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Vertical In-Vessel Composter for Stabilization of Market Vegetable Waste

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Abstract*: Composting can be one of the solutions to tackle the issue of handling solid waste. In the present research work, a bench-scale vertical in-vessel aerobic composter was designed to stabilize the Devaraja market vegetable waste, Mysore using horse dung and plantain leaves as seeding material and bulking agent respectively. On average, Devaraja market generate 4.8-5.6 ton per day. Mix proportion of organic waste, bulking and seeding materials fed into composter was in the ratio of 5: 1: 0.5. Initial and variation in physico-chemical characteristics of waste were monitored during the composting period. The initial concentration of total nitrogen, phosphorous, total organic carbon and C/N ratio which was found to be 1.67%, 0.78%, 1.93%, 43.5% and 26 showed a variation of 2.4%, 1.1%, 2% 29% and 15 respectively at the end of 21 days of composting.

Keywords: In-vessel composter, TOC, MSW, Stabilization, C/N ratio

I. INTRODUCTION

The improper management of waste leads to health threats to the general public, loss of aesthetic appeal and loss of usable land resources [1]. Devaraja market is one of the main market of Mysore city where fruit, flowers, vegetables and others basic things are sold. This market contributes nearly 10% of city's biodegradable waste. Devaraja market is an apt place to get a flavor of the local people's daily life. With more than 100 years of history, this market is well knitted into the heritage of Mysore. There are about 800 traders in and outer periphery of the market and nine cylindrical collection bins in the market and all the wastes collected from inside the market and collections bins are dumped at Mysore City Corporation (MCC) collection point. From MCC collection point, the discarded fresh market waste is sent to Pinjrapole Society for feeding the stray cattle's. Composting is one of the best methods for treating biodegradable solid waste, in which organic waste can be recycled as agricultural input for plant nutrients [2]. Different methods of composting are backyard or onsite composting, vermicomposting, aerated (tunnel) windrow composting, aerated static pile composting and in-vessel composting [3]. During active composting, organic carbon in the waste is converted to CO_2, CH_4 and VOCs. 90% of the aerobic degradation occurs during active composting, and 10% during maturation. Water is evaporated from the waste. In general, aerobic transformation of solid waste can be described by means of the equation as follows;

$$\text{Organic matter} + O_2 + \text{Nutrients} \rightarrow \text{New cells} + \text{resistant organic matter} + CO_2 + H_2O + NH_3 + SO_4^{2-} + \ldots + \text{heat} \quad \text{---------} \; (1)$$

The compost material is exposed to atmosphere for about 2-3 weeks to ensure complete stabilization. The stabilized material can be used as a soil conditioner or enriched with nutrient content and sold as organic manure for plant growth.

The In-vessel composter is equipped with stirrer to facilitate proper mixing, aeration and moisture content to the feed stock. The feed stock is homogenized by turning and mixing it frequently and to ensure transfer of oxygen. The pros of vessel systems is that odor can be controlled reasonably, require less area, rapid production of compost, highest control of composting parameters, and controls the release of leachate [4]. Nevertheless, greater research has to be made in the preparation of MSW, process acceleration, enhanced stabilization of organic matter, improved quality of compost and increased productivity of the technology. In-vessel composting is a good treatment methodology for organic waste and revenue generation from waste. Earlier researchers have worked on vegetable wastes composted either in batch or continuous type of reactor [5]. Hitherto, the research work is confined to horizontal type In-vessel composter. In this context, an attempt is being made in this research work to design a vertical bench-scale In-vessel composter to stabilize the market organic waste using horse dung as a seeding material and banana leaves as a bulking agent.

II. PROCEDURE FOR PAPER SUBMISSION

A. Sampling, Preparation and composting process:

100kg of discarded commingled waste was collected from Devaraja market in the early hours of the day and the sample was segregated to separate plastic, paper, thread and other waste materials. The sample size was reduced to 10kg by quadrature method. Segregated waste was shredded to 2-3 cm size before subjecting it to composting. Fresh horse dung was used as microbial inoculum and was collected from Tanga stand, Agrahara Circle, Mysore. Plantain leaves used for wrapping and discarded was used as bulking material, shredded and oven dried for 2 hours and blended with horse dung to compensate the moisture content. Organic waste, bulking agent and seeding material were mixed in the proportion of

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5:1:0.5 by weight. The blended mixture was analyzed for its initial characteristics and then fed into the reactor to 2/3rd capacity with a provision of 1/3rd volume for circulation of air and waste turning. The composting process was monitored for the entire period. The Physical and chemical characteristics of the sample material before composting, during composting with turning, and after composting were drawn on alternate days for analysis of nutrient values. Subsequent nutrient analysis was done for every 7 days. The sample was dried and sieved through sieve (1.18mm IS sieve) before analysis.

