BENCH SCALE COMPOSTING OF ORGANIC WASTE

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1. ABSTRACT

Composting is a common treatment to retrieval organic portion solid of waste. Numerous methods are applied for composting purposes. Bench scale composting method was selected in this study to see the compost-ability of the organic waste generated in AUST periphery. Forced and passive aeration were applied in this analysis. The use of forced aeration provided sufficient oxygen for decomposition process; an aerator was used for this purpose. The proportion of waste mixture in this research consisted of 70% food waste, 15% paper waste and 15% saw dust. At first collected waste materials were mixed properly and poured into some heat insulator reactors of 1000 ml capacity. A number of selected reactors were in passive aeration process and the other selected reactors followed forced aeration process. The result shows i) total waste product after composting in first stage is reduced further in mass after second stage of composting, ii) total dry solid after composting in first stage is also attenuated further after second stage of composting, iii) approximate area under the temperature curve in ^{0}C.h also decreased in second stage compared to the first stage, iv) disappearance of offensive odor, digression of moisture content and height of waste mixture and change of color from fade brown to dark brown or almost black. Finally earthy smelled, dark brown or black coloured, stable end product was found.

Keywords: *Organic waste, Bench scale composting, Dry solid, Temperature profile, Waste mixture*

1. INTRODUCTION

Composting is a common treatment of solid organic waste. Composting generates high temperature which eliminates malignant microorganisms. The purpose of this study was solid waste processing practices to recovery the solid waste. Hoornweg et. al. (2000) reported that over 50 percent of an average developing country city's municipal solid waste stream could be readily composted. Composting treatment holds the potential to serve as a low-cost method of treating hazardous waste with minimal environmental controversy (Potter et. al. 2015). Michael (2002) reviewed that less expensive bench-scale composting reactor systems which can mimic actual composting process via self-heating are needed. One can achieve such systems without using the expensive temperature feed-back control by properly insulating the bench composting reactors. Guttentag and Robert (2014) conducted that organic wastes can be treated as composting which can convert organic waste into rich, dark colored compost, or humus, in a matter of a few weeks or months. Cole (1998) conducted that all composting methods share similar characteristic features and processes. Initially high microbial activity and heat production cause temperatures within the compostable material to rise rapidly into the thermophilic range (50^{0}C and higher). This temperature range is maintained by periodic turning or the use of controlled air flow. After the rapidly degradable components are consumed, temperatures gradually fall during the 'curing' stage. At the end of this stage, the material is no longer self-heating, and the finished compost is ready for use. Substantial changes occur in microbial populations and species abundance during the various temperature stages. Inckel et. al (2005) reported that a good composting process passes through 3 consecutive stages, these are as follows: a heating phase (fermentation), a cooling down phase, a maturation phase. The above 3 phase can be written as 2 phases these are as follows: active phase, curing phase. Composting is the bio-logical degradation of highly concentrated bio-degradable organic wastes in the presence of O_2 to CO_2 and water according to the reaction below, where the biologically generated waste heat is sufficient to raise the temperature of the composting mass due to the thermophilic range (50^0-65^{0}C). The final product of composting is a stable-humans, like material known as compost.

$$\text{Organic waste} + O_2 \rightarrow \text{compost} + CO_2\uparrow + H_2O\downarrow + NH_3\uparrow \ldots\ldots + \text{Heat}$$

There are many advantages of composting such as improved soil structure, moisture management, modifies and stabilizes pH, increases cation exchange capacity, provides nutrients for plant growth, provides soil biota, binds contaminants and re-vegetation and reclamation of marginal and low quality soils (US Composting Council, 1996).Compost, with its high organic matter content, can absorb up to four times its weight in water and can replace essential organic material in wetlands. Compost is an excellent component to manufactured wetland soils because of its high organic matter content, water holding capacity and microbial activity (BM, 1999). Demars et. al (1998) showed that compost application reduced soil loss by 86 percent compared to bare soils, and sediments reaching nearby surface waters decreased by 99 percent when compared to silt fences**,** and 38 percent when compared to hydro seeding applications. Demars et. al (1998) reported that Once incorporated with the soil, compost can increase infiltration up to 125 percent. Using compost in highly erosive areas can decrease erosion and allow quicker establishment of vegetation. Bench scale composting method was selected in this study to see the compostibility of the organic waste generated in AUST boundary. Bench scale composting method is beneficial for its ease control of important variables, monitoring, and smaller volumes of material to be composted.

