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BENCH SCALE STUDY ON CO-COMPOSTING FOR ORGANIC SOLID WASTES AND FAECAL SLUDGE

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ABSTRACT

Faecal sludge has a high moisture and nitrogen content, while biodegradable solid waste is high in organic carbon and has good bulking properties (i.e., it allows air to flow and circulate). By combining the two, the benefits of each can be used to optimize the process and the product.This paper shows the variation of physiochemical characteristics in the different stages of combined treatment of faecal sludge and municipal solid waste through co-composting. The objectives of the study were to observe the extent of degradation by measuring the volatile solids, percentage carbon contents and area under temperature, determine the volume mass and height reduction and examine the temperature fluctuation for the different compost mixtures. Composting process was done in two stages by both active and passive aerobic condition for 51 days. In the compost mixture, solid waste was combined with dewatered faecal sludge in mixing ratio of 3:1 by weight. Samples were taken at the beginning and end of a stage and analyzed for percentage volatile solids, percentage fixed solids and percentage carbon content. Temperature, moisture content, height, weight and color were chosen as maturity indicators. Result showed a preference of using faecal sludge in composting process. It is clearly observed that the value of percentage volatile solids and percentage carbon were reduced to a significant amount which were almost half of the initial percentages. The output of this research can help to design the small-scale composting system for municipal solid waste management in low income countries.

Keywords: *Faecal Sludge, MSW, Organic Solid Wastes*

1. INTRODUCTION

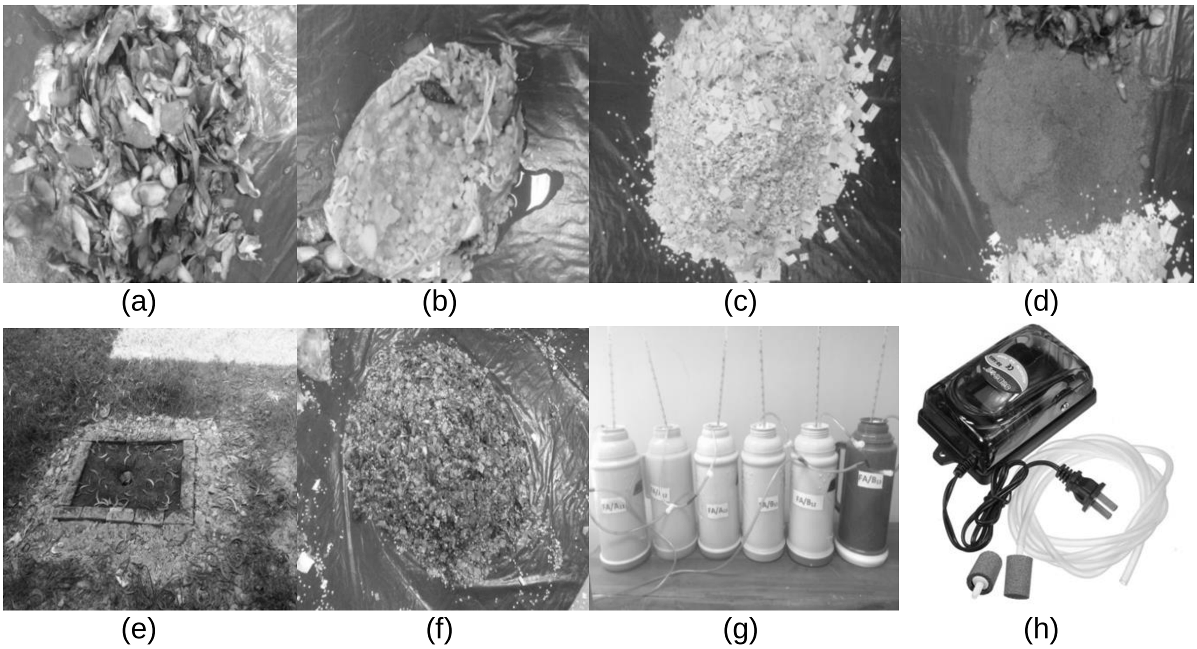
In many countries including USA, Germany, India and Bangladesh, composting has become one of the most economic ways of solid waste treatment. It requires lower equipment and operation cost. Organic waste composting techniques have been extensively developed in recent decades in response to the increasing concern about the amount and management of wastes. It is one of the most effective and efficient way to manage organic waste and it helps to reduce the volume of waste almost 50%. With this population growth, there is an increasing problem of waste management particularly in the larger cities. The large amount of municipal, industrial and agricultural wastes have led increasing environmental, social and economic problems. For these waste disposals agricultural lands are used as landfill. The two primarily environmental concerns related to landfills are leachate generation and gas emission. The leachate produced from landfills may contain a variety of toxic and polluting components. If managed improperly, leachate can contaminate groundwater and surface water. Landfill gas which is consists of carbon dioxide and methane, small amounts of nitrogen and oxygen. Methane is a greenhouse gas and very harmful for the environment. For this reason Municipal Solid Waste (MSW) management has become one of the largest environmental concerns in recent decades (Iqbal et al., 2010). The high organic fraction in MSW makes it easy to be converted to the energy sources through composting (Jolanun and Towprayoon, 2010; Ponsá, 2010).

