Plant Archives Vol. 18 No. 1, 2018 pp. 44-48 ***ISSN 0972-5210***

COMPARATIVE STUDY OF AEROBIC AND ANAEROBIC COMPOSTING FOR BETTER UNDERSTANDING OF ORGANIC WASTE MANAGEMENT: *A MINI REVIEW*

C. M. Mehta* and Kanak Sirari

School of Agriculture, Lovely Professional University, Jalandhar-Delhi G.T. Road, National Highway 1, Phagwara-144411 (Punjab) India

Abstract

Present day world is giving preference to organic produce over inorganic because of their awareness about the hazards of chemical produces. However, a limited supply of organic produce in the market is creating a huge gap among the costs of these produces. Major portion of organic produce is based on application of compost instead of applying microbial inoculants into the field. Previous studies reveal the benefits of compost application over chemical fertilizer in terms of quality produce and soil nourishment. Therefore, there is a need for better understanding of composting process so that the supply of organic produce can reaches upto the demand. In this review we are comparing two different types of composting process *i.e.* aerobic and anaerobic composting. A comparative analysis of these two types of composting can reveal the advantage of one over other and their limitations under natural/environmental conditions. Therefore, this review will be very useful in better understanding towards composting process.

Key words: Composting, aerobic, anaerobic, microorganisms, degradation.

Introduction

In all over the world, composting is becoming more common practice in response to concerns about pollution in agricultural produce and the violation of the urban population in rural areas. Many tropical farming systems have been evolved during last few decades and continuously expanding the cropped area and influencing on the environment. The major part of these farming practices is organic in nature. The major problem with developing countries is that they are importing a huge amount of cereals, pulses, food products etc. of non-organic sources from outside the tropics (Wackernagel *et al.*, 2004). Therefore, to compensate this gap between organic and inorganic produces there is a need of better understanding of composting process. Composting can be defined as mineralization and partial humification of organic substances by the action of microbes, under optimum condition and it is a natural way of dealing with waste, transforming it into soil improvement and plant nutrients (Mehta *et al.*, 2012; Mehta *et al.*, 2014). Two major techniques of decomposition of organic matter are aerobic decomposition (necessity of air) and anaerobic (no necessity of air). In this part we are explaining both composting methods, factors affecting these processes and the advances of aerobic over anaerobic composting.

***Author for correspondence :** E-mail : chandra_m_mehta@yahoo.com

Aerobic Composting

Decomposition of organic material with oxygen is an "aerobic" process. Aerobic microbes utilize oxygen to feed upon organic matter to develop their cell protoplasm from nutrients (mainly nitrogen, phosphorus, some of the carbon) present into the raw material of compost. Organic matter generally breaks down more efficiently and completely in conditions of ready oxygen availability, largely as a result of the energy produced from the aerobic respiration (Evans, 2001; Cadena *et al.*, 2009). In nature, most common area for aerobic decomposition process is forest, where dead and decayed material of animal and plant residue is in maximum amount and can be converted into relatively stable organic matter and due to the presence of adequate amount of oxygen this type of decomposition doesn't smell.

The first phase of aerobic composting is pile formation. Within the first couple of days of composting, temperature rises rapidly to 70-80^{0}C. Initially, mesophilic organisms (optimum growth temperature range = 20-45^{0}C) multiply rapidly due to adequate presence of available sugars and amino acids. The common mesophilic microbes are *Pseudomonas, Bacillus, Flavobacterium, Clostridium, Alternaria, Cladosporium, Aspergillus, Mucor, Humicola, Penicillium* and *Streptomyces* etc. Due to availability of plenty amount of food source these microbes grow rapidly and generate heat by their own metabolism and raise the temperature of pile to the point where their own activities become suppressed. Then several thermophilic fungi (*Aspergillus, Mucor, Chaetomium, Humicola, Absidia, Sporotrichum*, *Torula* (yeast) and *Thermoascus*), thermophilic bacteria (*Bacillus* and *Thermus*) and few actinomycetes (*Streptomyces, Micropolyspora, Thermoactinomyces* and *Thermomonospora*) continue the process of raising pile temperature upto 65 to 70^{0}C or higher. This necessity of this peak heating phase is that it can kill most of the pathogens and weed seeds that can contaminate the compost and later on soil and crop which are in contact of this compost (Bertoldi, 2010; Mehta *et al.*, 2012).