2. MATERIALS AND METHOD

The bench scale composting study was conducted at the Environmental Engineering Laboratories of Ahsanullah University of Science and Technology; Dhaka, Bangladesh. Adequate oxygen content is one of the fundamental requirements of composting. Passive and forced two types of aeration were piloted in this study. The biodegradable fraction of waste mixture was assumed to comprise three substrates, namely mixed food waste (FW), saw dust (SD) and paper waste (PW). To maintain the ratio 70:15:15 of food waste, paper waste and saw dust a waste mixture was prepared. Moisture content of these raw materials was 71.33%, 1.0795% and 2.675% respectively. Thermo-flasks were used as heat insulator rector as shown in Figure 1.

Figure 1**:** (a) Prepared waste mixture contains 60% moisture content approximately, (b) Thermometer and pipe were placed into the reactor; (c) Prepared waste mixture in porcelains before drying in oven, (d) Waste mixture in the reactor (Thermo flask) was covered by pieces of foam, (e) End product (compost) after ending of second stage.

Waste mixture was poured into 1 liter of heat insulator. Selected reactors were in passive aeration and other selected reactors were in forced aeration. Composting process completed by ending of 3 phases and it takes 30-45 days to complete the first stage. Than second stage of composting is started which is similar to first stage.

Total waste, dry solid and approximate area (^{0}C.h) under the temperature-time curve has reduced after composting in second stage than in first stage. Finally as a end product earthy smelled, dark brown or black coloured, stable product was found. Different wastes such as canteen wastes saw dust and paper waste were collected from AUST campus. Prepare the waste mixture by mixing these wastes materials manually as shown Figure 1 (a). Squeezing the waste mixture by hand is applied to identify the moisture content. After squeezing if water comes out through the finger it means that the mixture contains approximately 60% of moisture content. To determine moisture content take some samples in porcelain and weigh before and after diving it in oven as shown in Figure 1 (c). Then pour waste mixture into thermo-flask. Enter the pipe of the aerator to the bottom of the reactor for forced aeration as shown in Figure 1 (b). Some flasks were kept in normally without entering the pipe just only pouring waste mixture for passive aeration. Thermometer is then entered in all reactors for measuring temperature (Figure 1d).

Observe the temperature of mixture till the temperature comes down to the ambient temperature normally 30^0-35^{0}C after 30-45 days. When the temperature of the mixture comes down near to the ambient temperature, the mixture was taken out from the reactor. Then weigh the flasks again after composting has done and determine the moisture content, dry solid, volatile solid fixed solid. After the composting has done; oven dry the mixture and pack (air tight) the compost mixture according to their reactors number At the end of all stages such as second stage of composting the stable end product was attained as shown in Figure 1(e).

3. RESULTS AND DISCUSSION

3.1 First Stage Composting

The first stage continues 36 days (from 07-03-15 to 11-04-15). In first stage, initial moisture content of three constituents (food, paper, and saw) was calculated. The average moisture content of food waste, paper waste and saw dust were 71.33%, 1.08% and 2.68% respectively. Determination of initial moisture content (%) of three raw waste materials; materials were mixed (7.5: 1.5: 1.5) in such manner that it contains at least 60% of moisture. Ten samples were taken in individual porcelain and drying in oven; the average moisture content was 62.29%. In first stage seventeen reactor were used. Forced aeration was provided in 12 reactors and rest reactors were kept in normal aeration. Moisture content of waste mixture in each reactor were nearly 60%. In Table 1 shows the value of dry solid (gm.) moisture (gm.) before composting is done.