Compost can be used as soil conditioner that minimizes the use of chemical fertilizers and has significant environment benefits. It is made up of waste material that is generally high in either carbon or nitrogen. It improves soil water-holding capacity. Compost loosens clay soils and helps sandy soils retain water by binding soil particles together. Besides solid waste treatment, the management of faecal sludge is another concerning factor in an overpopulated country like Bangladesh. Faecal sludge, also known as bio-solids, is a by-product of faecal sludge treatment processes, which final disposal represents 50% of the total operating cost of faecal sludge treatment plants (BETTIOL and CAMARGO, 2007). Co-composting is a combined treatment of faecal sludge and municipal solid waste.

Co-composting of faecal sludge and organic solid waste allows recycling of nutrients into agriculture thereby closing the nutrient loop. The two materials compliant each other and provide missing component in inorganic fertilizer. However effective use of such compost in agriculture depends among other factors on its quality. Several authors have proposed some particular methods such as CO_2 evaluation, pH, C/N ratio, temperature, moisture and colour to determine compost maturity (Tiquia et al., 1996; Sharma et al., 1997; Lasaridiet et al., 2006). The compost product is adequately sanitized with co-composting process and can be used with reduced risk to applicator public health as well as the environment.

2. METHODOLOGY

The co-composting of solid waste and faecal sludge has performed in the laboratory of Ahsanullah University of Science and Technology. The experiment has done with a ratio 55:25:10:10 of mixed food waste, faecal sludge, saw dust and paper cutting and two types of aeration namely forced aeration and passively aeration. Food wastes consist of cooked rice, fried rice, cooked vegetables, bread, burger, noodles etc. Vegetable wastes consist of potato, cabbage, gourd, onion etc. Food wastes and vegetable wastes were collected from AUST hall and AUST canteen. Saw dust was collected from Badda saw mill and paper waste was collected from paper factory. Dewatered faecal sludge was collected from KUET waste management plant.



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 1: a) vegetable wastes, b) food wastes, c) paper cutting, d) saw dust and e) dewatered feacal sludge f) waste mixture g) reactors h) pumper

A number of equipment were required and used during the various stages of the study. In this experiment thermo flasks were used as heat insulator. The volume of each flask is 1 litre. Two types of electric balance were used in the experiment. One was normal electric balance which is not capable of measuring decimal numbers. Another was sensitive electric balance which can count up to three decimal numbers. Thermometers are used to measure temperature fluctuation and each thermometer was checked before installation whether it was working or not by using it in water at room temperature. Two plastic pipes were connected with two pumpers and then connected to the reactors. Several piping network were created from one point of the pump by using some connecting pipes. Air controller keys were used to control the air the approximately same amount of air was entered into several flasks. Air pressure of the pump was checked before installation. Normal oven and muffle furnace were used to determine the moisture content and organic content respectively. In the normal oven, the sample waste was kept for 24 hours. The temperature was maintained constantly 103 ºC to 105 ºC. In muffle furnace the temperature was maintained around 500~550 ºC.