The schematic of In-Vessel Composter used is represented in Fig.1. A plastic drum (HDPE) of capacity 0.084m^3 was used as a reactor. A central vertical pipe of height 0.87m and diameter 50mm with handle at the top to facilitate turning was used. Six horizontal branch pipes of length 0.15m with diameter 22.5mm were welded to vertical pipe. To initiate spiral rotation of the material, MS auger type mixer

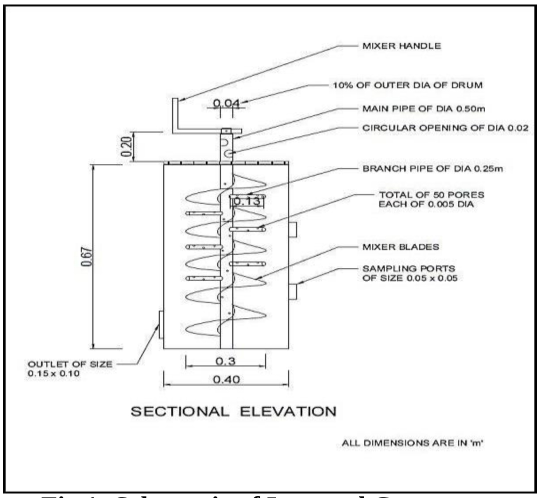


Fig.1: Schematic of In-vessel Composter

blades was welded to the main vertical column. Circular holes of diameter 0.02m were drilled on both vertical pipe and branch pipes for aeration based on the computation of air required as shown in the following section. An outlet of size 0.15m x 0.10m to withdraw compost and sampling port of size 0.05m x0.05m to draw samples for analysis was made. The mixer handle was rotated twice daily for 21days of composting for thorough mixing.

B. Design Criteria of In-Vessel Composter

Density of organic solid waste (d_0) = 178 - 415 kg/m^3

Typical Value = 330 kg/m^3

Mass of organic waste (m_0) = 10 kg

Volume of organic waste (V_0) = m_0/d = 10/330 = 0.030 m^3

2/3rd volume of the Reactor = Volume of organic waste filled (V_T)

$$2/3 \times V_T = V_0$$

$$V_T = 3/2 * V_0 = 3/2 \times 0.030 = 0.01125\ m^3$$

Volume of the cylinder = $\pi r^2 h$

Height of the composter (h) = 0.67 m

Radius (r) = 0.2 m

Diameter of composter = 0.4 m

C. Computation of Air Supply for Reactor

After ascertaining the working volume of the reactor, the diameter of holes to be drilled on main vertical pipe and branch pipes was computed to maintain aerobic condition through the rotation of blades.

The term $C_aH_bO_cN_d$ represents the empirical mole composition of the organic material. If complete conversion is accomplished, the corresponding expression is

$$C_aH_bO_cN_d + ((4a+b-2c-3d)/4)O_2 \longrightarrow aCO_2 + ((b-d/2)H_2O + dNH_3 \quad \text{............. (2)}$$

Assuming the composition of organic waste as $C_{48.5}H_{6.2}O_{39.5}N_{1.4}$, then for the given formula, [6]

a = 48.5, b = 6.2, c = 39.5, d = 1.4

48.5 x 12 + 6.2 x 1 + 39.5 x 16 + 1.4 x 14 = 1239.8

Oxygen required = (4 x 48.5 + 6.2 - 2 x 39.5 - 3 x 1.4)/ (4 x 1239.8) of O_2

= 117 / 1239.8

= 0.0943 lb/lb of waste

Assuming air contains 23% of oxygen having specific gravity of 0.075 lb/cubic feet

Air required for composting of 10kg of organic waste

= (20 x 0.0943) / (0.23 x 0.075)

= 109.3 cubic feet of air

= 3.093 m^3 of air

Aeration required for composting = (109.3 x 2 x 0.35) / 1440

= 0.053 cubic feet/min

= 1.5 x 10^{-3} m^3/min

Assuming mixing factor as 2,

Maximum oxygen demand of 35% during composting process

Available minimum size of drill bit was 5mm, 5mm holes was drilled.