The final phase of active composting stage is curing stage. This stage can be identified by no further change in temperature. At this phase, some of the microbes (mainly fungi) show their activity that decomposes plant cell wall material like cellulose and hemicelluose. Curing phase is one of the essential phases before the application of compost into the field. Immature compost can cause lots of risks like oxygen deficiency and nutrient hunger that can leads towards scarcity of nutrient in soil and also immature compost can leads towards release of organic acids that can cause toxic effect on crops growing into applied areas (Bernal *et al.*, 2009; Mehta *et al.*, 2014).

Finally, the temperature declines to ambient temperature. Mature compost pile become more uniform and less active to the microbes although mesophilic microbes recolonize the compost. The final composting material becomes dark brown to black in color that increases the amount of humus. The particle size of mature compost is near to soil like texture and the ratio of carbon to nitrogen (C:N) decreases, pH near to neutral and the exchange capacity of the material increases (Mehta *et al.*, 2014).

Major factors affecting aerobic composting

Aeration

In aerobic composting oxygen is a major limiting factor. The growth of aerobic microbes is directly affected by the oxygen supply (Parkinson *et al.*, 2004; Shen *et al.*, 2011). Lesser supply of oxygen to compost pile can restrict the growth of aerobic microbes and leads toward slower decomposition of raw organic material. In addition, proper aeration eliminates excessive heat, water vapor and other gases trapped in the pile. Therefore, good aeration is necessary for proficient composting. The proper aeration in composting can be achieved by controlling the particle size of raw material used in composting and also with the frequent turning of pile (Shen *et al.*, 2011).

Temperature

As explained above, composting involves two temperature phases: low temperature (mesophilic; 20-45 ^{0}C) and high temperature (thermophilic; 50-70^{0}C) phase (Liang *et al.*, 2003). If the temperature goes too high or too low, the activity of composting microbes adversely affected, which results immature and non effective composts. Most of the pathogens cannot survive at 55^{0}C and above and for elimination of weed seeds the critical temperature is about 62^{0}C and above. Therefore, for proper composting product temperature is a major factor and it can be regulated by turnings and aeration of compost (Atchley and Clark, 1979).

Moisture

The major role of moisture content in aerobic composting is to maintain the metabolic activity of the micro-organisms. If the compost is too dry, the activity of microbes rapidly reduce which results the slow composting process while moisture content in excess amount that develops an anaerobic condition for microbial growth. Therefore for proper aerobic composting process the moisture content should be 40-65 percent (Atchley and Clark, 1979).

pH value

pH of composting pile can directly affects the microbial population by restricting the availability of nutrients to microbes. Optimum pH for proper microbial growth in composting pile is recommended between 6.0 and 7.5 for most microbes (Atchley and Clark, 1979).

Nutrients

The major nutrients present in compost are; Carbon (C), Nitrogen (N), Phosphorus (P) and Potassium (K). Carbon to nitrogen (C:N) ratio is a limiting factor in composting process. At higher C:N ratio (40:1), excess amount of carbon source and limited amount of nitrogen source restrict the growth of micro-organisms and resulting slower decomposition process (Zhu *et al.*, 2007). In contrast, if C:N ratio is less than 20:1 it leads to under utilization of N and the excess may be released into atmosphere as ammonia or nitrous oxide resulting to odour problem (Jeong and Kim, 2001). Other major nutrient in composting process is phosphorus (P) which is a non-volatile nutrient that means no loss during the process but it can leach out from the system therefore the concentration of P in the raw material should be high. Similarly, potassium is another non-volatile nutrient that can leach from the composting system. The concentration of potassium in final product should be always greater than the original raw manure (Hu *et al.*, 2007)