Plastic spoon, bottle, polythene etc. were separated from the food waste because these do not decompose. In addition bones, tissue, fishbone etc. are also removed. Bones are very slow to decompose. These can also attract pests. These products can overheat the compost piles. From vegetable wastes tomato was removed as it increase the pH and toxic the compost mixture. Particle size affects the rate of organic matter breakdown. The more "surface area" available, the easier it is for microorganisms to work, because activity occurs at the interface of particle surfaces and air. Microorganisms are able to digest more, generate more heat, and multiply faster with smaller pieces of material. Although it is not required, reducing materials into smaller pieces will definitely speed the decomposition process. Larger part of bread and vegetables of food wastes and vegetable wastes were shredded into smaller pieces. Moisture content of all raw wastes was measured before mixing.

All the waste components namely food waste, vegetable waste, faecal sludge, saw dust and paper waste were taken according to predefined ratio. Then these wastes were mixed very carefully so that waste components are uniformly distributed. Composting proceeds best at a moisture content of 40-60% by weight. At lower moisture levels, microbial activity is limited. At higher levels, the process is likely to become anaerobic and foul-smelling. So we tried to keep moisture content of waste mixture 50 to 60%. To identify the moisture content the mixture is squeezed by hand. If water comes out of it, the compost is too wet. If the compost does not release water but crumbles apart when released, it is too dry. If the compost does not release water but stays compacted, it is in right condition of wetness to carry out composting process.

Before pouring the waste mixture, air pipe was placed in the reactor in case of forced aeration. The outer surface of the reactor was properly cleaned after pouring the waste mixture. Weight of reactor was taken before and after pouring of waste into it. Height of waste in reactor was measured by using scale. For both passively and forced aeration, the reactor was properly labelled and numbered before the final placement.

At the initial stage of composting, the rise of temperature was rapid. That's why the temperature reading was taken at least two times or more in a day. To observe the reduction of volume, the height of the sample was measured after each 10 days. In every stage, the reactors were kept under both passively and forced aeration condition. The difference in temperature fluctuation occurs due to the aeration condition. It has been observed regularly whether the aerator is working properly or not. Temperature fluctuation rate decreased at the end of a stage. When the temperature became stable, the temperature change was noticed after altering the aeration condition after 2 days. At the end of each stage, physical appearance and odor, moisture content and volatile solids percentage, volume and weight loss after composting etc. were measured.

3. RESULTS AND DISCUSSION

First Stage of Co-composting

Co-composting was done by mixing of solid wastes and faecal sludge. The compost mixture contains 30% food wastes, 25% vegetable wastes, 25% faecal sludge, 10% saw dust and 10% paper waste. Co-composting was run for total 51 days and done in two stages. First stage and second stage were carried out for 26 days and 25 days respectively. Moisture content and dry solids were measured before and after the composting process. Weight loss of raw waste mixture due to composting process was calculated. Temperature reading was observed throughout the composting process. It is recommended that 55% to 60% moisture content is suitable for composting process. The optimum MC was 60% during the composting of green waste and food waste at a low C/N ratio (19.6) (Kumar et al., 2010). In Table 1 moisture content of waste mixtures is shown and the average of moisture content was found near 53% before composting. In first stage of co-composting six reactors were used. Among these reactors three reactors were forced aerated and three were passively aerated. Moisture content of waste mixtures after composting in each reactor was nearly 48%. Before started composting process moisture content of waste mixture was nearly 53% means rest 47% was in dry. So the moisture is more than dry solids before composting. During composting waste starts to degrade and moisture is reduced and dry solids is also decreased than before. As a result end of the process a reasonable amount of weight is lost in each reactor as shown in Table 1.

