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# Why and How Aerobic Mesophilic Composting is Effective? A Comprehensive Study on Aerobic and Anaerobic Composting of Green Waste under Mesophilic and Thermophilic Conditions

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***Research Article***

***Abstract:***The relative advantage of aerobic-mesophilic(ARM) condition forgreen waste composting over other conditions such as aerobic-thermophilic(ART), anaerobic-mesophilic (ANM) and anaerobic-thermophilic (ANT) is evaluated in the present investigation. A perusal of results indicated that ARM is the most favorable condition for green waste composting as it facilitates the growth and development of cellulolytic microbesand increasing their cellulose activity required for lignocellulosic degradation. Although, aerobic thermophilic condition (ART)was found to increase the rate of cellulose degradation, it was not mediated through cellulase activity. The effect of thermophilic phase on lignocelluloses wasmere physical in nature. The quality assessment studies on finished compost also confirmed ARM as the most favorable condition for composting.

***Keywords:*** aerobic, anaerobic, composting, mesophilic, thermophilic, cellulase

## 1.Introduction

Composting of organic waste is an aerobic biotransformation process where complex organic matter is converted by the action of some microorganism under controlled conditions (aeration, moisture, temperature) into a hygienic humus rich product(compost) for use as a soil conditioner and organic fertilizer[1]-[4].The variability in compostingretention times and decomposition ratesled to the development of different kinds of compostingprocesses and are broadly classified as aerated piles, turned window, in-vessel composting, anaerobic composting, tunnel composting, windrow composting, composting by biological treatment, and vermicomposting[5].However, thechoice of composting method depends on nature of material to be composted i.e. for food waste, and different kind ofsludge, which are too wet and lack the texture for composting, is treated via anaerobic digestion whereas green waste is composted either aerobically or anaerobically [6],[7].

Aerobic composting is the principle at work in aboveground composting environment, where it takes place in a freestanding pile or in a container that provides air circulation, such as a bin with open sides or a tumbler with aeration holes[8]. Supply of oxygen is vital for composting as it is linked to the composition and succession of microbial community during composting process[9].Sundberg and Jonsson (2008) demonstrated that increased rate of aeration caused higher microbial activity and increased pH at the biowaste composting and succeeded in shortening the time required to produce a suitable compost product[10]. Anaerobic composting generally works without oxygen, so most of the anaerobic composting takes place underground in pits or trenches. Anaerobic degradation is slower than their aerobic counterparts Lopes et al.(2004);Mohaibes and Heinonen-Tanski(2004), and also exude smelly gas as a byproduct of their exertionsand because of the colder conditions, weed seeds and plant pathogens aren't destroyed[11]-[13]. Anaerobic composting is totally different from anaerobic digestion, farmer with 50-55% moisture and in later more than 80% [14].Moreover, temperature is always below $40^0$C in anaerobic digestion due to the presence of higher moisture content.

Another important parameter, which greatly influences composting process, is temperature. It is the most critical factor forcomposting because of its effect on microbial metabolic rate and population structure[15]-[17]. Studies indicated that the maximum composting activity may be achieved in thermophilic conditions with the temperatures in the range of 50–60°C [18],[4].On the contrary, Rao et al. (1996)andVikman et al. (2002) reported that degradation of organic matter is faster inmesophilic temperatures. In their studies, higher rate of decompositionwas observed at 35 $^0$C and increased rate of $O_2$ uptake was noted at a temperatureof 43°C. Similarly, the rate of mineralization of carbon to $CO_2$was also observedto be high inmesophilic temperature (37$^0$C)[19],[20]. These indicated that mesophilic composting at lower temperature ranges is more favorable for biowastedegradation, despite the fact higher temperature is effective for the elimination of pathogenic and weeds seed during composting [21],[22].

Although, aerobic mesophilic composting (composting without any external heat) is the common type of composting of organic wastes which is faster and economically viable[23].Some other studies reported that aerobic thermophiliccomposting (above 50$^0$C) is the best option for biowastecomposting[24]. This has created new space for further research in assessingthe effectiveness and advantage of aerobic mesophilic composting over other methods of composting via aerobicthermophilic (ART), anaerobicmesophilic (ANM) and anaerobicthermophilic (ANT). The present investigation therefore aims at a comprehensive study to compare and contrast bothaerobic and anaerobic composting of green waste undermesophilic and thermophilic conditions.

