RECIRCULATION OF VERMIWASH IN ARTIFICIALLY AERATED VERMICOMPOSTING

Palaniappan Senthilkumar[1*], Alagappan Murugappan[2]
[1,2]Department of Civil Engineering,
[1,2]Annamalai University, India.

Abstract: *The bulk of solid waste generated and the amount recycled or manured is not in balanced state. To tackle this problem, an attempt carried out to accelerate the conventional vermicomposting process by aerating the vermi bin (vertically elevated and radial bottom) and recirculating the vermiwash in the vermi reactor. The results were compared with the conventional vermicomposting process; vital parameters like temperature, moisture content, pH, and the biomass growth rate were periodically monitored for assessing the efficiency. After 30 days of vermicomposting, excellent percentage (84%) of waste volume reduction and appreciable rate of biomass growth were recorded in the vermi reactor aided by air and recirculated with vermi wash. Aiding the vermi reactor with air reduced the suffocation of worms and increased the mobility to reach the waste at different levels and thereby the span of vermicomposting much reduced. The results clearly suggest that aerated vermicomposting could be an ideal process for converting the green waste into organic manure.*

Keywords— **Vermicomposting, Earth worms, Aeration, Vermiwash**

I. INTRODUCTION

The fall in fertility of soil and the low crop production were due to extensive use of synthetic fertilizers and loss of soil organic matter in the soil [1]. This has provoked interest in amending the soil quality by adding organic manure in it [2]. On the other side, the solid waste generation rate to the percent to be treated or manured is not in balanced state. It reported that around 60% of solid waste has an organic part in it [3]. This organic part be able to convert into organic manure in many ways; they are composting, vermicomposting and in-vessel composting. Among these methods, vermicomposting is becoming increasingly popular across the world, because of its easy way of conversion and generation of enriched organic manure [4]. In addition, vermicomposting influences the microorganism growth and add additional effects in stabilizing the organic material; hence, the rate of degradation is high when compared to other techniques [5]. The foregut of vermi acts as mechanical blenders, modifies the physical status of ingested organic waste, and consequently increases the surface area for digestive enzyme actions [6]. Moreover, the biochemical mutuality between worms and microorganisms generates some essential enzymes for easy digestion of the organic fractions. The digested waste by the earthworms called vermicast holds a high percentage of nutrients, which attracts the microbial community [7]. Conventional organic waste treatments like composting or vermicomposting consume more time and hence the rate of inflow of waste and outflow (converted manure) are not equal. Moreover Sing [8], reported that 7.5 cm to 10cm depth is an ideal loading of substrate to be fed/spread over vermicomposting bins or windrows. Further, he added, the substrate depth above 10 cm will turn the vermi into anaerobic state during vermicomposting and thickness above 15 cm will produce heat during the initial period of vermicomposting, which will become lethal to the earthworms. This has doubled the area and the time requirement for vermicomposting the waste. Hence, the objective of the study is to produce nutrient rich bio-fertilizer (vermicast) by vermicomposting the vegetable market waste (green waste) in short. Ranganathan [9] reported that the time span of vermicomposting varies from 65 to 90 days and it depends on species of worms and substrate characteristics. In this study an attempt is made to reduce the time span of vermicomposting by aiding the vermi bins with aeration in two ways (1) vertically elevated aeration (referred as Bin-A) and (2) radial aeration at bottom zone (referred as Bin-B). Further, for boosting the process, vermi wash recirculated in these bins at the time of moistening the vermi bed. The comparison of results made between aerated bins and composting carried out in conventional vermi bins (referred as Bin-C). In parallel, a comparison also made between radial and elevated aeration to determine which proved to be more effective in accelerating the composting process.

II. MATERIALS AND METHODS

The study aims in vermicomposting the organic waste. Hence, a vegetable market waste taken as substrate in the process. Vegetable waste collected from the local vegetable market, which weighed approximately 30 kg. Collected waste screened manually for deporting the inorganic and other debris in it. Then, the waste chopped to desirable size and pulverized into paste. Cow dung, approximately 2 kg, added to the pulverized waste as a seeding agent. Finally, 1 kg of sawdust added in the mixture as a bulking agent. The mixture dried under the Sun for a week and then shifted for vermicomposting. Four identical bench scale reactors made of PVC, with geometry of 23 cm × 23 cm × 40 cm used for the study (Fig 1). Bins A and B were augmented by controlled airflow. Airflow more than 5 liters will disturb the worms in the bed and reduce the moisture content in the bed. Considering this, air pumped at a rate of 4.5 liters per hour with the help of an aerator. The air was allowed to flow approximately for 6 hours per day, in order to maintain the optimum moisture content (55-65%) in the substrate. Bin C is a conventional one. A control bin also kept in parallel during the experimental period. After a week of vermicomposting, the collected vermiwash are recirculated in bins A and B with their respectively. The characteristics of vermiwash of all the three bins, given in table 1.