Table 1: Percentage weight loss, area under temperature and Moisture content before and after composting

Reactor name	**Waste mixture weight (before), gm**	**Waste mixture weight (after), gm**	**Percentage weight loss**	**Moisture content (%) (before)**	**Moisture content (%) (after)**	**Area under temperature, °C.hr**
PA11	410	283	30.97	53.76	50.88	6456
PA12	459	333	27.45	53.76	49.36	8040
PA13	430	313	27.20	53.76	51.51	7518
FA11	433	383	11.54	53.76	46.25	6948
FA12	436	308	29.35	53.76	45.83	7132
FA13	413	360	12.83	53.76	46.14	5112

FA=Forced aerated PA= Passively aerated

From the value of Table 1 it is seen that the weight decreasing rate of forced aerated reactor is higher than the passively aerated reactor. Percentage weight losses of passively aerated reactors are around 11% to 29% and forced aerated reactors are around 28%. First stage of co-composting process was continued for 26 days and the temperature measured in °C. For forced aerated reactors the area under temperature is varies between 5112 °C.hr and 7132 °C.hr. Whereas the area under temperature for passively aerated mixture varies from 6456 °C.hr to 8040 °C.hr. It indicates that the co-composting of organic solids waste requires less time to be composted than composting of organic solids waste.

Temperature which is as a result of microbial activity is an important factor in a composting process. The temperature of the composting pile expresses the breakdown of the organic matter and the quality of the compost, since the rise of temperature is the result of readily available organic matter and nitrogen compounds decomposition by microorganisms (Ros et al., 2006; Lee et al., 2007). Temperature is one of the important indices to evaluate compost efficiency (Lee et al., 2007) because it affects the biological reaction rate, the population dynamic of microbes, and the physiochemical characteristics of the compost (Hu et al., 2009).

The microbial activity and the organic matter breakdown rate decreased when the organic matter becomes more stabilized and consequently the temperature drops to the ambient temperature (Ros et al., 2006). The composting materials went through the three typical degradation phase: mesophilic, thermophilic and curing. Decomposition occurs most rapidly during the thermophilic Stage of composting (40-60°C). High temperatures destroy pathogenic bacteria and protozoa and weed seeds, which are detrimental to health and agriculture when final compost is used on the land. By the standard of best practice for temperature of a formulated compost pile, it is recommended to manage pile to achieve an average temperature greater than or equal to 65 ºC (≥65 ºC) for at least 3-7 days. Temperature profiles of forced aerated and passively aerated reactors are shown in Figure 2. It is seen that temperature rises sharply after first day and reached at thermophilic Stage and stayed about 5 days. Peak was found about 65 ºC. Temperature in excess of 60°C could reduce the activity of the microbial community as the thermophilic optimum of microorganisms is surpassed. Ambient temperature varies from 25 ºC to 27 ºC. Temperature was increased sharply within 2 days and crossed 50 ºC. The Second peak of temperature was found after 10 to 12 days. Temperature was fall near ambient temperature at the end of the Stage.

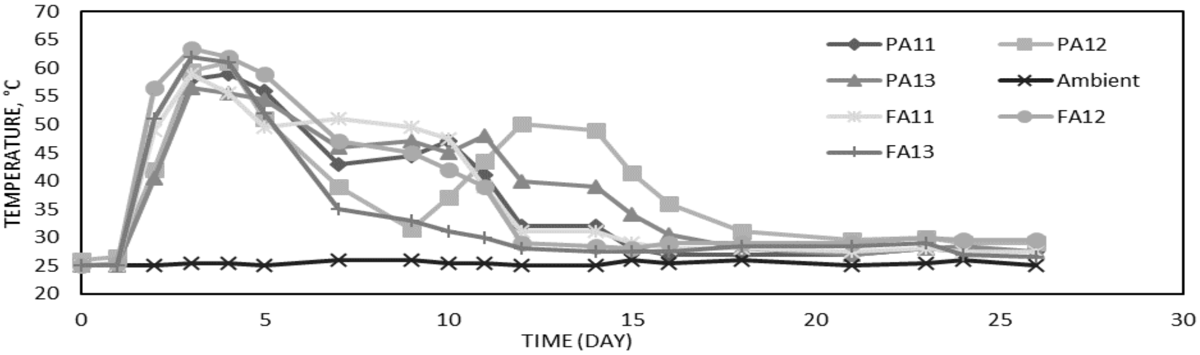


Figure 2: Temperature profile of forced aerated and passively aerated reactors in stage-1

The reduction of height of the sample mixture is very high at the initial Stage. For force aerated waste mixture the sample have gained 80% height reduction of its total reduced height at about 10 days after the first setup. But for passively aerated waste mixture, it takes up to 20 days to gain 80% height reduction of the total reduced height during Stage-1.