50 pores were provided each of diameter 5mm Assuming the average wind velocity in Mysore city as 3.5kmph (i.e., 0.97m/s) during the study period,

Air that enters vessel = 1.5 x 10-3 x 50 x d2 /4

= 2.9 x 10-3 m3/min

Air entry into the vessel is almost double to that required, aerobic condition may be maintained.

III. RESULTS AND DISCUSSION

The quantification of the organic waste generated in the Devaraja Market was made through survey for the entire week including working days and weekends. Table 1 represents the quantity of waste generated in the market during study period.

On an average, about 4.8 – 5.6 ton/day of waste was generated during normal days. During weekends and occasions, the waste generated was high (i.e., about 7-8 ton of waste per day). This increase is attributed to the increased trade of materials in market. Further, the waste composition of Devaraja market included 97% of degradable and 3% of non-biodegradable wastes. Out of 97% degradable waste, major component was vegetable waste which constituted 70%. The fruit waste was found to be 25%, about 5% of discarded waste flower, 7% of waste paper and 3% of non-biodegradable waste.

The composition of waste fed into the in-vessel composter in two different cycles in % by weight is mentioned below.

Table 1:Quantification of Devaraja Market Waste

Observed Day	Day	Generation Rate, Ton			
		7-10.30am	11am-2pm	2.30 -5pm	Total/day
Day1	Thursday	2.65	1.23	0.99	4.9
Day2	Friday	3.3	1.6	0.7	5.6
Day3	Saturday	4.25	1.26	1.64	7.15
Day4	Friday	2.42	1.4	0.88	4.7
Day5	Saturday	2.86	1.1	1.14	5.1
Day6	Sunday	2.73	1.05	1.07	4.85
Day7	Monday	3.16	1.35	0.79	5.3

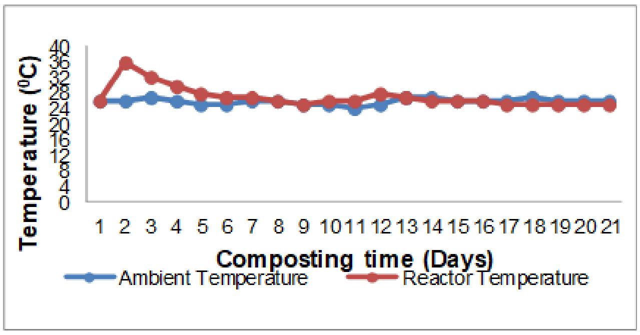
Cycle 1: Apple (2%), Banana (8%), Beans(2%), Beat Root (4%), Bitter guard (1%), Bottle guard (7%), Brinjal (5%), Cabbage(2%), Carrot (5%), Cauliflower (8%), Chikku (1%), Cucumber (9%), flowers (7%), grapes(3%), Ivy guard (2%), Kiwi (5%), Mango (2%),, Mixed leaves (5%), onion (3%), Papaya (12%), Pomogranete (2%), Potato (5%), Radish (7%)
Cycle 2: Apple (2%), Banana (12%), Beans(4%), Beat Root (4%), Bitter guard (5%), Brinjal (6%), Cabbage(5%), Carrot (7%), flowers (9%), Mango (5%),, Mixed leaves (25%), Potato (3%), Radish (3%), Ridge Gourd (4%), Sweet potato (3%), Turnip (3%).

Horse dung was used as seeding material and its initial NPK and TOC values obtained were found to be 2.47%, 2.11%, 2.54% and 50.88% respectively.

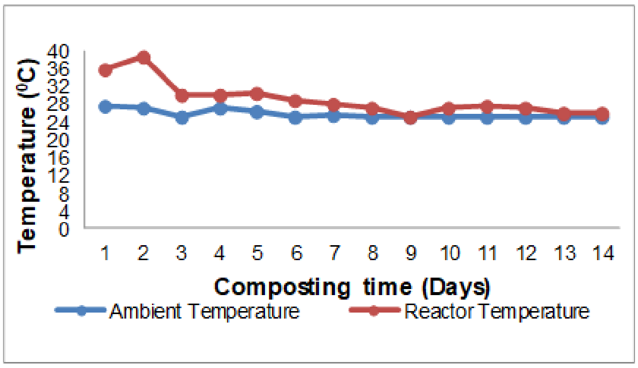
The physico-chemical characteristics of organic waste, bulking agent and seeding material for mix proportion (Organic waste: Bulking agent: Seeding material) of 5:1:0.5 in cycle 1 and cycle 2 were analyzed and the results obtained are presented below.