Completion of all necessary set-up composting process is begun. Waste starts to decompose. In active phase waste decompose rapidly and temperature rise sharply within 10 to 20 days of starting process. With the increasing of days curing phase takes place and decomposition rate turns to slow and temperature falls gradually. Actually this decomposition is never stoppable; mainly rate of decomposition is slowed down with time. With the degradation of waste mixture; weight of mixture is decrease as shown in Table 1.
During composting waste are degraded. As a result moisture content before composting is much than dry solid. During composting waste starts to degrade and moisture is reduced and dry solid is also decreased than before. At end of the process a reasonable amount of weight is lost in each reactor. In case of first stage of 12 reactors were followed by forced aeration and rest 5 reactors were followed by passive aeration. From Figure 2 it can be seen that the average amount of dry solid of 12 forced aerated reactors; before and after composting were 232.9 and 167.3 gm respectively. The average amount of moisture for forced aerated rectors; before and after composting were 349.33 and 52.87 gm respectively. The average amount of dry solid of 5 passive aerated reactors; before and after composting were 273.8 and 246.8 gm respectively. The average amount of moisture for natural aerated rectors; before and after composting were 411.3 and 95.1 respectively. In both case; forced aerated and passive aerated the amount of moisture is decreased after ending of composting. The decomposition rate is better in forced aerated than to normal aerated reactor.

In forced aeration extra oxygen is provided for continuing the process smoothly and rapidly. This extra oxygen helps to dry the wsate mixture properly. The amount of dry solid is much in passive aerated reactor than forced aerated reactor. Total amount of dry solid and moisture in stage-1 before completion of composting were 4163 gm. and 6248 gm, respectively. Total amount of dry solid and moisture in stage-1 after completion of composting werre 3237 gm. and 1110 gm, respectively.

Table 1: In first stage total weight and moisture content before and after composting. Before composting the moisture content of all waste mixture was 62.29%. Area under ambient temperature curve was 13376 °C.h

Reactors/ FA or NA	Before Total weight of waste mixture in gm	After Total weight of compost in gm	After Moisture content %	Area under Temperature curve °C.h
A1/ FA	650	235	22	13274
A2/ FA	491	199	23	13013
A3/ FA	536	236	25	12991
B1/ FA	651	206	25	8545
B2/ FA	644	260	21	8356
B3/ FA	653	293	28	8709
C1/ FA	643	303	22	13295
C2/ FA	487	196	27	13508
C3 / FA	588	210	23	13570
D1/ FA	468	116	24	13900
D2/ FA	620	265	22	12950
D3/ FA	553	121	28	13650
E1 /PA	580	305	25	8763
E2/ PA	614	295	28	9625
E3/ PA	680	371	30	11229
F1/ PA	730	363	29	10262
F2/ PA	822	373	32	6397
Average	613	256	26	11296

FA=Forced Aeration and PA=Passive Aeration

First stage of composting runs for 36 days. During the active phase of composting temperature rise sharply. A1, A2, A3, B1, B2, B3, C1, were selected forced aerated reactors represented in Figure 3. In reactor A1 temperature starts to rise from 12 day to 22 days. In A2 temperature starts to rise from 10 days to 17 days. In A3 temperature starts to rise 6 days to 15 days. Pathogens are killed in temperature 50^{0}C; in A2 peak temperature is 65^{0}C and stayed for 5 days, that means pathogens are died in reactor A2.

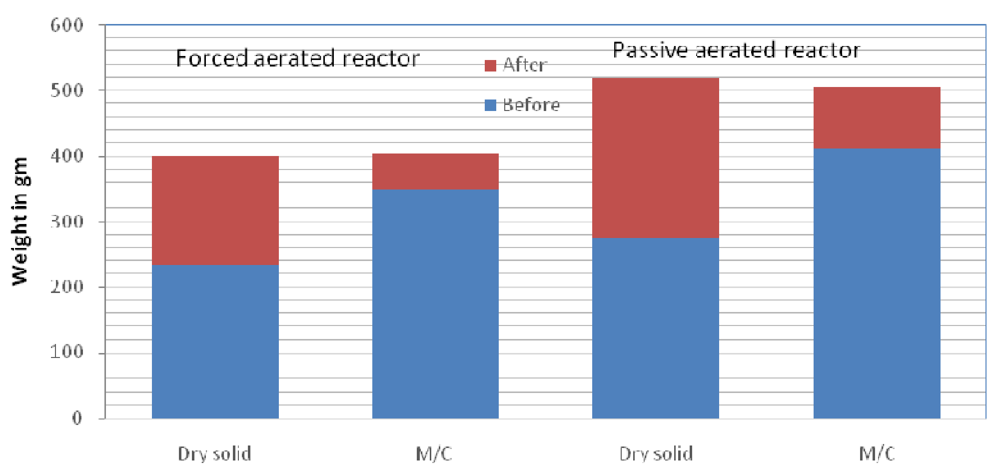

Figure 2: The average MC and dry solid for forced aerated and passive aerated reactors in stage 1.