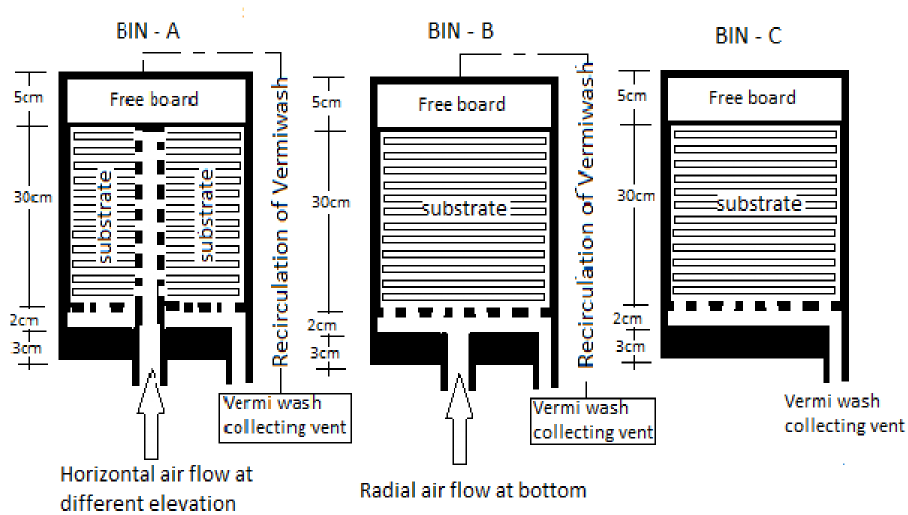

Fig 1: Experimental Set-up

During the experimental period, vital parameters like temperature, pH, moisture content, substrate depth reduction and biomass growth rate monitored and recorded for assessing the performance of individual bins. The measurement methods for these parameters listed in table 2. To protect the worms from predators and to avoid the direct contact of sunlight, the reactors constantly monitored and kept at a higher ground with proper shading. Drainpipe kept at the base of the reactor to drain excess vermi wash from vermin beds. Identifying the correct species of vermi is a key task in vermicomposting.

TABLE: 1
CHARACTERISTICS OF VERMIWASH

Bin	Hardness (mg/l)	Chloride (mg/l)	Iron (mg/l)	Ammonia (mg/l)	Phosphate (mg/l)	NO2 (mg/l)	pH	Turbidity (NTU)	EC (µs/cm)	DO (mg/l)
A	40	56	3.8	3.8	1.3	0.4	7.4	6.8	3.0	3.6
B	49	47	3.95	2.4	1.1	0.6	7.4	6.5	3.4	3.7
C	60	52	4.1	1.2	1.2	1.1	7.3	7.4	3.5	2.6

Senthikumar [10] reported that top dwelling worms are highly suitable for vermicomposting. Considering this, a worm species called '*Eisenia fetida'* of 4–7 cm in length collected from the local vermicomposting yard and shifted to the reactors for vermicomposting. About 100 grams by weight of worms inoculated in each reactor, which approximately counts 75–85 by number. Before that the reactors (A and B) were kept running with air augmentation for three days. This will drain off the presence of any other organic gases in the substrate and it will stabilize the unit to avoid shock load on worms

TABLE. 2
ANALYTICAL METHODS USED FOR VARIOUS TESTS

Parameters	Methods	Unit	Reference
Temperature	Soil thermometer	˚C	Luster Leaf 1618 Rapitest Soil Thermometer
Moisture content	Soil Moisture meter	%	KC-300 Soil Moisture Meter
pH	Soil pH meter	-	KC-300 Soil PH Meter
Wasted depth reduction	Measuring scale	cm	Steel ruler of 30cm length
Biomass growth rate	Digital Weigh balance	gm	Ace Electronic Digital weighing scale (7 kg to 1gm)

III. RESULTS AND DISCUSSION

The experimentation conducted for a span of 30 days and the obtained results pictured in table 3. On the vermicomposting system, the rate of oxygen supply and aerobic biodegradation depends on the seepage velocity in the media. The seepage velocity is the driving force that diffuse oxygen in the substrate and in parallel ejects CO_2 out of the media. In order to make the system purely aerobic, diffusion of O_2 is critical. The diffused flow of oxygen across the partly saturated pores will play an influencing role in the substrate moisture and temperature. To find the influence aeration on bin temperature and moisture, a correlation matrix drawn between bin temperature and moisture content and the values reported in table 4.

