# Composting: Phases and Factors Responsible for Efficient and Improved Composting

**Technical Report** · January 2021

DOI: 10.13140/RG.2.2.13546.95689



**4 authors:**

Amrit Lal Meena
Indian Council of Agricultural Research


Minakshi Karwal
Krishna Institute Of Engineering And Technology


Debashis Dutta
ICAR-Indian Institute of Farming Systems Research


R.P. Mishra

# Composting: Phases and Factors Responsible for Efficient and Improved Composting

**Article ID: 10028**

**Amrit Lal Meena[1], Minakshi Karwal[2], Debashis Dutta[3], R.P. Mishra[4]**
[1,3,4]ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut-250110.
[2]KIET group of Institutions, Ghaziabad, Delhi-NCR, India-201206.

## Abstract

Microbial degradation of the organic matter over a period of time is known as compost. Biodegradable organic materials are the integral part of compost preparation. Being an 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. Composting is a biological process that occurs under aerobic conditions (presence of oxygen) with an adequate moisture and temperature, hygienic transformation of organic wastes in a homogeneous and plant available material. The three main phases of composting have been identified based on the temperature variations besides a phase of maturation. Being a biological process, microorganisms play a crucial role in composting process, therefore, factors affect the growth and reproduction of these microorganisms should be taken into account. These factors include aeration or oxygen, temperature, pH, moisture of substrate and C:N ratio.

**Key Words:** Biodegradable, Compost, C:N ratio, Microorganisms.

An organic matter (plant and/or animal residues), which has been degraded by the action of microorganism i.e., bacteria, fungi, actinomycetes etc. over a period of time 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 has characteristics of dark brown colour, crumbly in nature with a pleasant smell (Goluekem, 1991). Being an 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.

This can help to produce better yields. Compost can reduce pest and disease problems in the soil and on the crop. The crop will be stronger and healthier and therefore resist pest and disease attack better. Compost is a better way of feeding plants than using chemical fertilizers. Chemical fertilizers provide nutrients for plants but do not improve the structure or quality of the soil very much. Also, the nutrients present in chemical fertilizers are available to the crops of particular season. Compost, on the other hand, is not washed away through the soil like chemical fertilizers, so the beneficial effects are longer lasting (BSI PAS, 2005). Plants that are grown with chemical fertilizers are more attractive to pests and diseases because they have a greener, juicy growth. Crops grown on compost applied soils have better ability to withstand against the pest and disease infestation compared with inorganically grown crops.

## Phases in Composting

Composting is a biological process that occurs under aerobic conditions (presence of oxygen) with an adequate moisture and temperature, hygienic transformation of organic wastes in a homogeneous and plant available material. During composting process various microorganisms performed the complex metabolic processes to produce their own microbial biomass in the presence of oxygen, nitrogen (N) and carbon (C). In this process, additionally, the microorganisms generate heat and a solid substrate, with less carbon and nitrogen, but more stable, which is called compost (FAO, 1980 and 2020). During the decomposition process of initial complex organic C, N and organic matter a measurable heat is generated due to metabolic activities of microorganisms which causes temperature variations over the time period of decomposition process. The three main phases of composting have been identified based on the temperature variations besides a phase of maturation. These different phases of composting have been classified according to their temperature as:

1. Hot Phase (Mesophilic Phase).
2. Curing Phase (Thermophilic and Hygienization Phase).
3. Cooling or Mesophilic Phase II.
4. Maturation Phase.

## Hot Phase (Mesophilic Phase)

The composting process starts at ambient temperature and in a few days (or even hours), the temperature rises to 45°C. Metabolic activity of various heterogeneous group of microorganisms results in increased temperature as these microbes utilizes the N and C of the organic matter for their body assimilation. Decomposition of soluble compounds, such as sugars, produces organic acids and hence, pH can drop (to about 4.0 or 4.5). the hot phase lasts for two to eight days.