Temperature starts to rise in B1, B2 and B3 forced aerated reactors within 10 to 20 days. Peak temperature was around 60^{0}C for all reactors; enough for pathogen died. In all of these reactors composting has done smoothly and equally. In first five days temperature rises quite slowly and in uniform rate in C1, C2 and C3 reactors. Temperature starts to rise of all three forced aerated reactors within 7 to 15 days. Peak temperature is 65^{0}C; enough for pathogen killing. In Figure 3 it can be seen that in forced aerated reactor D1; temperature fluctuates much. Due to the proper presence of oxygen composting cannot be done in proper way; temperature ups and down much. Ambient temperature varies 26^{0}C -27^{0}C.

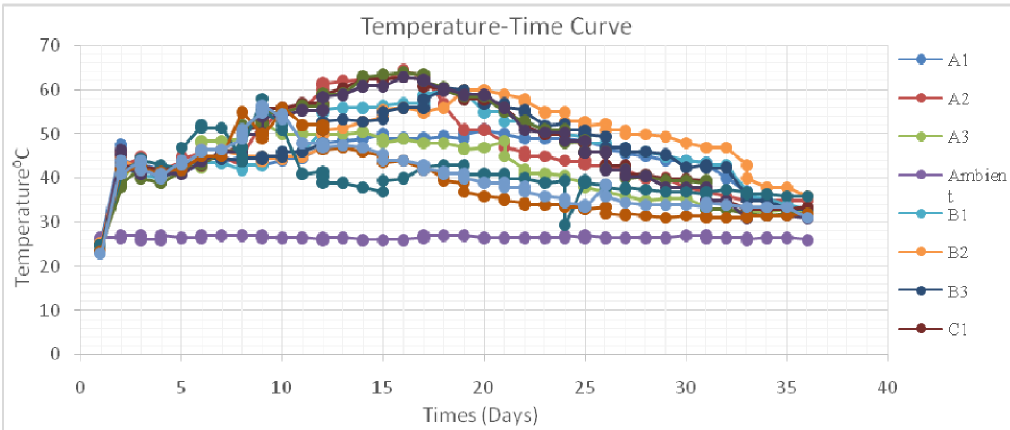

Figure 3: Temperature profile of twelve forced aerated reactors in stage-1.

In Figure 4 temperature starts to rise of all three normal aerated reactors within 10 to 25 days. Peak temperature is around 56^{0}C for reactors E3. Normally 50^{0}C is needed for all pathogen killing. This peak temperature remains unchanged for long 15 days; it ensures that pathogens are died in E3 reactor. In E2 peak was 50^{0}C and lasted for 15 days; more than enough time for all pathogen killing. In E1 peak was 46^{0}C; temperature does not rise smoothly. In all of these reactors composting has done smoothly and equally. Ambient temperature varies 26^{0}C -27^{0}C.In Figure 6 temperature starts to rise of both normal aerated reactors within 10 to 25 days. Peak temperature is 52^{0}C for F1 and 45^{0}C is not enough temperature for pathogen has died in these reactors. In all of these reactors composting has done smoothly and equally.

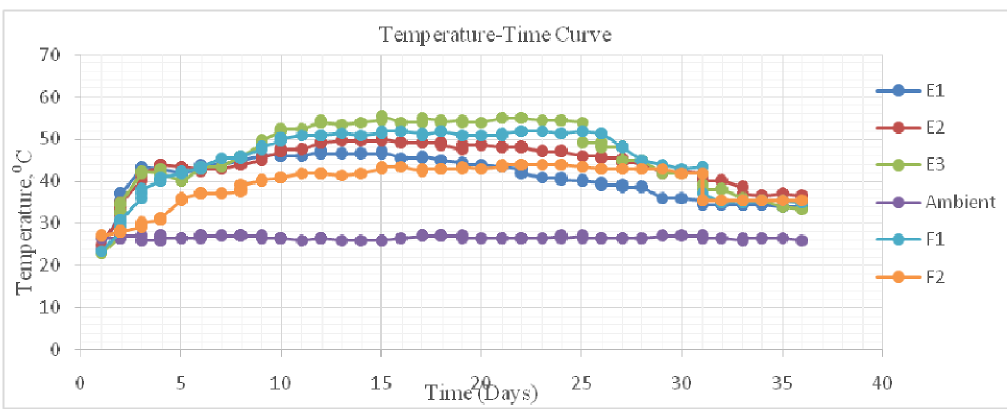

Figure 4: Temperature profile of five passive aerated reactors in stage-1.