## 2. Materials and Methods

### 2.1. Collection and processing of composting material

Greenwaste(GW) consisting of grass cuttings and fallen leaves were collected from the garden area of National Environmental Engineering Research Institute (NEERI).After initial screening, GW was air-dried for 24 hrs followed by 3 days of sun drying .The dried material was hand crushed to the size of 10 to 25 mm for further experiments. Known quantity of thishand crushed materialwas subjected to initial compositional analysis and the remaining used for further experiments.

### 2.2. Experimental set up

Composting experiments were carried out in glass composters of 2 kg capacity.Twelve composters (4x3) comprising three replicates for each (ARM, ART, ANM, ANT) experiment was maintained and in each composterone kilogram of dried and shredded material sprinkled with water was taken. Six composters were evacuated for anaerobic condition and placed in incubatorsfor both mesophilic (37$^0$C) and thermophilic (50$^0$C) conditions, respectively. The other six composters were keptunderaerobic condition with temperatures maintained for both mesophilic (37$^0$C) and thermophilic (50$^0$C) conditions, respectively in separate incubators. Changes in temperature during composting were recorded everyday using a mercury thermometer. The physico-chemical and biological parameters of compost samples were analyzed by drawing compost samples from different composters at an interval of seven days.

### 2.3. Chemical analysis of compost

Dried and powdered samples were used for all the chemical analysis. ThepH of compost was determined in deionized water with 1:10 (W/V) compost: water ratio [25]. The organic carbon content of compost was estimated by combustion method [26].The total nitrogen (TN) content ofcompost sampleswas estimatedusing LECO Protein-Nitrogen Analyzer (Model FP528). The concentration ofcellulose in compost sampleswas estimated by $HNO_3$-ethanol method of [27]. Lignin content of samples was estimated by 72% (v/v) $H_2SO_4$method according to[27]. The concentration ofpotassium was estimated by Flame photometric methodand phosphate by stannous chloride method [28].

### 2.4 Estimation of biological parameters

### 2.4.1. Cellulase activity

The activity of cellulase was determined in fresh samples (1g) after 7 days interval up to 21 days by filter paper assay of Adney and Baker (1996)[29].Theactivity reported in FPU/g/ hr. The value of 2.0 mg of reducing sugar as glucose from 50 mg of filter paper (4% conversion) in 60 minutes has been designated as the intercept for calculating filter paper cellulase units (FPU) as per IUPACstandards.

### 2.4.2. Estimation of microbial population

Total microbial biomass of compost samples was determined by serial dilution method. 1 g of compost sample on dry weight basis was taken and serially diluted in sterile distilled water. 1 ml from each dilution was plated onto potato dextrose agar media and nutrient agar followed by incubation at 30$^0$ C for 48 hrs. The colony forming units (CFU) were counted and the values after multiplied with dilution factor expressed in CFU/g of compost.

### 2.5. Statistical analysis

All the experimental analyses were carried out in triplicates and the mean values with standard deviation are presented. The data of cellulose degradation and final characterization of compost were statistically analyzed by one way ANOVA and Duncan's Multiple Range Test (DMRT) using IRRISTAT software.

## 3.0 Result and discussion

### 3.1 Characterization of greenwaste (GW)

The GW used in the present investigation consisted of grass cuttings and fallen leaves in the ratio of 1:1.The characterization of GW presented in Table 1. GW contained 50.55% organic carbon, 14.17% protein, 2.31 % total nitrogen, 43.86 % cellulose, 21.75% lignin, and 18.12% of hemicelluose. The initial C/N ratio of GWwas 21.88.

**Table 1. Initial characterization of thecomposting material**

| Parameter | Value |
|---|---|
| Organic Matter (%) | 80.63± 1.74 |
| Ash content (%) | 19.37± 1.03 |
| Organic carbon (%) | 50.55± 0.90 |
| Total Nitrogen (%) | 2.31± 0.27 |
| C/N ratio | 21.88± 1.96 |
| Cellulose (%) | 43.86± 0.54 |
| Lignin (%) | 21.75± 0.48 |
| Hemicellulose (%) | 18.12± 0.76 |
| Protein (%) | 14.71± 0.50 |
| Potassium (%) | 1.38± 0.03 |
| Phosphate (%) | 1.44± 0.03 |

Data are means ± SD (n=3)

### 3.2. Changes in temperature profile

The temperature profile of all four experiments Aerobic mesophilic(ARM),Aerobicthermophilic(ART),Anaerobicmesophilic (ANM) and Anaerobic thermophilic(ANT) are presented in Figure 1.The results showed a distinct thermophilic phasein aerobic (ARM and ART) conditions, wherein ART recorded an extended thermophilic phaseupto 7 days against 4 days in ARM composting. The temperature during thermophilic phase was above $60^0$C substantially enough to make physical impact on the substrate. Therefore, the marginal increase in the rate of cellulose degradation as observed in ART treatment (Figure. 4) could be due to the extended thermophilic phaseand high temperature that favored destabilization of lignocellulosic moiety through partial cooking effect. In contrast, anaerobic treatments recorded more or less same temperature during thermophilic phase corresponding to their incubation temperatures of $37^0$C and $50^0$C, respectively.