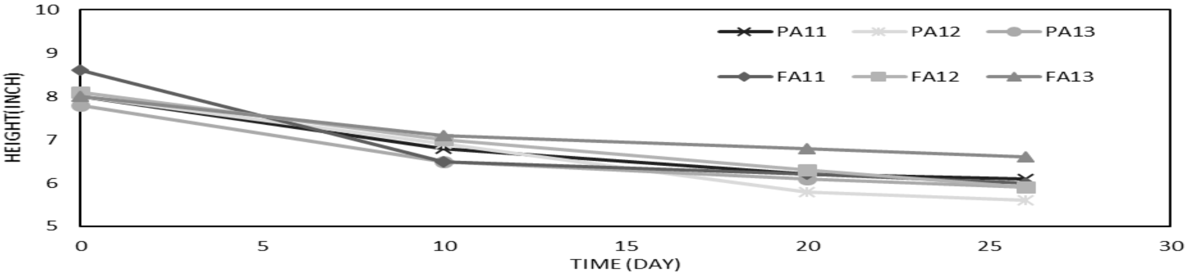


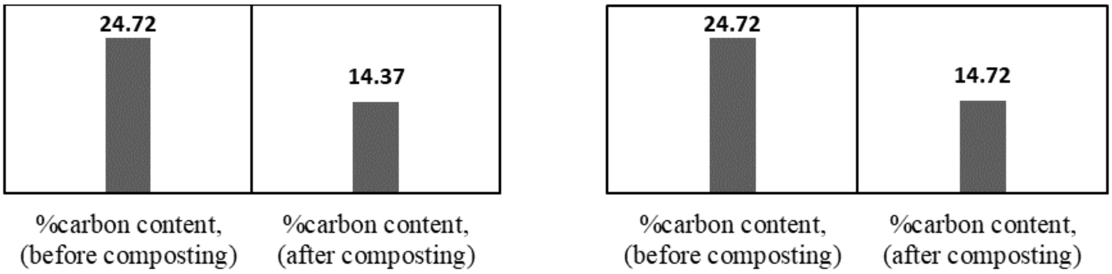
Figure 3: The height of the Compost mass vs Time graph for forced aerated (FA11, FA12, FA13) and passively aerated (PA11, PA12, PA13) test mixture at first stage of co-composting

Percentage volatile solids and carbon contents were calculated before and after co-composting as shown in Table 2. Volatile solids was determined by putting the dry solids into Muffle Furness at 550 ºC for 1 hour and then percentage volatile solids was calculated. For most biological materials the carbon content is between 45 to 60 percent of the volatile solids fraction. The formula is:

% Carbon = (% VS) / 1.8.

Table 2: % Volatile solids and % Carbon before and after composting

Sample	Average % Volatile solid (before composting)	% Volatile solids (After composting)	Average % carbon (Before composting)	% Carbon (After composting)
PA11	44.13	25.48	24.72	14.27
PA12		27.10		15.17
FA11		24.49		13.71
FA12		26.83		15.03



a) Forced aerated

b) Passively aerated

Figure 4: Carbon content variation for initial and finished co-compost

In first stage of co-composting, the initial percentage carbon content of forced and passively aerated was 24.72. In the finished co-compost percentage carbon content decreased to the values of 14.37 and 14.72 respectively.

3.2 Second Stage of Co-composting

Second stage was carried out for 25 days. Moisture content, dry solids, volatile solids and percentage carbon was measured before and after the composting process. Moisture and dry solids in gm of waste mixture before and after composting are shown in Table 3. It is seen that moisture content reduced from nearly 50% to 43% in passively aerated reactors and for forced aerated reactor moisture content decreased from around 45% to 34%. Before started composting process moisture content of waste mixture was nearly 50% and 45% in passively and forced aerated reactors respectively means rest 50% and 55% was in dry. So the moisture is almost same as dry solids before composting. During composting, waste starts to degrade and moisture is reduced and dry solids is also decreased than before. As a result end of the process a reasonable amount of weight is lost in each reactor as shown in Table 3. From the value of Table 3 it is seen that the weight decreasing rate of forced aerated is higher than the passively aerated reactor. Percentage weight losses of passively aerated reactors are around 9% to 16% and forced aerated reactors are around 45% to 75%. From the time-temperature curve in Figure 5, the approximate area under temperature is calculated and shown in the Table 3. The temperature was measured in °C. In the case of forced aeration the area under temperature is 1818 °C.hr for First reactor and 5544 °C.hr for Second reactor. Whereas the area under temperature for passively aerated mixture varies from 3072 °C.hr to 4548 °C.hr, indicating the completion of co-composting process.