A. Influence of aeration on bin temperature and moisture content

Temperature is a key parameter in the vermicomposting process. Ranganathan (2006) reported that optimum temperature for E. fetida is 27 ± 2˚C. The temperature in bins A and B was recorded under 29 ˚C during most of the vermicomposting period. This might be due to the air augmentation in these bins. And the same was evidenced from the correlation matrix (table 4), that bins which are aerated (A and B) were not influenced by ambient temperature (0.192 and 0.123). But in bin C and control unit holds a positive correlation of 0.524 and 0.616 with ambient temperature. This clearly shows that artificial aeration influences the temperature in the vermicomposting process. Excess moisture content (>60%) affects oxygen transport in several ways. (1) Diffusing the oxygen in the partly saturated mass will increase the aqueous film thickness and create a denser film around the waste particles in the mass and (2) Matrix effect, acting on the aggregate of substrate particles. The matrix effect states that, as moisture content increases capillary action and fills the small pores with water, which often dramatically increase the distance oxygen diffuse through the aqueous phase. This may be the reason for the unstable moisture level in the bins during the course of vermicomposting. It is known that temperature is inversely proportional to the moisture content and the same was well evidenced in table 4 as indicated by the negative correlation between temperature and moisture content. In the first week of vermicomposting the moisture content was more similar in bins A, C and Control. But, it shows high variations (between 60% and 70%) in bin B. This might be due to matrix effect in the substrate and it was proved by the very low correlation value of -0.278. In bin A, the correlation value is -0.508, which is the highest one and it clearly pictures that elevated aeration in the bin will aerate the substrate better and thereby provide maximum reduction in moisture content than the radial bottom aeration.

Table 3

RECORDED VALUES OF DIFFERENT PARAMETERS DURING THE COURSE OF VERMICOMPOSTING

Days	Tem ˚C	Bin A			Bin B			Bin C			Control Bin		
		Tem	pH	MC	Tem	pH	MC	Tem	pH	MC	Tem	pH	MC
1	28	29.2	7.2	72.3	29.2	7.6	72	29.11	7.5	72	29.0	7.5	72
2	27.2	27.1	7.8	63	29.0	8.0	70	28.9	8.2	71	28.0	8.2	73
3	29.6	28.6	7.6	68	29.2	8.2	71	29.4	8.1	71	29.0	8.2	69
4	28.9	28.7	8.2	66	28.8	8.1	72	28.8	8.2	70	28.0	8.6	68
5	28.5	28.7	8.1	64	29.6	8.2	67.5	29.2	8.1	70.5	28.1	8.1	69
6	27.2	27.6	8.1	65	28.5	8.1	68	28.4	8.1	69.8	27.5	8.1	68
7	28.6	29.1	8.2	67	30.1	8.2	67	29.8	8.2	69	28.8	8.2	70
8	29.1	29.8	8.1	70	29.6	8.1	63	30.2	8.1	68	29.3	8.1	70
9	29.3	28.4	8.1	66	30.1	8.2	65	29.9	8.1	70	29.1	8.1	68
10	28.8	28.6	7.8	63	28.6	7.8	63	28.6	7.9	68	29.3	7.9	67
11	28.9	29.5	8.1	68	30.4	8.2	60	29.9	8.1	65	29.4	8.0	66
12	29.9	30.1	7.9	62	31.3	7.8	60	30.4	7.8	65	29.5	8.2	67
13	29.5	30.1	8.1	60	30.4	8.1	60	30.5	8.1	61	29.7	8.1	62
14	29.4	29.8	7.18	64	29.8	8.1	60	29.2	8.0	64	29.6	8.0	61
15	30.6	29.6	7.9	65	30.2	7.9	60	29.8	8.1	66	29.3	8.0	68
16	29.9	29.7	8.0	60	30.0	7.8	65	29.7	7.9	67	29.1	7.5	64
17	28.5	28.8	7.9	56	30.1	7.9	55	30.1	7.9	62	29.6	7.8	63
18	29.1	29.3	7.8	55	29.6	8.0	53	29.6	8.2	58	29.0	7.9	64
19	28.1	29.7	8.1	60	29.9	8.0	55	30.2	8.0	57	29.5	8.0	62
20	30.2	29.5	8.1	68	29.2	7.9	52	30.6	8.0	56	30.1	8.0	61
21	31.2	30.2	8.0	60	30.7	8.0	56	30.2	8.0	55	30.1	8.0	66
22	30.9	29.8	7.8	58	30.4	8.2	54	31.0	8.1	54	30.4	8.0	64
23	31.2	29.7	8.0	65	30.4	8.0	55	30.6	8.0	53	30.6	8.0	63
24	30.4	29.3	8.1	60	29.7	8.0	53	30.4	8.1	54	30.4	8.1	64
25	30.6	28.2	7.7	53	29.4	7.7	53	30.2	7.7	53.2	30.2	7.7	64
26	29.8	28.1	7.8	54.5	29.3	7.8	49.8	30.4	7.8	52.3	29.7	7.8	61
27	30.2	28.3	7.6	53	29.6	7.6	49.3	30.2	7.6	53	30.4	7.6	62
28	29.5	28.5	7.66	53.8	28.9	7.66	48.9	30.3	7.66	53.2	29.6	7.66	61
29	30.4	28.3	7.8	54	28.6	7.8	48.5	30.6	7.8	52.5	30.2	7.8	63
30	30.3	28.2	7.2	52.3	28.4	7.1	48.4	30.4	7.3	52	31.0	7.4	64

