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Comparative Review of Aerobic and Anaerobic Composting for the Reduction of Organic Waste

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ABSTRACT

Composting is a self-heating, aerobic, bio-decomposition process of organic waste that has advantages over other disposal strategies since it reduces waste volume by 40-50% and kills pathogens by the heat generated during the thermophilic phase. This process uses organic waste (food scraps, grass chipping, *etc.*), water, soil (for added microbes) and either incorporation of air by turning the compost (aerobic) or lack of air within the compost (anaerobic). This study is designed to comparatively assess aerobic and anaerobic composting mechanisms on the productivity rate and analyse the different variables influencing the process. Based on the results obtained the time taken to completely compost the organic materials might not always be the same, because composting time is dependent on the percentage of microorganisms, water content, temperature and C:N ratio present in the pile at the said time along with the amount of material to be composted. Finally, this study will not only help farmers but also the general public in choosing a cost-effective and environmentally friendly way of reducing organic waste from landfills and reduction of greenhouse gases in the ozone layer.

Key words: Aerobic, Anaerobic, Composting, Landfill, Organic waste.

Available and arable land spaces decrease with a rapid increase in the human population over the years (UN, 2019; FAO *et al*. 2021). In countries like Afghanistan, Liberia, Niger and the Democratic Republic of Congo, the population is expected to increase threefold, while in Ethiopia, Nigeria and Yemen it is surging to double by the middle of this century (Walker, 2016). Moreover, even if we try to make do with the space that is here presently, survival may be hard if we do not properly dispose of our waste and try to reduce it to maximize land space and reduce the production of greenhouse gases (FAO *et al*. 2021). The increased population will lead to an enormous buildup of waste in landfills which will add to the increase in greenhouse gases in the atmosphere because of the organic materials that will be decomposing among the other solid waste found in the landfill (Höglund-Isaksson *et al*. 2020; Crippa *et al*. 2020; IPCC, 2021). Henceforth, an effective system to employ in the consumption of waste materials sustainable is to produce compost to enhance crop growth and development. Furthermore, the process will foster the principle to foster reducing, reusing and recycling wastes because if we do not it will help to occupy our already decreasing land space.

Urban waste generation began with human civilization and urbanization (Diaz and De Bertoldi, 2007). Globally, urbanisation promoted a paradigm shift in lifestyle and habits from nomadic hunters and gatherers to productive farmers and effective breeders of desirable livestock (Diaz and de Bertoldi, 2007). According to Diaz and de Bertoldi (2007), "the first waste pits was made out of stone and built outside the houses were found in Sumerian cities about 6000 years ago." Back then there was not as much waste as compared to now because of the population size. Currently, the world's population is approximately 7.7 billion people and yields

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approximately 3.5 million tons of waste daily or 1.3 billion tons annually, in which the developing countries account for about 54.02% (UN, 2019; FAO *et al*. 2021; Adipah and Kwame, 2018). Interestingly, more than 50% of this comprises organic matter and hence composting can play an integral role in the diversification of its usage and rapidly alleviating existing pressure on landfills. Therefore, conserving landfill space and reducing the release of leachate and methane gas, which poses a threat to the ecosystem and environmental safety and contributes to about 5% of global greenhouse gas emissions (Amritha and Anilkumar, 2016; Zhang, 2019; IPCC, 2021). Gases emitted from landfills vary in composition with methane (CH_4) and carbon dioxide (CO_2) constituting 90 to 98%, while nitrogen (N), oxygen (O_2), ammonia NH_4^+), sulphides, hydrogen and various other gases make up the remaining 2 to 10% (Fig 1) (Zhang *et al*. 2019; Dodick and Kauffman, 2017; Takuwa *et al*. 2009). Some of these landfill gases result in adverse health effects for the general population residing within proximity (Takuwa *et al.,* 2009). The quantity of greenhouse gas emissions from landfills is concomitant with landfill volume and age, climatic conditions of landfill sites, organic composition, the age of the waste, oxygen content, moisture content and temperature (Njoku *et al*. 2019; Zhang *et al*. 2019; Takuwa *et al.* 2009). However, while these gases are being produced in one locale and then transferred to wider areas by permeating into the soil or by air and can seep into buildings through the air by windows, doors and ventilation systems. More so, exposure and inhalation to these gases can result in the prevalence of headache, difficulty breathing, coughing, eye irritation and nausea (Takuwa *et al*. 2009; Njoku *et al*. 2019). These gases can also cause serious illnesses and pose an elevated of gastrointestinal complications concomitant with the pathogens released from the sewage treatment plants including gastroenteritis, cryptosporidiosis, campylobacteriosis and serious respiratory complications which can lead to asthmatic response (Giusti, 2009; Sharma *et al*. 2018; Njoku *et al*. 2019). Hence, it is essential to reduce the use of landfill sites as means of decomposition and employ the alternative of composting which is environmentally friendly and sustainable. Instead of dumping organic wastes into landfills, these can be diverted to composting units where the products can be applied to plants to better growth and higher plant productivity (Fig 2).