a. Variation of Temperature

Variation of temperature in composting process indicates the rate of degradation and the type of microbial biomass present. Reaching the peak temperature is very important because the peak temperature of 50-60°C causes further degradation of organic matter and destruction of the pathogens. The variation of temperature of the composting material for Cycle 1 and Cycle 2 is illustrated in Fig 2(a) & (b). The maximum temperature of compost (36°C & 38°C) was observed on third day and second day of cycle1 and cycle respectively. The high temperature remained for just two days. Thereafter, the temperature varied within a narrow range (27-25°C). The temperature variation pattern were similar for both the cycles, i.e., first an increase to a high temperature and declined to a low temperature. The temperature level in the compost tend to increase and reach 36-40°C due to the energy released from the biochemical reactions taking place in composter by the micro-organisms, while the temperature level in composter declined after the thermophilic phase due to a loss of substrate and a decrease in microbial activity. The temperature in the composter can be used as an indicator of the compost maturity. The compost material can be considered mature when an ambient temperature is reached.



(a)



(b)

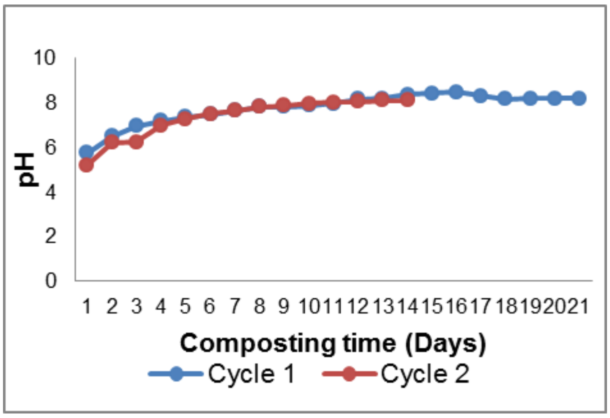
Fig.2a & b: Temperature Variation (°C) for (a) Cycle 1 & (b) Cycle 2

B. Variation of pH

The variation of pH during composting time is shown in Figure 3a. The pH of the Cycle 1 and 2 were similar. At the beginning of the cycle1 and 2, the pH of both Cycles were 5.72 and 5.22 respectively. Then the pH increased to 8.48 after 16 days of cycle 1 and 8.12 after 14 days of cycle 2. This increase in pH during the composting process could be due to the degradation of protein. After the completion of thermophilic stage, nitrification bacteria take over the process. Due to nitrification process, the pH decreased at the end of the composting period. The decrease in pH at the later stage of composting might be due to the volatilization of ammoniacal nitrogen and released of H^+ ion as a result of microbial nitrification process by nitrifying bacteria.

C. Moisture Content

Moisture loss during the composting process can be viewed as an index of decomposition rate, since the heat generation which accompanies decomposition drives vaporization or moisture loss. However, the composting material should have minimum moisture content for the survival of micro-organisms. The optimum initial moisture content should vary between 50-60%. But, moisture content at the beginning of cycle 1 and 2 (Fig.3b) was 84% and 76% respectively, which was then reduced to 81% and 79% within 14 days. In literatures, moisture content was found to be 50%. But, the moisture content that was observed in present research was very high because of vegetable and fruit waste which contains high moisture content.



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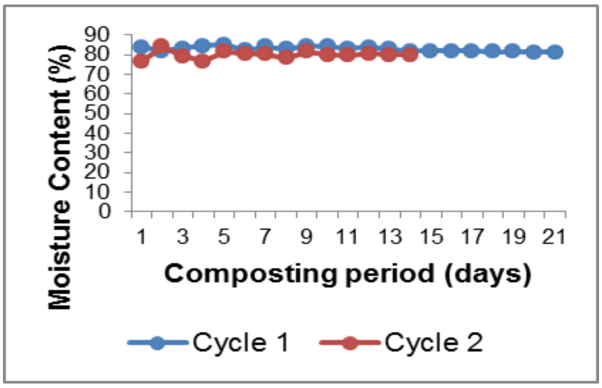


(b)

Fig. 3a&b: (a) pH and (b) Moisture content during composting

D. Nutrient Value

Soil is a major source of nutrients needed for growth of plants. The three main nutrients are nitrogen (N), phosphorous (P) and potassium (K) which are known as macro nutrients. Together make up the trio known as NPK. Other important nutrients are calcium, magnesium, sulphur. Plants also need small quantities of iron, manganese, zinc, traces are needed by the plants. Copper, boron and molybdenum known as trace elements/ micro nutrients because only traces are needed by the plants. This research mainly concentrated on NPK values of compost.

