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Aerobic composting versus Anaerobic composting: Comparison and differences

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ABSTRACT
In recent decades the increased harmful effects of agro-chemicals and synthetic fertilizers both in plant and animal health have created awareness about the use of organic inputs in agriculture. These increased demands of organic inputs have raised concern about the management of waste material through different composting techniques. Therefore, to meet out the demand for organic produces, there is a need for better understanding of composting methods. In this article, comparisons between aerobic and anaerobic composting processes have been discussed. Also, a comparative analysis of both the methods in terms of microbes involved, decomposition process, gaseous emission and superiority in pathogen suppression under both the processes have been discussed.
Keywords: Aerobic, Anaerobic, Compost, Decomposition, Gaseous emission, Pathogens.

In recent decades, expansion of agricultural area and increased pollution level in agricultural produces due to unbalanced use of agro-chemicals and synthetic fertilizers has lead to the use of compost in agriculture. Composting can be defined as decomposition/ mineralization followed by partial humiliation of organic materials by the biological metabolic action of microorganisms i.e. bacteria, fungi, actinomycetes etc. under optimum conditions over a period of time to a stable end product. The end product is known as compost. Many types of organic matter, such as leaves, straw, fruit and vegetable peelings and manures can be used to make compost. The degraded end product is completely different from the original organic materials which have characteristics of dark brown colour, crumbly in nature with a pleasant smell (Mehta and Sirari, 2018; Meena *et al*., 2021). Being easily available, cost-effective and easy to prepare, compost is an important source for improvement of soil and crop quality. Compost improves the structure of the soil. It allows more air into the soil improves drainage and reduces erosion. Compost helps to stop the soil from drying out in times of drought by holding more water. Compost helps in improvement of soil physico-chemical properties as it adds the nutrients to the applied soils as well as acts as a binding agent for the soil particles; thus, increase the nutrient availability for the plants. Based on the nature of microorganisms involved in the decomposition process of organic wastes, composting can be divided into two broad categories *i.e*. aerobic and anaerobic.

Aerobic Composting

Decomposition of organic matter using microorganisms that require oxygen is known as aerobic composting. These microorganisms are inhabited naturally in the moisture surrounding organic matter. The oxygen diffuses in the moisture from the air is utilized by the aerobic microorganisms for their respiration and other metabolic activities. As a result of aerobic decomposition carbon dioxide (CO_2), water and heat are released as by-products. Production of heat in aerobic decomposition accelerates creation of micro-environments within the compost heap which helps in killing catastrophic pathogens and bacteria due to non-adaptability of these harmful organisms to these environmental conditions. These environmental conditions also help in proliferation of diverse bacterial species i.e. psychrophilic, mesophilic and thermophilic. These microorganisms are basically classified as: First level decomposers, second level decomposers and third level decomposers (fig. 1).

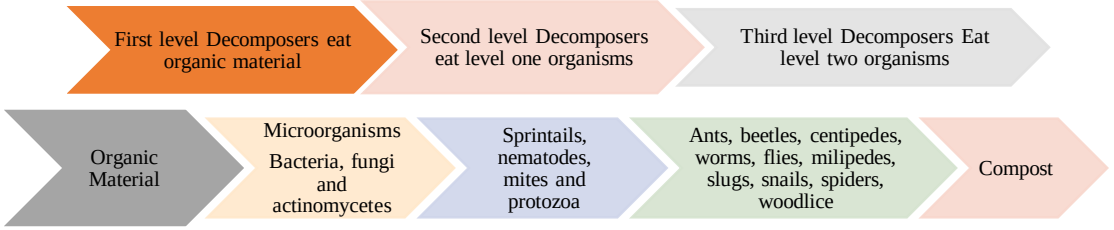

Fig.1. Types of different organisms involved in composting process (Source: compost.css.cornell.edu/On Farm Handbook/P12sidebar.html).