Anaerobic composting

Anaerobic composting process takes place without the involvement of oxygen. It commonly takes place in the nature. The anaerobic decomposition results the breakdown of organic compounds by the application of anaerobic microorganisms. Similar to aerobic process, anaerobic microbes also utilize nitrogen, phosphorus, and other nutrients to develop their cell protoplasm. The major difference is between decomposition of organic and inorganic compounds present into the compost pile like breakdown of organic nitrogen to organic acids and ammonia. Similarly major portion of carbon is released in the form of methane gas (CH_4) and a small portion of carbon can be respired as CO_2 (Jiang *et al.*, 2011; Cayuela *et al.*, 2012). Since the major part of anaerobic composting is breakdown of organic matter through reduction process but the final product is subject to have some aerobic oxidation. There are no consequences of this oxidation process on utilization of material as it is there for only short duration.

Four major stages take place during the anaerobic composting process: hydrolysis, acidogenesis, acetogenesis and methanogenesis. The first stage is hydrolysis where the fermentative microbes breakdown the insoluble complex organic matter, such as cellulose into soluble molecules as fatty acids, amino acids and sugars. The hydrolytic activity is a rate limiting factor as it is having a significant impact on raw material with high organic content (Vavilin *et al.*, 2008). The second stage of anaerobic decomposition *i.e.* acidogenesis, involved in further breakdown of remaining complex molecules by acidogenic (fermentative) bacteria. In the next phase of anaerobic digestion, simple molecules created through the acidogenesis phase are further digested upto acetic acid, as well as carbon dioxide and hydrogen by acetogenesis. The major bacteria of this phase are *Clostridium aceticum, Acetobacter woodii* and *Clostridium termoautotrophicum*. The final phase is methanogenesis, methane is produced by bacteria called methane formers (e.g. *Methanosarcina*) (Demirel and Scherer, 2008).

Major factors affecting anaerobic composting

Temperature

Temperature is a major limiting factor in anaerobic composting process. Optimum temperature considered for optimum growth of mesophilic digester for biogas production is 35^0C. Previous study on effect of temperature on mesophilic digester reports that for each 10^0C drop the activity and growth rate of bacteria decrease by 50% and with 20^0C decrease in temperature biogas production falls down and even stops at 10^0C (Samir *et al.*, 2010). Temperature above 37^0C leads to prolong digestion process and leads to reduced rate of biogas generation.

pH

pH is the second major factor that affect the processing of anaerobic composting. Digestion process is significantly affected by variation in pH (Romano *et al.*, 2011). The optimum pH range for anaerobic digester is considered between 6.8 to 7.2. However, the anaerobic decomposition process can tolerate a range of 6.5 up to 8.0.

Substrate

The initial substrate concentration directly influence the anaerobic digestion (Fernández *et al.*, 2008) and also methane gas production during anaerobic decomposition is critically depends on initial substrate concentration.

Pathogens

Unlike aerobic decomposition, in anaerobic composting pathogens are major threats to composting material because there is not enough heat that can destroy the pathogens. The only way of eradication of pathogen during this process is unavailability of oxygen that provides unfavorable condition to the pathogens and can be slowly disappears from compost. In addition to this, biological antagonisms against these pathogens in compost can also reduce the chances of vaiability of pathogen in anaerobic compost. Therefore, it is necessary that the condition should be completely anaerobic and the composted material must be held for a periods of six months to a year to ensure complete destruction of pathogens (Hoitink and Fahy, 1986; Yazdani *et al.*, 2012).

Aerobic vs. Anaerobic composting

Anaerobic composting was considered as a possible alternative to aerobic composting. The major support of anaerobic composting was the minimisation of nitrogen loss (Yu *et al.*, 2015). Even had this advantage, the imitation and disadvantages of the anaerobic mode cannot be neglected. There are several advantages of aerobic composting over anaerobic composting like: a) rapid decomposition of raw material, b) temperature of pile raises upto that level where pathogens and weeds cannot survive, c) the number and intensity of objectionable emissions are sharply reduced and, 4) can be generated in a short period of time (Zeng *et al.*, 2012; Gill *et al.*, 2014).