E. Total Nitrogen (N)

Nitrogen is a part of all living cells and is a necessary part of all proteins, enzymes and metabolic process involved in the synthesis and transfer of energy. Nitrogen is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis. It helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops. Atmospheric nitrogen is a source of soil nitrogen. When applied to soil, nitrogen is converted to mineral form, nitrate, so that plants can take it up. Plants normally contain between 1 and 5% N, absorbed as nitrate, ammonium ions and urea. Nitrate is most often available but must be reduced to $NH4^{+}$ or NH_3 for plant utilization. The initial total nitrogen of cycle 1 and cycle 2 is 1.67% and 1.63% respectively. The final total nitrogen of both the cycles after 14days are 2.35% and 2.30% respectively (Fig. 4a). It was observed that the nitrogen content of the mature compost is within the limits. So the compost is best suitable to apply for plants.

F. Phosphorous (P)

Phosphorous (P) makes up about 0.1 and 0.4 % of a plant and is involved in energy storage and transfer, root growth, early maturation, quality and disease resistance. Plants absorb H_2PO_4 or HPO_4 - orthophosphate ions. Like nitrogen, phosphorous (P) is an essential part of the process of photosynthesis. It involved in the formation of all oils, sugars, starches, etc and helps in the transformation of solar energy into chemical energy, proper plant maturation. The phosphorus content of cycle 1 is 1.06% and that of the cycle 2 is about 0.38 (Figure 4b). The phosphorus content of the cycle 1 is within the limits. A phosphorus deficiency in plants will cause stunted growth and prevent them from producing fruit.

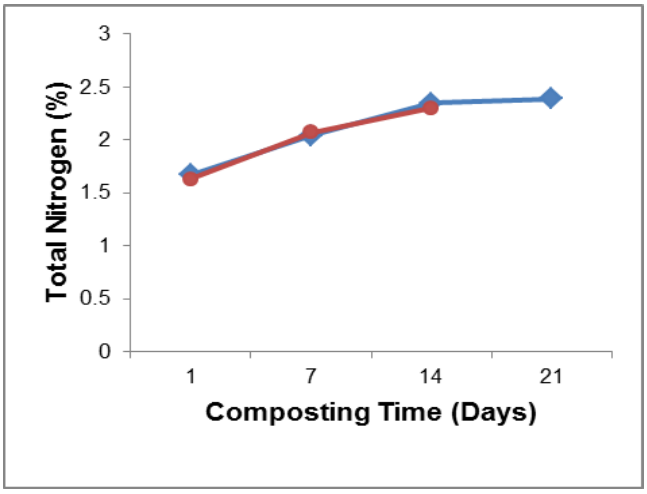
G. Total Organic Carbon (TOC) & (C/N ratio

Fig. 5 shows the variation of TOC and C/N ratio during the composting process. TOC is useful for estimating age and physical properties of compost. Initial were found 43% and reduced to 22% after composting, while C/N ratio was found to be 27 initially and reduced 15 after composting process.

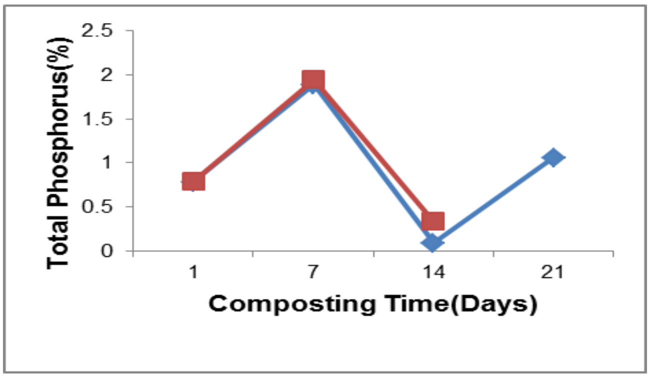
H. Potassium (K)

Potassium concentration in vegetative tissue usually ranges from 1 to 4% of dry matter. Potassium influences enzyme activity, water and energy relations, transpiration and translocation and N uptake and protein synthesis. The potassium content of the cycle 1 and cycle 2 after 14 days are 2.41% and 2.07%, which are well within the limits (Fig.6). So, it is well suitable for plant growth.