From temperature variation in Figure 3 and 4 approximate areas (^{0}C.h) is found. From the whole composting temperature area the ambient temperature area is subtracted. Composting of first stage was continued 36 days (864 hrs.). Area under temperature curve of seventeen reactors is given in Table 1. The average area over 21 days for seventeen reactors is 11296 ^{0}C.h.During composting waste mixture is decomposed; volume of the mixture is decreased. Height of the composting mixture is decreased gradually in each reactor. In Figure 7 average height of 17 reactors is shown. From Figure 7 it can be seen that height decrease rapidly in Forced aerated reactor than passive Initial height for both forced and passive aerated reactor was 21.59 cm; after completion of composting height of waste mixture in forced aerated and passive aerated reactors decreased to

16.764 cm and 18.3 cm after 36 days. The difference in height decreasing of waste mixture between forced and passive aerated reactors was 1.536 cm. In an average height of waste mixture in case of passive aeration decreased 1.5- 2 cm less than in forced aeration.

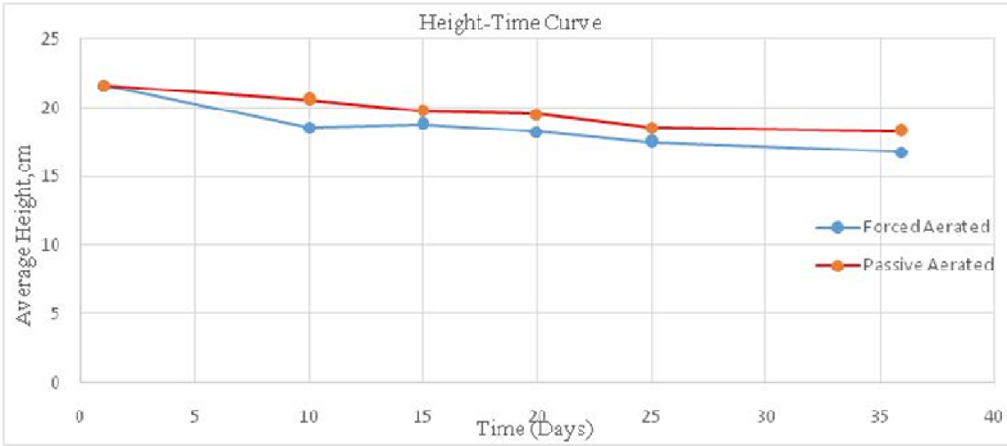

Figure 5: Average height-time curve for all forced aerated and passive aerated reactor in stage-1.

3.2 SECOND STAGE OF COMPOSTING

After completion of first stage of composting average moisture content of the mixture was 33.23% is calculated. Moisture content is kept 55% in the next mixture for second stage. This stage continued for 21 days (from14-06-15 to 05-07-15). Adding necessary amount of water with waste than mixed the mixture carefully in such manner that it contains 55% of moisture. Than five sample of waste mixture is taken into the individual porcelain and drying for 24 hours; determined the average moisture of five sample of waste mixture was 56.7%. In second stage five reactors were used. Forced aeration was provided in 3 aerators and two reactors were kept in normal aeration. In second stage the total weight and moisture content before and after composting is shown in Table 2.

Table 2: In second stage total weight and moisture content before and after composting. Before composting the moisture content of all waste mixture was 56.7%. Area under ambient temperature curve was 13376 ^{o}C.h.