Composting is a natural process of recycling that breaks down plant and other living materials and transforms them into an organic fertilizer that can be applied to the plants for better growth and high productivity It requires basic ingredients such as air, water, soil and microorganisms (Debertoldi *et al*. 1993). Compost enriches the soil with all the nutrients required for plant growth through mineralization, sustain soil moisture. Moreover, it is concomitant with suppressing plant pathology and pest infestations, providing a conducive environment for beneficial microorganisms and creating symbiotic associations with plant roots, (Meyer-Kohlstock *et al*. 2013; Favoino and Hogg, 2008). Biodegrading needs 65% moisture, while landfill materials contain approximately 25-30%, thus the bio-degradation process is slow since adequate water is not supplied (Meyer-Kohlstock *et al*. 2013). Composting is one of the most effective methods of recycling to reduce organic waste from landfills. Composted products usage should be considered because they foster greater levels of carbon sequestration and hence provide insights into policy initiation and formation relative to climate change (Favoino and Hogg, 2008). As easy as composting sounds there is an art to it, which comes with different techniques, based on turning time (aeration). This paper will focus on two types of composting aerobic and anaerobic. Anaerobic composting takes almost no effort at all just place the materials in and water frequently. This paper reviews the literature on research comparing aerobic and anaerobic composting based on the different periods it takes to compost and analysing the different variables responsible.

Aerobic and anaerobic composting

Aerobic composting involves the introduction of air to break down the materials, this compost needs to be turned regularly, whether daily, twice a week or thrice a week.

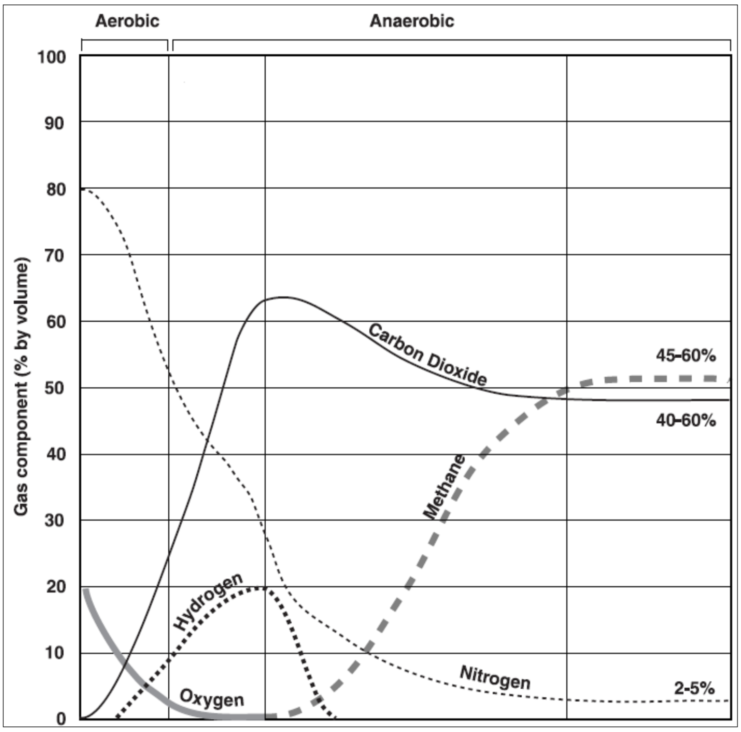

Fig 1: Gases released from landfills during aerobic and anaerobic respiration.
Source: US EPA, 1997 and Maheshwari *et al*. 2015.