Decomposition

Decomposition of organic material in aerobic composting proceeds more rapidly as compare to anaerobic process. In anaerobic decomposition the composted material must be held for periods of six months to a year to ensure the proper decomposition of organic material while in aerobic composting the complete decomposition time (or composting time) is about 3 to 6 months (Gabhane *et al.*, 2012; Tian *et al.*, 2012).

Pathogen suppression

Both aerobic and anaerobic composting requires microbes for decomposition of raw material. Most of the pathogens are not susceptible to high temperature and anaerobic conditions. Under aerobic conditions, compost pile may attain a temperature upto 60^0Cto 70^0C which is high enough to kill the pathogens present in the raw material. While in anaerobic composting process temperature never reaches upto 70^0C. Therefore, the possibility of the pathogens to remain into the compost is significantly higher as compare to aerobic decomposition.

In aerobic composting systems, the most important factor is interaction between weed species and different composting parameters like temperature, time, and moisture (Egley,1990; Larney and Blackshaw *et al.*, 2003). During aerobic composting, higher temperature (upto 70^0C) increases the mortality rate of weed seeds. Therefore, the longer the duration of high-temperature exposure in composting, the higher the weed seed mortality (Dahlquist *et al.*, 2007). Similar study on compost (Wiese *et al.*, 1998) reports that, at 35% moisture and 50-70^0C the weed seeds like barnyardgrass, pigweeds, and kochia were killed.

Generally in aerobic composting process fungal pathogens do not survive due to high temperature (Hoitink and Fahy, 1986). However, many of them form a reproductive structures are usually more heat resistant than their vegetative structures. Many pathogenic fungi like *Fusarium oxysporum*, *Olpidium brassicae*, *Synchytrium endobioticum* and *Plasmodiophora brassicae*, *Phytophthora infestans* can produce their reproductive structure that can survive from 40^0C to 65^0C for 10-30 minutes (Golueke, 1982; Bollen, 1993; Mehta *et al.*, 2016). Similarly bacterial plant pathogens are unlikely to survive composting, where temperature normally rises above 50^0C (Bollen, 1993). Therefore an optimum exposure of high temperature is necessary for complete removal of pathogenic fungi from the compost. All these studies support the important role of thermophilic phase of aerobic composting processes over anaerobic composting where the temperature never raises upto 65^0C.

Emission of gases

At the initial phase of composting of waste material, emission of some unpleasant odors is predictable. The source of this unpleasant smell is mainly because of rapid activity of microbes towards degradation of complex compounds into simple compounds. The intensity and extent of odours during anerobic composting is more as compare to aerobic composting. In aerobic composting, a frequent supply oxygen to heap helps to reduce the chances of formation and emission of unpleasant gases while in anaerobic composting, due to closed system formation and emission of objectionable odor is more. The possible solution for controlling the emissions of gases is chemical and or biological treatment (Maulini-Duran, 2013; Jiang *et al.*, 2015).

All above studies supports the advances of aerobic composting over anaerobic. However, a transient anaerobic phase is recognized as essential part of composting to destruct the halogenated hydrocarbons combined with conservation of nitrogen. Therefore, there is a need of future study to explore the composting stages in details for better understanding of efficient compost formation.

References

Atchley, S.H. and J.B. Clark (1979). Variability of temperature, pH, and moisture in an aerobic composting process. *Appl. Environ. Microbiol.* **38(6)**: 1040-1044.

Bernal, M.P., J.A. Alburquerque and R. Moral (2009). Composting of animal manures and chemical criteria for compost maturity assessment. A review. *Bioresour. Technol,* **100(22)**: 5444-5453.

Bollen, G.J. (1993). Factors involved in inactivation of plant pathogens during composting of plant residues. In Science and Engineering of Composting, eds. H.A.J. Hoitink and H.M. Keener, pp. 301-18. Ohio, USA, Renaissance Publications, 728 pp.