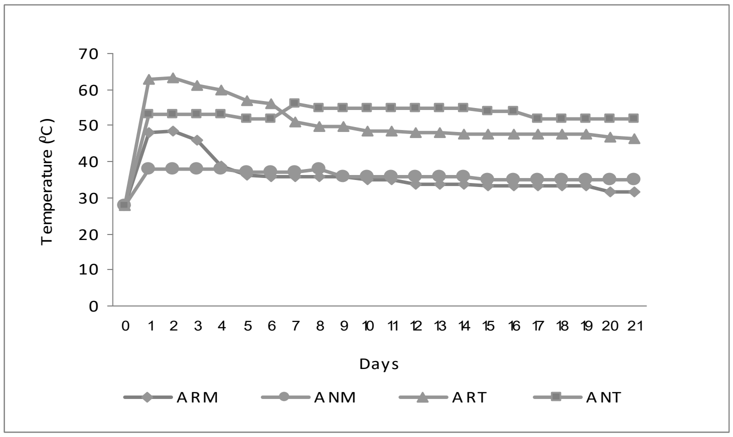

***Figure 1.****Influence of different conditions on temperature during composting*

### 3.3. Changesin pH

Mesophilic and thermophilic conditions of composting did not show any significant variationin pH among themselves. However, significant variation in pH was found between aerobic and anaerobic conditions of composting (Figure.2).The initial pH of 6.58 in ARM and ART composting rose to 9.35 and 9.08, respectively in 21 days without showing any significant variation among themselves. Similarly, in anaerobic (ANM and ANT) composting alsothe initial pH of 6.58 rose to 7.82 and 7.43, respectively in 21 days without any significant variation among themselves.Conversely, the range (6.32- 9.35) of pH in aerobic composting was significantly higher than that of anaerobic (6.32-7.82) composting. The variation in pH as observed between aerobic and anaerobic compositing may be due to the community of micro-organisms adopted in different environment and end product of their metabolism.

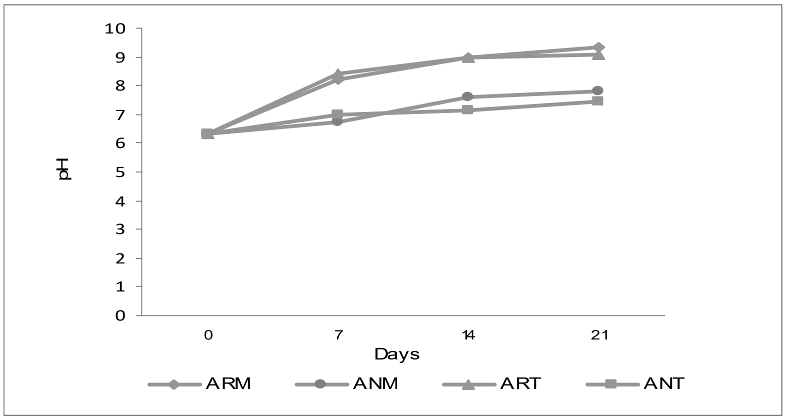

***Figure 2.*** *Influence of different conditions on pH during composting.*

### 3.4. C/N ratio

Reduction in C/N ratio of composting material under different experimental conditions is presented in Figure 3.TheC/N ratio reduction wasmore prominent in aerobic experiments (ARM (10.39) and ART (11.98)).Whereas, anaerobicexperiments (ANM and ANT) showed only a small decrease in C/N ratio, probably due to slowrate of organic matter degradation asreported by[11],[12].