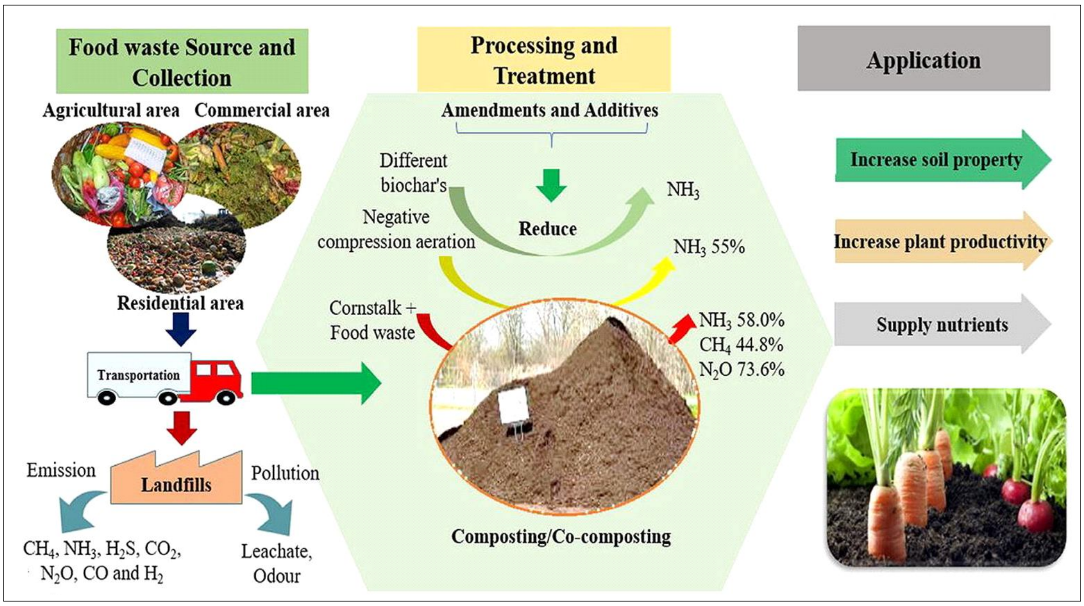

Fig 2: Gases released from landfills and benefits of composting the wastes. (Source: Awasthi *et al.* 2020).

This turning could be done with a tumbler composter for efficiency and reduced labour. However, plenty of green matter contains a significant amount of nitrogen. As the bacteria disintegrate the high-nitrogen-content materials, the temperature of the compost will increase resulting in increasing the rate of decomposition.

Anaerobic composting is slightly different from aerobic composting is does not require the incorporation of air, so it is less time-consuming. This involves leaving the materials in a compost heap of compost to decompose. Anaerobic composting entails placing the materials in a compost heap or composter and leave undisturbed until decomposition is completed. This compost will have a stench because of the different forms of bacteria present and the release of various substances during decomposition. This is what takes place in a landfill and it is not healthy because of the gases present.

Aerobic composting is the decomposition of organic matter using microorganisms that need oxygen to survive, aerobes. Contrastingly, anaerobic composting occurs with microorganisms that do not require oxygen to survive, anaerobes. In an anaerobic decomposition, most of the chemical energy contained in the starting substrate is released as methane gas (Swarthout, 1993). The process is characterized by very intense odours and lower heat is generation denotes decomposition takes longer and does not reach lethal temperatures to destroy the microorganism, weeds and seeds. To supersede these limitations, heat is added to the system. In anaerobic digestion, a sludge-like material is produced which seems to be more difficult to disintegrate. This sludge requires aerobic composting to complete the stabilization and decomposition. The heat produced in aerobic composting maintain the growth of beneficial bacteria including psychrophiles, mesophiles and thermophiles. However, turning can affect this process thereby can slow down the rate of composting. The microorganisms found in the compost establish an association that fosters the efficiency of the decomposition. The organic materials are consumed by the primary consumers (earthworm, bacteria such as actinomycetes and fungi) which are then consumed by the secondary consumers (beetle, mite, flatworm) and then consumed by the tertiary consumers (centipedes, ant, ground beetle) (Singh, 2012). The humus produced by composting contains a significant amount of fibre and inorganic nutrient composition including phosphorus, potassium and nitrogen and makes organic fertilizer that is beneficial to the ecosystem (Paul *et al*. 2019). Swarthout (1993) found that the microbes responsible for composting dwell in the moisture surrounding organic matter. Therefore, the right amount of moisture in compost can speed up the rate of decomposition which will increase the rate of microbes at the different phases of composting to quickly break down the organic materials. Thus, aerobic compost requires more moisture since turning will increase microbial activity and decrease moisture content rapidly while creating hot compost. Whereas, anaerobic compost does not require as much moisture as aerobic since it is a cold compost because of its slow decomposition.