Cadena, E., J. Colón, A. Artola, A. Sánchez and X. Font (2009). Environmental impact of two aerobic composting technologies using life cycle assessment. *Int. J. Life Cycle Assess.,* **14(5)**: 401-410.

Cayuela, M.L., M.A Sánchez-Monedero, A. Roig, T. Sinicco and C. Mondini (2012). Biochemical changes and GHG emissions during composting of lignocellulosic residues with different N-rich by-products. *Chemosphere,* **88(2)**: 196-203.

Dahlquist, R.M., T.S. Prather and J.J. Stapleton (2007). Time and temperature requirements for weed seed thermal death. *Weed Sci.,* **55**: 619–625.

de Bertoldi, M. (2010). Production and utilization of suppressive compost: environmental, food and health benefits. In Microbes at Work (pp. 153-170). Springer Berlin Heidelberg.

Demirel, B. and P. Scherer (2008). The roles of acetotrophic and hydrogenotrophic methanogens during anaerobic conversion of biomass to methane: a review. *Rev. Environ. Sci. Biotechnol., 7***(2)**: 173-190.

Egley, G.H. (1990). High-temperature effects on germination and survival of weed seeds in soil. *Weed Sci.,* **38**: 429–435.

Evans, T.D. (2001). An Update on Developments in Regulations Affecting Biosolids in the European Union. Proceedings of the WEF/AWWA/CWEA Joint Residuals and Biosolids

Management Conference, San Diego, California.

Fernández, J., M. Pérez and L.I. Romero (2008). Effect of the substrate concentration on dry mesophilic anaerobic digestion of organic fraction of municipal solid waste (OFMSW). *Bioresour. Technol*, **99**: 6075–6080.

Gabhane, J., S.P. William, R. Bidyadhar, P. Bhilawe, D. Anand, A.N. Vaidya and S.R. Wate (2012). Additives aided composting of green waste: Effects on organic matter degradation, compost maturity, and quality of the finished compost. *Bioresour. Technol*., **114**: 382-388.

Gill, S.S., A.M. Jana and A. Shrivastav (2014). Aerobic bacterial degradation of kitchen waste: A review. *J. Microbiol. Biotechnol. Food Sci.,* **3(6)**: 477.

Golueke, C.G. (1982). When is Compost "Safe" *BioCycle,* **23**: 28-38.

Hoitink, H.A.J. and P.C. Fahy (1986). Basis for the Control of Soilborne Plant Pathogens With Composts. *Annu. Rev. Phytopathol,* **24**: 93-114.

Hu, T.J., G.M. Zeng, D.L. Huang, H.Y. Yu, X.Y. Jiang, F. Dai and G.H. Huang (2007). Use of potassium dihydrogen phosphate and sawdust as adsorbents of ammoniacal nitrogen in aerobic composting process. *J. Hazard Mater,* **141(3)**: 736-744.

Jeong, Y.K. and J.S. Kim (2001). A new method for conservation of nitrogen in aerobic composting processes. *Bioresour. Technol.,* **79(2)**: 129-133.

Jiang, T., F. Schuchardt, G. Li, R. Guo and Y. Zhao (2011). Effect of C/N ratio, aeration rate and moisture content on ammonia and greenhouse gas emission during the composting. *J. Environ. Sci.,* **23(10)**: 1754-1760.

Jiang, T., G. Li, Q. Tang, X. Ma, G. Wang and F. Schuchardt (2015). Effects of aeration method and aeration rate on greenhouse gas emissions during composting of pig feces in pilot scale. *J. Environ. Sci.,* **31**: 124-132.

Larney, F.J. and R.E. Blackshaw (2003). Weed seed viability in composted beef cattle feedlot manure. *J. Environ Qual.,* **32**: 1105–1113.

Liang, C., K.C. Das and R.W. McClendon (2003). The influence of temperature and moisture contents regimes on the aerobic microbial activity of a biosolids composting blend. *Bioresour. Technol.,* **86(2)**: 131-137.