The survey conducted in the market area showed that, on an average about 4.8 – 5.6 ton of waste per day is generated in Devaraja market. From the total quantity of waste, about 90-92% was biodegradable and 5-8% of non-biodegradable wastes are generated in market. The total organic fraction consists of 50-60% of vegetable waste, 20-30% of fruit waste and 2- 5% of paper waste. The designed Composter was found to be effective, as no operational problem.

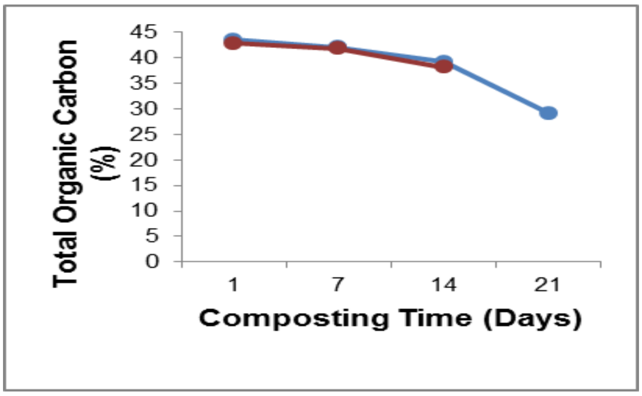


(a)



(b)

Fig.4a&b: Variation of (a) Total Nitrogen (%) & (b) Total Phosphorus (%)during Composting Process



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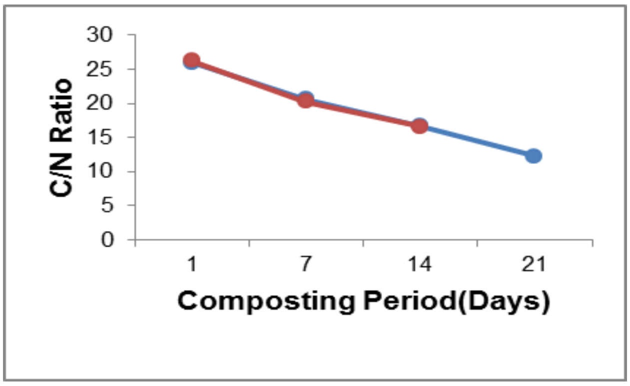

(b)

Fig. 5 a& b: Variation of (a)TOC (%) and (b) C/N ratio during Composting Process

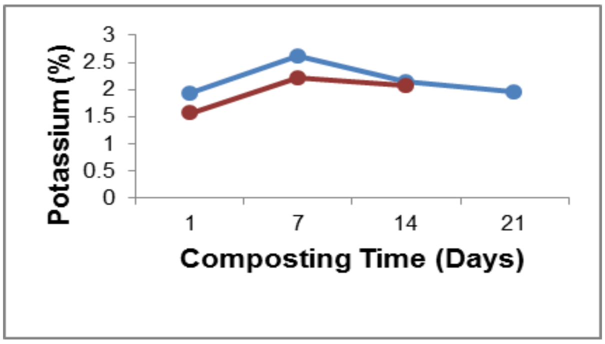

Fig. 6: Variation of Potassium (K) (%) during Composting Process

IV. CONCLUSION

The survey conducted indicated that, on an average,4.8 to 5.6 ton of waste per day is generated in Devaraja market. From the total quantity of waste, about 90 - 92% was biodegradable and 5-8% of non-biodegradable wastes are generated. The designed composter was found to be effective as no opeartional problem, no odour and vectors were observed. Total Nitrogen content (N) of the compost was varied between 2.3% - 2.4% .Total Phosphorus content (P) of the compost of Cycle 1 and Cycle 2 are 0.1% and 0.4% respectively. Total Potassium content (K) of the compost was found to be 2.4% and 2.1%, which possess the sufficient nutrient value. C/N ratios of finished compost for both cycles were 15 and 16 respectively, which are less than the standard value of 30. All the above nutrients are found to be meeting the standards valves, it can be concluded that the compost produced with the designed composter is of good quality. Various mix proportions of bulking agent can be used to compensate the moisture content. Study on varying proportion of seeding material can be continued.

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