Reactors/ FA or NA	**Before Total weight of waste mixture in gm**	**After Total weight of compost in gm**	**After Moisture content %**	**Area under Temperature curve ^{o}C.h**
F1/ FA	695	297	31	9960
F2/ FA	644	297	34	9684
F3/ FA	630	292	34	10230
E3/ FA	612	301	31	9480
E2/ FA	646	323	33	9636

FA=Forced Aeration and PA=Passive Aeration

The average amount of dry solid of 3 forced aerated reactors; before and after composting were 295.45 and 199.13 respectively as shown in Figure 6. The average amount of moisture for forced aerated rectors; before and after composting were 361.09 and 93.67 respectively. The average amount of dry solid of 2 passive aerated reactors; before and after composting were 283.15 and 211.9 respectively. The average amount of moisture for forced aerated rectors before and after composting were 346.06 and 89.95 respectively. In both case; forced aerated and passive aerated the amount of moisture is decreased after ending of composting. The decomposition rate is better in forced aerated than to normal aerated reactor.

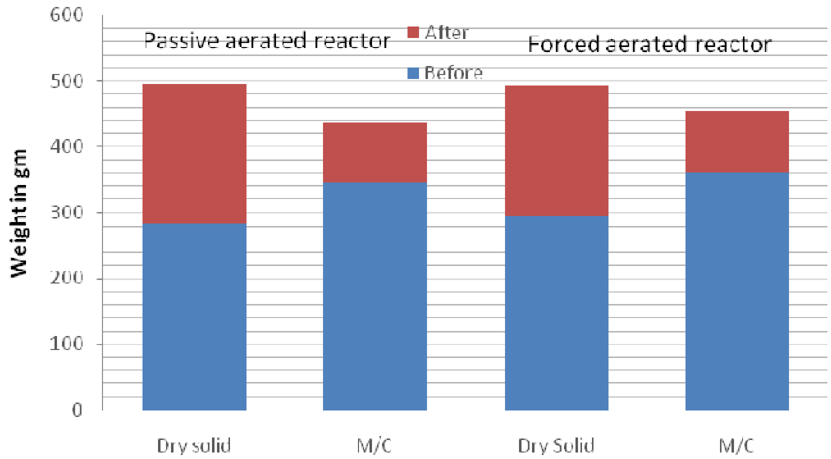

Figure 6: The average mc and dry solid for Passive aerated and forced aerated reactors in stage 2

Compare to first stage temperature rises very sharply in second stage than first stage. In Figure 7 represent the temperature profile of forced aerated F1, F2 and F3 reactors. Second stage of composting runs for 21days. During the active phase temperature rise very sharply with time compare to first stage. In reactor F1 temperature starts to rise from 5 days to 12 days. Peak temperature was 66^0C. In F2 temperature starts to rise from 5 days to 12 days. Peak temperature was 67.5^0C. In F3 temperature starts to rise 5 days to 12 days. Peak temperature was 68^0C. In all reactors contains enough temperature and this temperature is remain unchanged for 3 to 4 days; indicates that all pathogens are killed in all of these reactors. Passive aerated reactors E2 and E3 temperature rises very sharply from 5 days to 12 days and then decreased gradually. Peak temperature was 65^0C and 66^0C respectively. Peak temperature was above 65^0C for both reactors; enough temperature for pathogen is killed. Ambient temperature varies 26^0C -27^0C.

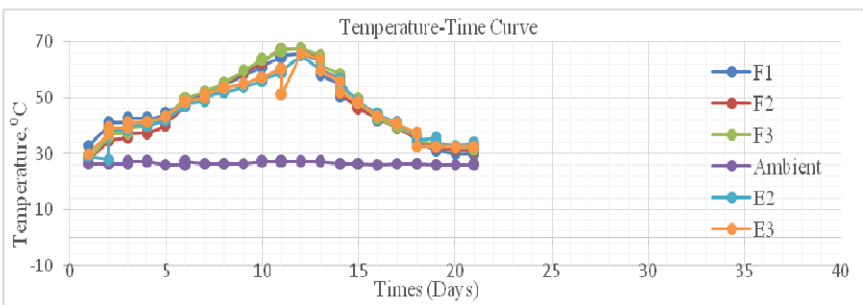

Figure 7: Temperature profile of forced aerated reactors and passive aerated reactors.

From temperature profile graph in Figure 7 approximate area (^{0}C.h) is found. From the whole composting area in temperature curve subtracts ambient area; only composting area is found. Temperature was in ^{0}C and time counted in hour. Composting of second stage was continued 21 days (504 hrs.). Approximate areas under temperature curve of 5 reactors are shown in Table 2. The average area of five reactors is 9798 ^{0}Ch.