Maulini-Duran, C., A. Artola, X. Font and A. Sánchez (2013). A systematic study of the gaseous emissions from biosolids composting: Raw sludge versus anaerobically digested sludge. *Bioresour. Technol.,* **147**: 43-51.

Mehta, C.M., V. Gupta, S. Singh, R. Srivastava, E. Sen, M. Romantschuk and A.K. Sharma (2012). Role of microbiologically rich compost in reducing biotic and abiotic stresses. In: T. Satyanarayana, B.N. Johri and A. Prakash (Ed.) Microorganisms in environmental management. Springer, New York pp. 113-134.

Mehta, C.M., U. Palni, I.H. Franke-Whittle and A.K. Sharma (2014). Compost: its role, mechanism and impact on reducing soil-borne plant diseases. *Waste Manage,* **34(3)**: 607-622.

Mehta, C.M., D. Yu, R. Srivastava, A. Sinkkonen, J.M. Kurola, V. Gupta, H. Jääskeläinen, U. Palni, A.K. Sharma and M. Romantschuk (2016). Microbial Diversity and Bioactive Substances in Disease Suppressive Composts from India. *Comp. Sci. Uti.,* **24(21)**: 105-116.

Parkinson, R., P. Gibbs, S. Burchett and T. Misselbrook (2004). Effect of turning regime and seasonal weather conditions on nitrogen and phosphorus losses during aerobic composting of cattle manure. *Bioresour. Technol.,* **91(2)**: 171-178.

Romano, R.T. and R. Zhang (2011). Anaerobic digestion of onion residuals using a mesophilic Anaerobic Phased Solids Digester. *Biomass Bioenerg,* **35(10)**: 4174–4179.

Samir, K.K., Y.S. Rao, C.Z. Tian, P.L. Buddhi, R.D. Tyagi and C.M. Kao (2010). Bioenergy and biofuel from biowastes and biomass. Reston: American Society of Civil Engineers: 44.

Shen, Y., L. Ren, G. Li, T. Chen and R. Guo (2011). Influence of aeration on CH_4, N_2O and NH_3 emissions during aerobic composting of a chicken manure and high C/N waste mixture. *Waste Manage,* **31(1)**: 33-38.

Tian, W., L. Li, F. Liu, Z. Zhang, G. Yu, Q. Shen and B. Shen (2012). Assessment of the maturity and biological parameters of compost produced from dairy manure and rice chaff by excitation–emission matrix fluorescence spectroscopy. *Bioresour. Technol,* **110**: 330-337.

Vavilin, V.A., B. Fernandez, J. Palatsi and X. Flotats (2008). Hydrolysis kinetics in anaerobic degradation of particulate organic material: an overview. *Waste Manage,* **28(6)**: 939-951.

Wackernagel, M., D. Moran, S. Goldfinger and M. Wallace (2004). Ecological Footprint Accounting: Comparing Resource Availability with an Economy's Resource Demand. *Aging Americans*, 85.

Yazdani, R., M.A. Barlaz, D. Augenstein, M. Kayhanian and G. Tchobanoglous (2012). Performance evaluation of an anaerobic/aerobic landfill-based digester using yard waste for energy and compost production. *Waste Manage,* **32(5)**: 912-919.

Yu, H., J. Jiang, Q. Zhao, K. Wang, Y. Zhang, Z. Zheng and X. Hao (2015). Bioelectrochemically-assisted anaerobic composting process enhancing compost maturity of dewatered sludge with synchronous electricity generation. *Bioresour. Technol.,* **193**: 1-7.

Zeng, J., G.W. Price and P. Arnold (2012). Evaluation of an aerobic composting process for the management of Specified Risk Materials (SRM). *J. Hazard Mater.,* **219**: 260-266.

Zhu, N. (2007). Effect of low initial C/N ratio on aerobic composting of swine manure with rice straw. *Bioresour. Technol.,* **98(1)**: 9-13.

Wiese, A.F., J.M. Sweeten, B.W. Bean, C.D. Salisbury and E.W. Chenault (1998). High temperature composting of cattle feedlot manure kills weed seed. *Appl. Eng. Agric.,* **14**: 377–380.