A-Tem: Ambient temperature ˚C *MC: Moisture content in percentage* *Bin A: Horizontal air flow at different elevation*
Bin B: Radial air flow in bottom zone *Bin C: Conventional vermicomposting bin*

TABLE. 4

CORRELATION MATRIX BETWEEN BIN TEMPERATURE AND BIN MOISTURE CONTENT

	Amb Tem	Bin - A Tem	Bin - B Tem	Bin - C Tem	Control-Tem	Bin – A MC	Bin – B MC	Bin - C MC	Cont MC
Tem	1.000								
Bin A - Tem	0.192	1.000							
Bin B- Tem	0.123	0.749	1.000						
Bin C- Tem	0.524	0.503	0.491	1.000					
Cont- Tem	0.616	0.402	0.305	0.867	1.000				
Bin A -MC	-0.508	-0.173	-0.117	-0.775	-0.803	1.000			
Bin B- MC	-0.278	0.189	0.160	-0.444	-0.490	0.762	1.000		
Bin C- MC	-0.477	-0.143	-0.095	-0.733	-0.801	0.942	0.776	1.000	
Cont- MC	-0.507	-0.297	-0.176	-0.634	-0.637	0.836	0.617	0.788	1.000

Amb Tem – Ambient Temperature *Cont - Control* *MC- Moisture Contant*

B. Heat evolved during the process

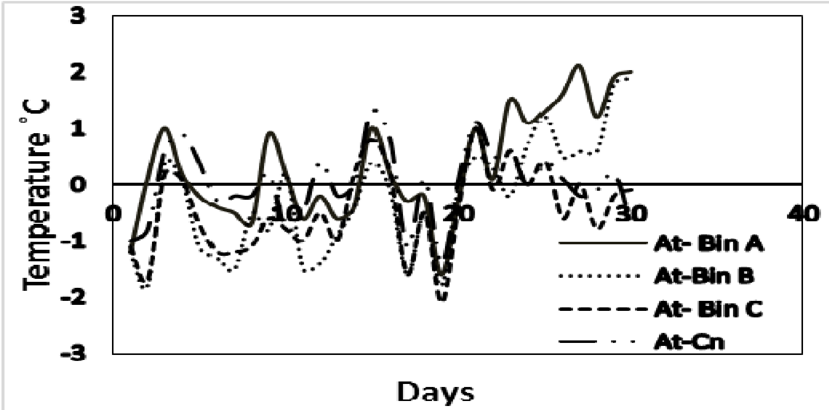

Fig 2. Difference between ambient temperature and bin temperature.