Table 3: Percentage weight loss, Area under temperature and Moisture content before and after composting

Reactor name	**Waste mixture weight (before), gm**	**Waste mixture weight (after), gm**	**Percentage weight loss**	**Moisture content (%) (before)**	**Moisture content (%) (after)**	**Area under temperature, °C.hr**
PA11	437	394	9.83	50.28	44.26	3072
PA12	481	404	16.00	50.28	42.18	4548
FA11	455	114	74.94	45.15	35.33	1818
FA12	454	239	47.35	45.15	36.66	5544

FA=Forced aerated, PA=Passively aerated

Temperature profiles of forced aerated and passively aerated reactors are shown in Figure 5 As temperature reached in thermophilic level at stage-1 and active phase of composting has already done, after this phase, microbial activity and organic matter decomposition rates slowed down and the temperature decreased gradually. Temperature gradually increased in passively aerated reactors. Peak temperature was found 37 ºC for passively aerated and 42 ºC for forced aerated reactors. The ambient temperature varies between 25 ºC to 27 ºC.

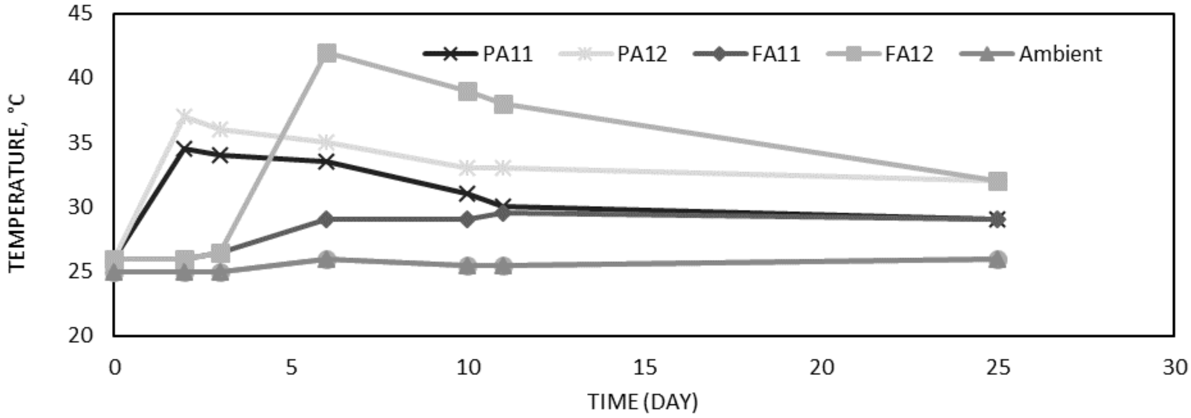


Figure 5: Temperature profile of forced aerated and passively aerated reactors in stage-2

For co-composting of faecal sludge with organic solids waste, the maximum height reduction of the waste mixture was gained at the first stage of co-composting and there was a little height reduction during the second stage. And the height of the waste mixture have become stable at about 10 days after the Second setup.