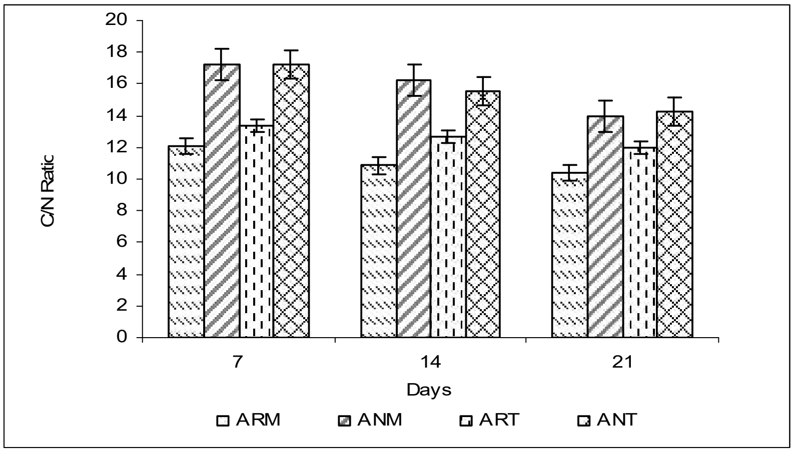

***Figure 3.*** *Influence of different conditions on C/N ratio during composting.*

### 3.5 Cellulose degradation

Figure. 4explainsthe rate of cellulose degradation as influenced by aerobic and anaerobic conditionsundermesophilic and thermophilic temperatures. The results showed an increase in cellulose degradation rate in case ofaerobic experiments, more specifically in ART.Whereas, anaerobic treatments showed an overall reduction in the rate of cellulose degradation due totheir insufficient load of cellulolytic microbes and activities.

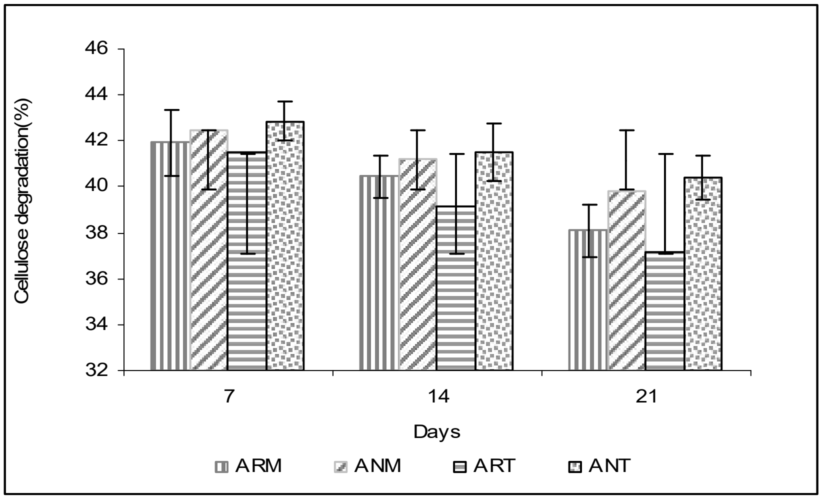

***Figure 4***. *Rate of cellulose degradation (%) as influenced by different composting condition.*

### 3.6 Microbial biomass and cellulase activity

Cellulase activity is responsible for the degradation of cellulose. It also signifies the density of cellulolytic microbes and their activities.A perusal of resultsshowed highestactivity of cellulose only in ARM experiment(Table 2). This could have been attributed to the favorable growth conditions existed in ARM experiment that facilitated the growth and development of cellulolytic microbes (Figure.5), leading to an increase in cellulase activityas well. It is usually envisioned that under aerobic conditions dedicated cellulase production will be carried out by aerobic microorganisms. This is because of the much higher ATP yields, and correspondingly higher potential cellulase yields of aerobic metabolism compared to anaerobic metabolism [30].In ART, temperature rose above 60 $^0$C which is unfavorable for the growth of cellulolytic microbes and cellulaseactivity.Both high (above 65$^0$C) and low (below 30$^0$C) is not favorable for cellulolytic activities because at high temperaturesenzymes become inactive and at low temperatures metabolic rate is hampered[31].On the other hand, the cellulase activity in anaerobic treatments was much lower due to low pH and anoxic condition.It is presumed that low pH conditions leads to anion toxicity that affects the growth of cellulolytic microbes[32].Cellulase activities among the anaerobic (ANM & ANT) treatments did not differ significantly. Both ANM and ANT recorded more or less same values forcellulase activity and microbial biomass. This indicates that the inhabitant anaerobic microbes were temperature independent but very specific to pH as explained by[33].