## Curing Phase (Thermophilic and Hygienization Phase)

When the temperature of the parent organic material attains temperature higher than 45 °C, the mesophilic microorganisms are replaced by the thermophilic microorganisms (mostly thermophilic bacteria) which has capacity to grow at higher temperature. These thermophilic microorganisms facilitate the degradation of complex organic matter i.e., cellulose and lignin. Conversion of nitrogen into ammonia by the thermophilic microbes results in pH rise of the compost pile during this stage (FAO, 1980 and 2020). In particular, over 60°C, bacteria producing spores and actinobacteria which are responsible for breaking down waxes, hemicellulose and other compounds of C complex, begin to develop. High temperature of compost pile during this phase helps in killing of contaminants and bacteria of faecal origin i.e., *Escherichia coli*, *Salmonella sp*. Helminth's cysts and eggs, phytopathogen fungi spores and weed seeds etc. thus this phase is also known as hygienization phase. Concurrently, this phase is very conducive as high temperature (above 55 ºC) helps in elimination of spores of phytopathogen fungi, helminth's cysts, weed seed and other harmful bacteria present in the parent material if any and raise a hygienized product.

## Cooling or Mesophilic Phase II

After the exhaust of carbon and nitrogen sources from the composting material, temperature of the pile decreases again to about 40-45 ºC. During mesophilic phase, polymers degradation as cellulose continues and some fungi visible to the naked eye appear. As temperature goes below 40 ºC, activity of mesophilic organisms resumes and pH of the compost pile decrease slightly, whereas in general pH of the compost pile remain slightly alkaline (Acharya, 1950). Some fungi can develop and even produce visible structures. This cooling phase requires several weeks and may be confused with the maturation phase.

## Maturation Phase

During maturation phase the temperature of the compost pile drops to the ambient temperature level (20-30 ºC) and during this phase condensation of carbonaceous compounds and polymerization occurs, which further helps in formulation of fulvic and humic acids.

## Factors Affecting the Composting Process

Being a biological process, microorganisms play a crucial role in composting process, therefore, factors affect the growth and reproduction of these microorganisms should be taken into account. These factors include aeration or oxygen, temperature, pH, moisture of substrate and C:N ratio (TNAU, 1999). Externally, the composting process largely depends on environmental conditions; the method used, raw materials, and other elements, so that some parameters may vary (Manickam, 1967). However, these parameters should always be within an optimal range and must be under constant surveillance. The parameters and their optimal ranges are listed below.

1. Aeration (Oxygen).
2. Carbon dioxide.
3. Moisture.
4. Temperature.
5. Carbon-nitrogen (C:N) ratio.
6. pH.
7. Particle size.

## Aeration (Oxygen)

Composting is an aerobic process and adequate ventilation should be maintained to allow respiration of microorganisms that release carbon dioxide (CO2) into the atmosphere. Similarly, aeration also helps in reducing compaction or water filling in the compost material. Oxygen requirements vary during the process, reaching the highest rate of consumption during the thermophilic phase.

The oxygen saturation level of the compost pile should not be <5% (optimum level 10%) (Raabe, 2001). Excessive aeration level results in temperature drop and moisture loss by the evaporation process and the low level of moisture hamper the decomposition process. Excess aeration also causes the dehydration of microorganisms' cells which further hampers production of the spores and enzymes which proliferate the degradation of various compounds of added organic matter (NRAES, 1992).

Contrarily, low aeration level (usually below 5%), results in excessive moisture which further generate excess moisture and anaerobic environment. Odours and acidity are then produced by the presence of compounds such as acetic acid, hydrogen sulphide (H2S) or methane (CH4) in excess.

**Table 1.** Aeration control during composting:

| Aeration percentage | Problem | | Solution |
|---|---|---|---|
| <5% | Low Aeration | Insufficient water evaporation, generates excessive moisture and anaerobic environment | Chop the material in order to reduce porous size and hence, aeration. Moisture should be regulated by adding water or fresh material or with more water content (fruit and vegetable craps, grass, liquid manure and others) |
| >15% | Excessive aeration | Drop in temperature and excess evaporation of water, causes the decomposition process to stop due to lack of water | |
| **5%-15% ideal range** | | | |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## Carbon Dioxide ($CO_2$)

Among all the aerobic processes, either human/animal/plant breath or compositng, oxygen plays a crucial role in transformation (oxidation) of carbon in to fuel present in the raw material. The oxidation process, tranform the carbon into biomass and carbon dioxide generated during respiration of microbes perform the photosynthesis for plants and other autotrophic microorganisms (Virginia, 1997).