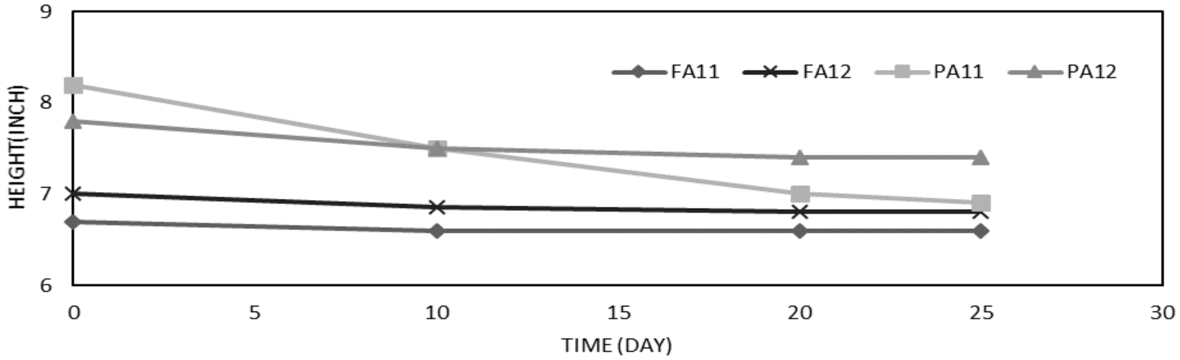
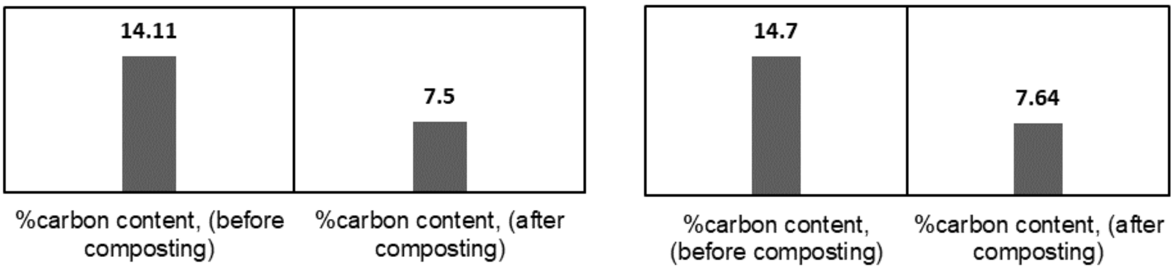


Figure 5: The height of the Compost mass vs Time for forced aerated (FA11, FA12) and passively aerated (PA11, PA12) Test mixture at second stage of co-composting.

Percentage volatile solids and carbon content were calculated before and after co-composting and are shown in Table 4. Percentage carbon was found from percentage volatile solids. In second stage of co-composting, the initial carbon content of the co-composts of forced and passively aerated were 14.11% and 14.7% respectively. In finished co-compost these values decreased to 7.5% and 7.64% respectively. According to SRDI standard the total carbon content (%) of finished co-compost should be within 10-25%. So the values of carbon are not within the standard limit.

Table 4: Percentage Volatile solids and %carbon before and after composting

Sample	Average % volatile solid (before composting)	% Volatile solids (after composting)	Average % carbon (Before composting)	% Carbon (After composting)
PA11	26.26	13.67	14.70	7.66
PA12		13.62		7.63
FA11	25.11	14.41	14.11	8.07
FA12		12.43		6.96



a) Forced aerated b) Passively aerated

Figure 6: Carbon content variation for initial and finished co-compost

4. CONCLUSIONS

The initial moisture content for test mixtures was 53%. After completing the first stage of composting process, moisture content of the waste mixture was found 50% and 46% for passively and forced aerated reactors respectively and after 2nd stage, final moisture content was found 43% to 35%. The reduction of moisture content for test mixture in forced aerated reactors is higher than the passively aerated reactors.

In stage 1 and 2, peak temperature was found 50°C to 60°C indicating the thermophilic stage. Test mixture in forced aerated reactors reached the thermophilic stage during the first stage of composting within 2 to 3 days and lasted for 3 to 5 days but it took more time to reach the thermophilic stage for passively aerated reactors.

The height of the test mixture reduced rapidly within 10 days and then slowly reduced. The total height reduction was higher in passively aerated reactors than the forced aerated reactors. It is clearly observed that the value of percentage volatile solids and percentage carbon were reduced to a significant amount which is almost half of the initial percentage.

Bulking agents (paper waste and sawdust) affected the pH profile. Its interaction with aeration ratio impacted germination index value. Waste mixture had offensive odor before composting which was disappeared in the final compost. The color of the final compost was grey and dark brown.

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