Carbon and nitrogen ratio

Kale (1998) noted the composition of organic waste and posited that it constitutes two important elements, carbon (C) and nitrogen (N), which should be in the ratio 30:1. During the process of composting, the conditions become apposite for the growth and development of microbes. Fresh substrate high in C (plant materials) should be combined with raw materials high in N (manure) will render the appropriate 30:1 ratio for ideal composting conditions (Awasthi *et al*. 2020; Dodick and Kauffman, 2017). More so, when the C content is above 30, heat production decreases thereby effectively reducing the rate of composting (Kale, 1998). Additionally, if the C:N ratio is 20:1 the pH will increase (loss of nitrogen as ammonia) creating untenable conditions for the functioning or can even result in the death of the microbes thereby halting the entire process. Oxygen is a prerequisite for aerobic composting and therefore avenue for its inclusion must be facilitated through proper aeration to enhance circulation within the composting materials (Alkoaik, 2019). Besides, an improper ventilation system will lead to insufficient oxygen resulting in anaerobic conditions and the production of unpleasant odours (Dickerson, 1999). Effective composting system must remain moist ranging between 40-60% that is adequate for the growth of microorganisms and sustain the microbial activity (Dickerson, 1999). Anaerobic compost contains higher levels of ammonium (NH_4^+) because anaerobes tend to utilize less N than aerobes during decomposition (Awasthi *et al*. 2020; Dickerson, 1999). Composting anaerobically produces a significant volume of biogas (*e.g.* methane and carbon dioxide), which as a by-product can be captured and used as a source of alternative energy adding value to it rather than releasing it into the atmosphere to further concentrate greenhouse gas accumulation. On the contrary, aerobic composting is more stable and the well-ordered decomposition and the speed of composting are reliant on the moisture, aeration and C:N ratio of the heap.

Temperature changes and microbial interactions

Jeong and Kim, (2001) posited that temperature is integrally involved in the composting and also a determinant factor on the survival of the microbes and the completion of the process. As temperatures constantly fluctuate in the compost, it provides the right environment for different bacteria to have become more active. For example, psychrophilic, mesophilic and thermophilic bacteria operate best within specific temperature ranges. The psychrophiles function optimally at temperatures 0 and 13°C but can also be active at temperatures as low as -18°C. The heat generated makes provision for the growth of mesophiles that operate in temperatures between 15 and 40°C but thrive when temperatures are within the range of 21 to 32°C. The heat generated by mesophiles increases the temperature in the heap, thus creating conditions suitable for the subsequent thermophilic bacteria to function. Thermophiles are initiated and start to function at temperatures around 40 to 45°C and will continue at the temperatures rise to about 70°C, the optimal temperature when their population will decline. Constant turning of the heap provides sufficient aeration for maintaining the activity of thermophiles for a longer period. Decreasing temperatures result in the reduction of the thermophiles colony which indicates that the compost has reached some level of maturity. Mesophiles and psychrophiles will become active again at the reduced temperature and start to increase their populations at the periphery of the heap. The last stage of decomposition is done by Actinomycetes that produce antibiotics found in the compost and which inhibits the growth of bacteria. They release C, nitrate (NO^{3-}) and NH_4^+, resulting in the mineralization of nutrients to plants. Based on these papers aerobic composting is more suitable because most of the microbes depend on oxygen to break down the organic materials since the air will also contain other microbes and mixing will shuffle microbes to different places that they are needed. On the other hand, anaerobic composting heats up on its own based on the microbes present so the temperature is solely dependent on the activities of the microbes in the compost.

CONCLUSION

Globally, solid waste generated is contributing adversely to environmental pollution. Solid waste landfills are contaminated by heavy metals and gases and these can undoubtedly prove to be harmful to the ecosystem and some extend result in fatality. Moreover, implementing an environmentally friendly and sustainable system of disposing of solid waste is being trialled in many countries. Composting helps the environment by using organic waste and turning it into fertilizers, which can be used, in the agricultural industry. The two main methods of composting reviewed in this paper are Aerobic and Anaerobic. Aerobic composting works quickly but requires a high amount of maintenance, as the moisture and temperature need to be monitored closely along with the incorporation of air regularly. Even though the temperature is an important factor for composting, its effect is less influential than moisture content. Anaerobic composting does not need as much attention as aerobic as the microbes found in this compost does not need oxygen to survive. While anaerobic composting may be easier and less labour-intensive, because you do not need to turn the pile, than aerobic composting, it is smellier and takes a lot longer to produce usable compost compared to aerobic composting as the different types of microbes and organisms work at a much slower rate due mainly to the colder conditions. However, it is the surrounding environments and elements along with microbes that are available within the compost that determines the time of finished compost; this is so because microbes such as bacteria, fungi and other microorganisms need a suitable environment to degrade the organic materials.

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