During composting process, type of raw material used and activity of hetrotrophic microbes release $CO_2$ through their respiration. Generally, an amount of 2-3 kg $CO_2$/tonne of composting material is generated which has a low environmental effect as it is used by plants for photosynthesis.

E-ISSN: 2581 - 8317

## Moisture

The microbial activity and moisture level in composting material are closely related to each other as the water present in the raw material is used by the microorganisms for transportation of nutrient and energy through their cell membranes. The moisture level in the composting material varies based on the size of particles, physical condition of the material and the composting system. The ideal level of moisture in the compost material should be around 55%.

Table 2. Moisture control during composting:

| Moisture percentage | Problem | | Solution |
|---|---|---|---|
| <45% | Insufficient moisture | Can stop composting due to lack of water for microorganisms | Moisture should be regulated, either by adding water or fresh material with higher water content (fruit and vegetal waste, grass, liquid manure or others) |
| **45%-60% ideal range** | | | |
| >60% | Insufficient oxygen | Too wet material, oxygen is displaced. Can develop zones of anaerobic. | Turn the mixture and/or add low moisture content material with high carbon content such as sawdust, straw or dry leaves. |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## Temperature

Ambient temperature has a wide range of variation depending on the phase of the process. Composting begins at ambient temperature that can rise up to 65 °C with no need of human intervention (external heating). While, during maturation phase the compost pile attains the ambient temperature. The high temperature and longer time period possess high rate of decomposition and hygeinization, thus the temperature of the pile should not drop at faster rate.

Table 3. Temperature control during composting:

| Temperature | Problem | | Solution |
|---|---|---|---|
| Low temperature (ambient T < 35°C) | Insufficient moisture. | Low temperatures can occur by several factors, such as lack of moisture, so that microorganisms reduce the metabolic activity and therefore, temperature drops. | Wet the material or add fresh material with higher moisture percentage (fruit or vegetable waste or others) |
| | Insufficient material. | Insufficient material or inadequate pile shape to reach the appropriate temperature. | Add more material to the composting pile. |
| | Nitrogen deficit or low C:N ratio | The material has a high C: N ratio and hence, the microorganisms are lacking the necessary N to produce proteins and enzymes and slow down their activity. The pile takes more than week to increasing the temperature. | Add high N content material such as manure. |
| **20-70 0C ideal range** | | | |
| High temperature (ambient T | Insufficient ventilation and moisture | The temperature is too high and the decomposition is inhibited, since | Turn the mixture and/or add high C content material of slow degradation (wood or |

| | | | |
|---|---|---|---|
| >70°C) | | most microorganisms are inactive and die. | dry grass) to slow down the process. |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## pH

The composting pH depends on the source materials and varies in each phase of the process (from 4.5 to 8.5). During the early phases of composting, the pH of compost pile acidified due to release of various organic acids by the microorganisms. In the thermophilic phase, due to the conversion of ammonium into ammonia, the pH rises, the medium is alkalized to finally stabilize at values close to neutral. The pH is a determinant factor for microorganisms' survival and the various group of microorganisms have their optimal pH range for growth and multiplication. Most bacterial activity occurs at pH 6.0-7.5, while most fungal activity occurs at pH 5.5 to 8.0. The ideal range is from 5.8 to 7.2.

**Table 4.** pH control during composting:

| pH | Related Causes | | Solution |
|---|---|---|---|
| <4.5 | Excess of organic acid | Plant materials such as kitchen waste, fruit, release many organic acids and tend to acidify the medium. | Add material rich in nitrogen until an appropriate C: N ratio is achieved. |
| **4.5-8.5 ideal range** | | | |
| >8.5 | Excess of N | When there is excess of nitrogen in the source material, with poor C: N ratio related to moister and high temperatures, ammonia is produced and the medium is alkalized. | Add dry material with high carbon content (pruning, dry leaves, sawdust) |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## Carbon-Nitrogen (C: N) Ratio

The C:N ratio changes according to the parent material used for composting. The C:N ratio varies throughout the composting process, with a continuous reduction from 35:1 to 15:1.