During composting waste mixture is decomposed; volume of the mixture is decreased. Height of the composting mixture is decreased gradually in each reactor. In Figure 8 the average height stage-2 of 5 reactors is shown. From Figure 8 it can be seen that height decrease rapidly in Forced aerated reactor than passive Initial height for both forced and passive aerated reactor were 20.8 and 20.6 cm respectively. After composting the height of waste mixture in forced aerated and passive aerated reactors decreased to 17.5 cm and 18.3 cm over 21 days. The difference in height decreasing of waste mixture between forced and passive aerated reactors was 0.8 cm. In an average height of waste mixture in case of passive aeration decreased 1.5 cm less than in forced aeration.

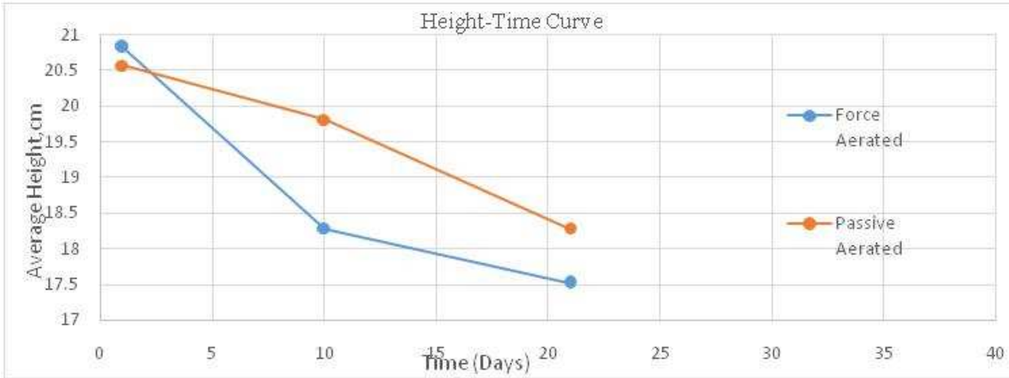

Figure 8: Average height variation for all reactors in stage-2.

Moisture content (%) in every stage of composting is reduced. This indicates the completion of composting. Before starting of composting process moisture content of mixture was about 50%-60% and after composting is reduced. Average moisture content of waste mixture in 17 reactors after composting was 25.54% of stage-1. Average moisture content of waste mixture in 5 reactors after composting was 32.4% of stage-2. In most of the reactors the height of the waste initially was 20.828 cm. to 20.32 cm. and after completion of composting it reduced to 17.78 cm. to 15.24 cm. Height decreased rapidly in passive aerated reactors than in forced aerated reactors. In an average height of waste mixture in case of passive aeration decreased 1.5 cm less than in forced aeration. The average temperature area for both stages was calculated for 21 days. The average area of seventeen reactors is 11296 ^{0}Ch for first stage of composting. The average area of five reactors is 9798 ^{0}Ch. Area is decreased in second stage than first stage; indicates the high degradation in first stage than second stage. Before composting waste mixture has offensive odor at the end it is disappeared. At the end of the composting waste color was almost dark.

4. CONCLUSIONS

- Moisture content in every stage of composting is reduced. Before starting of composting process moisture content of mixture was about 50%-60% and after composting is reduced. Average moisture content of waste mixture in 17 reactors after composting was 25.54% in first stage. Average moisture content of waste mixture in 5 reactors after composting was 32.4% in second stage.
- Peak temperature was ranged between 45^{0}C and 55^{0}C, respectively for first stage and 60^{0}C and 66^{0}C respectively, for second stage. Peak temperatures counted in second stage are enough temperature for pathogen destruction.
- In most of the reactors the height of the waste initially was 20.8 cm. to 20.3 cm and after completion of composting it reduced to 17.8 cm to 15.2 cm. Height decreased rapidly in passive aerated reactors than in forced aerated reactors.
- The average temperature area for both stages was calculated over 21 days. The average area of seventeen reactors was 11296 ^{0}C.h for first stage of composting. The average temperature area of five reactors is 9798 ^{0}C.h. Area is decreased in second stage than first stage; indicates the high degradation in first stage than second stage.

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