**Table 2.Cellulase activity (FPU/g) in different composting conditions**

| Days | ARM | ANM | ART | ANT |
|---|---|---|---|---|
| 7 | 0.7630 ± 0.0101**d** | 0.2199 ± 0.0012**b** | 0.5624 ± 0.0006**c** | 0.1406 ± 0.0003**a** |
| 14 | 0.3615 ± 0.0006**d** | 0.1050 ± 0.0055**a** | 0.1861 ± 0.0007**c** | 0.1332 ± 0.0004**b** |
| 21 | 0.1121 ± 0.0006**d** | 0.0754 ± 0.0008**b** | 0.0999 ± 0.0009**c** | 0.0518 ± 0.0008**a** |

Data are means ± SD (n=3) (Means followed by a common letter in row are not significantly different at the 5% level DMRT)
*ARM- Aerobic mesophilic, ANM-Anaerobic mesophilic, ART-Aerobic thermophilic, ANT-Anaerobic thermophilic

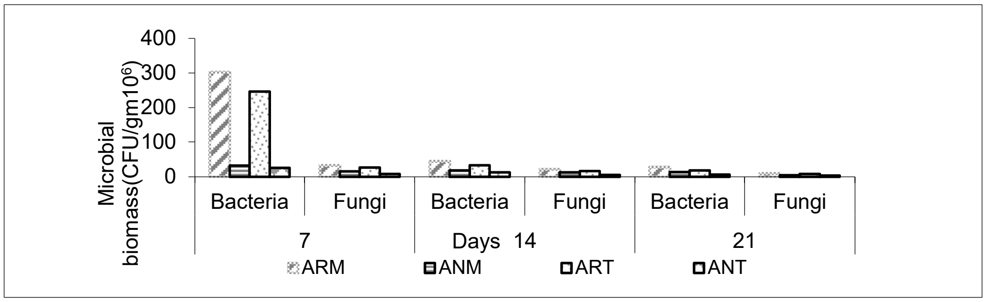

*Figure 5.Microbial biomass in different composting conditions*

### 3.7. Quality of the finished compost

Various physico-chemical parameters were analyzed in order to evaluate the influence of different composting conditions on the quality of finished compost (Table 3). The quality of finished compost obtained through aerobic composting process was better than the compost from anaerobic process. Concentration of macro and micro nutrients such as nitrogen, phosphorus and potassium in aerobic (ARM and ART) composts was higher than that of anaerobic (ANM and ANT) ones. The effect of aeration on C/N ratio was well pronounced that maximum reduction in C/N ratiowas observed only in aerobic composting. On the contrary, effect of temperature on C/N ratio was insignificant, although theromophilic phase caused a marginal reduction in C/N ratio.

**Table 3.Quality of the finished compost**

| Parameters | ARM | ANM | ART | ANT |
|---|---|---|---|---|
| Organic Matter (%) | 68.64 ± 4.82**a** | 75.80 ± 2.92**ab** | 74 ± 4.98**ab** | 77.42 ± 2.93**b** |
| Ash content (%) | 31.36 ± 0.91**d** | 24.2 ± 0.32**b** | 26 ± 0.97**c** | 22.58 ± 0.81**a** |
| Organic carbon (%) | 39.82 ± 2.80**a** | 43.97 ± 1.69**ab** | 42.95± 2.89**ab** | 44.91 ± 1.70**b** |
| Total Nitrogen (%) | 3.83 ± 0.20**b** | 3.08 ± 0.30**a** | 3.67 ± 0.05**b** | 3.15 ± 0.04**a** |
| C/N ratio | 10.39 ± 0.19**a** | 13.94 ± 1.46**b** | 11.98 ± 0.35**a** | 14.25 ± 0.63**b** |
| Cellulose (%) | 38.08 ± 1.96**a** | 39.84 ± 3.63**a** | 37.13 ±1.02**a** | 40.38 ± 1.68**a** |
| Potassium (%) | 2.65 ± 0.20**b** | 2.03 ± 0.10**a** | 2.44 ± 0.06**b** | 2.12 ± 0.07**a** |
| Phosphate (%) | 4.68 ± 0.30**b** | 3.36 ± 0.61**a** | 4.59 ± 0.16**b** | 3.78± 0.03**a** |

Data are means ± SD (n=3) (Means followed by a common letter in a row are not significantly different at the 5% level DMRT)

*ARM- Aerobic mesophilic, ANM-Anaerobic mesophilic, ART-Aerobic thermophilic, ANT-Anaerobic thermophilic

## 4.0 Conclusion

The main aim of the present investigation was to find out the influence of aerobic and anaerobic conditions under mesophilic and thermophilic temperatures on composting process. The results of the present investigation clearly indicated that aerobic composting under mesophilic temperature (ARM) is the most effective means of composting followed by aerobic composting under thermophilic condition (ART). All the vital parameters of composting responded positively for ARM than any other condition. Anaerobic condition did not favour composting process under both mesophilic and thermophilic phase. It can be concluded that aerobic composting under mesophilic composting in the efficient means of composting of organic wastes.

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