Table 5. Carbon-nitrogen (C:N) ratio parameters during composting:

| C:N ratio | Related Causes | | Solution |
|---|---|---|---|
| >35:1 | Excess of Carbon | There is a large number of carbon-rich materials in the mixture. The process tends to cool and to slow down. | Add nitrogen-rich material until an appropriate C: N ratio is achieved. |
| **15:1 – 35:1 ideal range** | | | |
| <15:1 | Excess of nitrogen | There is a higher amount of nitrogen-rich material in the mixture. The process tends to overheat generating odours from the ammonia released. | Add material with high carbon content (pruning, dry leaves, and sawdust). |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## Particle Size

Microbial activity is related to particle size, that is, easy access to the substrate. A very small size of composting particles increases the specific surface area, which facilitates greater access the substrate. The ideal size of the parent materials for composting is 5 to 20 cm. the density of composting material, is closely related to particle size and ultimately affects the aeration and moisture retention of the compost pile. The density of the composting material at the start of composting remains approximately 150-250 kg/m3 which increases up to 600-700 kg/m3 with progress of composting process.

**Table 7.** Particle size control during composting:

| Particle size | Related Causes | | Solution |
|---|---|---|---|
| >30 cm | Excess of aeration | Oversized materials form aeration channels, dropping the temperature and slowing down the process | Chop the material up to an average size of 10-20 cm. |
| **5 – 30 cm ideal range** | | | |
| <5 cm | Compaction | Too fine particles form small pores that fill with water, facilitating compaction of the material and a restricted flow of air causing anaerobiosis. | Turn and/or add larger particles to homogenise. |

**Source: http://www.fao.org/3/y5104e/y5104e09.htm**

## Conclusions

Compost plays a crucial role in improvement of 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. Composting is a biological process that occurs under aerobic conditions (presence of oxygen) with an adequate moisture and temperature, hygienic transformation of organic wastes in a homogeneous and plant available material. For preparation of an ideal compost and within short period of time there is need of keeping all the factors affecting compost preparation in ideal range.

## References

1. "Open Pit Surface Mine" Mine Engineer Community (2000) accessed 19 December 2011.
2. Acharya C N. 1950. Preparation of compost manure from town wastes, Calcutta. Indian Council of Agricultural Research, Ministry of Agriculture, Bulletin No. 60.
3. BSI PAS (2005) Specification for Composted Materials British Standard Institution, London, UK, 100: 2005.
4. FAO. 1980. A manual of rural composting. FAO/UNDP Regional Project RAS/75/004 Field Document No. 15. Rome.
5. FAO. 2002. Biofertilizer production plant, Myanmar (FAO/UNDP Project), by H. Hiraoka. Back to Office Report. Bangkok, FAO-RAP.
6. Goluekem C (1991) The Staff of Bio Cycle Journal of Waste Recycling. The Art and Science of Composting, The JG Press Inc, Pennsylvania, USA, pp. 14-27.
7. Manickam, T.S. 1967. Chemistry of fertilizers and manures. Coimbatore, India, Division of Soil Science and Agricultural Chemistry, Agricultural Research Institute.
8. Natural Resource, Agriculture, and Engineering Service (NRAES). 1992. On-farm composting, edited by R. Rynk. Ithaca, USA, NRAES Cooperative Extension.
9. Raabe, R.D. 2001. The rapid composting method. University of California, US, Co-operative Extension, Division of Agriculture and Natural Resources.
10. Tamilnadu Agricultural University (TNAU). 1999. Crop production guide. Coimbatore, India.
11. Virginia, C.C. 1997. Rapid composting technology in Philippines: its role in producing good quality organic fertilizers. Extension Bulletin. Taiwan Province of China, FFTC.