate change.

There are many different composting technologies available, each with its own advantages and disadvantages. The most common composting technologies include:

- Open windrows: Open windrows are the simplest type of composting system. They consist of a pile of organic materials that are turned regularly to aerate it. Open windrows are easy to set up and maintain, but they can be susceptible to pests and diseases.
- Closed bins: Closed bins are a more enclosed type of composting system. They can be made from a variety of materials, such as wood, plastic, or concrete. Closed bins help to reduce the risk of pests and diseases, but they can be more difficult to set up and maintain than open windrows.
- Vermicomposting: Vermicomposting is a type of composting that uses worms to break down organic materials. Vermicomposting is a relatively new technology, but it has the potential to be a very efficient way to compost organic materials.

The factors that affect the composting process include:

- The type of materials being composted: Different materials decompose at different rates. Some materials, such as leaves and grass clippings, decompose quickly, while others, such as manure and food scraps, decompose more slowly.
- The moisture content of the materials: The moisture content of the materials should be kept between 50% and 60%. If the materials are too dry, they will not decompose properly. If the materials are too wet, they will become anaerobic, which can produce foul odors and harmful pathogens.
- The temperature of the materials: The temperature of the materials should be kept between 55°F and 160°F. If the temperature is too low, the composting process will slow down. If the temperature is too high, the composting process will stop.
- The aeration of the materials: The materials should be turned regularly to aerate them. Aeration helps to ensure that the composting process is aerobic, which produces less foul odors and harmful pathogens.

By understanding the different composting technologies and factors that affect the composting process, you can choose the right composting system for your needs and ensure that your compost is produced in a safe and efficient manner.

In addition to the factors mentioned above, there are a number of other factors that can affect the composting process, such as the size of the materials, the presence of pests and diseases, and the pH of the materials. It is important to monitor the composting process closely and make adjustments as needed to ensure that the composting process is proceeding smoothly.

Composting is a valuable tool that can be used to reduce waste, improve soil quality, and help mitigate the effects of climate change. By understanding the different composting technologies and factors that affect the composting process, you can choose the right composting system for your needs and ensure that your compost is produced in a safe and efficient manner.

Composting is a beneficial practice that has the potential to reduce waste, improve soil quality, and help mitigate climate change. However, it is important to be aware of the limitations of composting before starting a composting system (Table 1).

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