First level Decomposers

The first level decomposers consist of the small size microorganisms that shred the organic material and eat the shredded organic matter, basically, the bacteria (*Bacillus coagulans, B. megaterium, B. subtilis, B. sphaericus, B. licheniformis, B. circulans, Arthrobacter, Alcaligenes faecalis, Bacillus brevis, B. pumilus, Pseudomonas sp., Streptococcus sp., Thermus sp.),* fungi *(Aspergillus fumigatus, Basidiomycetes sp., Humicoligrisea, H. insolens, H. lanuginosa, Malbranchea pulchella, Myriococcum thermophilium, Paecilomyces variotii, Papulaspora thermophilia, Penicillium dupontii, Scytalidium thermophilim, Termonmyces sp., Tricoderma sp.)* and actinomycetes (*Streptomyces, Frankia, Actinomycetes micromonospora* and other 14 species) which play a crucial role in composting process. These microorganisms through their metabolic chemical reactions breakdown the complex organic materials into different simple organic materials (Fig. 2) (Mehta *et al.*, 2012).

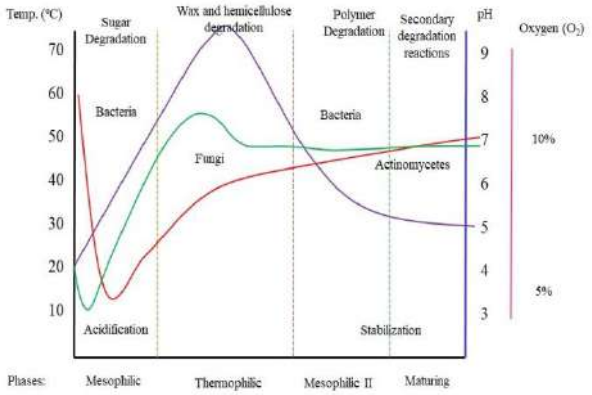

Fig. 2. Stepwise degradation of various organic matter components by different level of microbes

Second level Decomposers:

The second level decomposers inherited by nematodes, mold mites, beetle mites, springtails and protozoa which decompose the organic material and eat the organisms of first level decomposers. These organisms are small in size and use of stereoscopic microscope or hand lens is useful to scrutinize them in details.

Third level Decomposers:

The larger creature generally known as macro-organisms i.e. beetles, ants, centipedes, millipedes, flies, snails, slugs, composting worms and woodlice (sow bugs) physically break down the composting materials into small pieces through their tearing, chewing and sucking actions. These organisms can be seen through naked eyes (Bernal *et al.*, 2009).

Anaerobic Composting

Anaerobic composting generally takes place in nature. Composting which progresses without the entanglement of oxygen is known as anaerobic composting. In this process, the organic material is breakdown by the different species of anaerobic microorganisms. Like aerobic microorganisms, anaerobic microbes also employ the N, P, K and other nutrients for their metabolic development. The major differences between aerobic and anaerobic composting are: breakdown of organic nitrogen to ammonia and organic acids; release of methane (CH_4) from the decomposition of carbon compounds (Jiang *et al.*, 2011). Reduction is the main process of breakdown of organic matter under anaerobic composting, though for a shorter period of time oxidation also takes place for preparation of final end product in anaerobic composting. There are four major stages of anaerobic decomposition i.e. Hydrolysis, acidogenesis, acetogenesis and methanogenesis.

In hydrolysis which is the first stage, the insoluble complex organic materials i.e. cellulose, hemicelluloses, lignin etc. are hydrolysed into the soluble simple amino acids, fatty acids and sugars. The hydrolysis process has a significant stage in anaerobic composting as it decomposes the raw organic matter with high complex organic content. The fermentative acidogenic bacteria further decompose the remaining complex organic matter into simple molecules under the acidogenesis process which is the second stage of anaerobic composting. In the third stage i.e. acetogenesis, simple organic molecules created by the acidogenesis process are further digested to acetic acid, carbon dioxide (CO_2) and hydrogen. The microbes involved in acetogenesis process are: Acetobacter woodii, Clostridium aceticum and Clostridium termoautotrophicum. Production of methane gas (CH_4) by methane forming microbes i.e. Methanosarcina takes place in the fourth and final stage which is known as methanogenesis (Mehta and Sirari, 2018).

Aerobic versus anaerobic composting

The consumption and decomposition of organic matter by the microorganisms have broadly been categorized into two categories: first one that require oxygen (aerobic) and those that don't require oxygen (anaerobic). Though many studies have considered anaerobic composting as a suitable alternative to aerobic composting due to minimized loss of nitrogen in anaerobic composting (Yu *et al.*, 2015). But the aerobic composting has considerable advantages over anaerobic

composting i.e. rise in the temperature of the pile as high as up to 60ºC-70ºC which helps in killing of weed seeds and pathogens; aeration increase the decomposition rate of the organic material; shorter period of time requires for compost preparation and the intensity and number of objectionable emissions are distinctly reduced (Gill *et al.*, 2014). Three main broad categories have been identified between aerobic and anaerobic composting i.e. Decomposition; pathogen suppression and emission of gases.

Decomposition

Turning and proper aeration increase the decomposition rate of organic material in aerobic composting compared with anaerobic composting. For the proper decomposition of organic material, it should be kept at least for six to twelve months in anaerobic composting while; a time of period of 30 days to 120 days is far enough for complete decomposition of organic material in aerobic composting (Tian *et al.*, 2012).

Pathogen suppression

Microbes are the essential component of composting both in aerobic and anaerobic methods. Presence of diversified microorganisms in aerobic composting raises the compost pile temperature up to 60ºC-70ºC which is far enough to kill the harmful pathogens and weed seeds present in the composting materials. Whereas, on the other hand, the low temperature and presence of specific species of microorganisms in anaerobic compost are unable to kill the pathogen and weed seeds and they remain in the composting material. It has been observed by several studies that presence of 50-70ºC temperature and 35% moisture level in aerobic composting is high enough to kill the weed seeds of pigweed, barnyard grass, kochia etc. Also, several pathogenic fungi species viz. *Olpidium brassicae, Fusarium oxysporum, Plasmodiophora brassicae, Synchytrium endobioticum, Phytophthora infestans* and various bacterial plant pathogens are unable to survive at the higher temperature generated during the aerobic composting (Mehta *et al.*, 2016). Thus, it has been observed that the optimum exposure of the composting material at high temperature is required for preparation of pathogen free compost. All these beneficial effects support the importance of thermophilic phase of aerobic composting compared with the anaerobic composting where the temperature level never reaches up to 65ºC.

Gaseous Emission

In both aerobic and anaerobic composting processes some unpleasant odours emitted from the composting materials which are generated due to rapid microbial degradation of complex organic matter into simple compounds. The extent and intensity of odours emission are high in aerobic composting as compare to anaerobic composting but rapid turning and frequent supply of oxygen in aerobic composting decrease the chances of evolution and emission of unpleasant gases whereas, because of closed systems and low level of oxygen causes higher formation and emission of unpleasant gases in anaerobic composting (Jiang *et al.*, 2015). Application of various chemical and biological treatments can reduce the emission of these gases from the composting materials. Thus all the above discussed benefits support the superiority of aerobic composting over the anaerobic methods.

Conclusions

The main aim of this article was to discuss the types of composting, microbes involve in composting processes and comparison between the aerobic and anaerobic composting methods. Both aerobic and anaerobic composting techniques have significant environmental impacts through management of the waste materials which include: management of VOC (volatile organic compounds) and odour emissions and killing of pathogens and weed seeds. It has been clearly found out that rapid turning and presence of oxygen fasten the composting process in aerobic composting compared with the anaerobic method.

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