Figure 2 the temperature difference between substrate and ambient air with respect to time. The substrate temperature observed to be 29 ±2˚C, in the initial period of vermicomposting in all the bins and the ambient temperature was 28°C. All bins were loaded with the substrate and the bin environment (temperature and moisture content) monitored and controlled to the desired level before inoculating the worms in the bins. During the stabilization period, the microbial metabolic activity and decomposition of substrate may cause the initial rise in the substrate temperature. The temperature above 35°C reported to be lethal for many varieties of earthworms [11], hence the bed periodically moistened to balance the temperature rise and that might be the reason for the fluctuations in the temperature profile. Out of the three experimental bins, the average temperature of bin A was 29.12 ˚C and it was 29.21 ˚C and 30.5 ˚C in bins B and C respectively. In bins A and B average temperature was found to be less than the average ambient temperature (29.7 ˚C). This might be due to the aeration in the bins. Aerating the bins will helps the water molecules to drain slowly in the substrate and this helps in retaining the moisture in bed for longer duration than the other sets. During the last stage of experimentation, a Sharpe rise of temperature in Bin A and B recorded. This might be due to the substrate depth reduction in these bins

C. Substrate moisture content

During the experimentation period the moisture content was periodically monitored and maintained. The moisture content of the waste mass was restricted within the permissible limits (50% to 70%, [12]). The outcomes are pictured in figure 3. In parallel, the bin depth wise moisture content variations also measured and reported in figure 4.

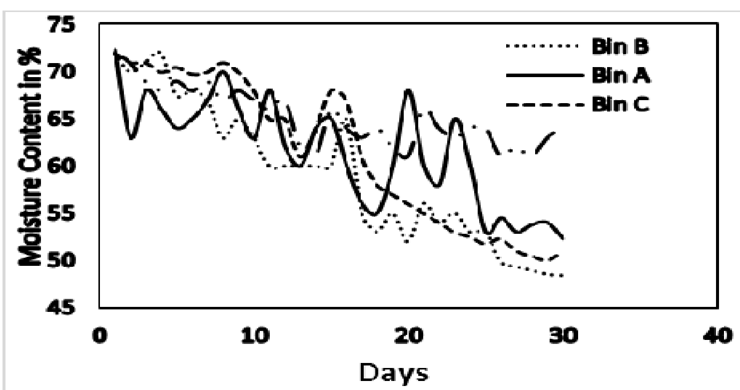

Fig 3. Variation of moisture content in the bins

Out of the three bins, bin A and B hold high variations in the entire test run. This may due to the air argumentation in these bins. From figure 3, it is clear that the moisture content shows a falling trend with respect to time irrespective of bins. This might be attributed to the factors viz., substrate depth reduction, leaching of water from bin bed, respiration activity of worms and conversion of organic waste into vermicast [13]. During the last stage of vermicomposting, the bin moisture was well below 60 % and the lowest percentage (48%) was recorded in bin B. This might be due to the bottom aeration in the bin.

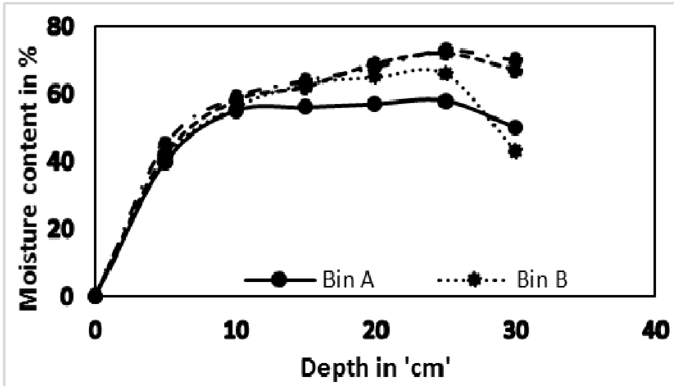

Fig 4. Average Depth wise moisture content during the period of vermicomposting

Figure 4 reveals the average depth-wise moisture content of the bins. It is very clear from figure that there is not much deviation in moisture content in bin C and in control unit during the run. In bin A, the moisture content starts to vary from the 10 cm depth. Wide variations were recorded in bin A moisture tended to fall with respect to the depth in the bin. The reason for this fall is due to the vertical aeration of the bin and enhanced bio mass activity of the bin. Bin B holds a similar pattern with control and conventional one, but at 25cm depth sudden dip of moisture content was recorded. This may due to radial bottom aeration in the bin.

D. Variations in pH

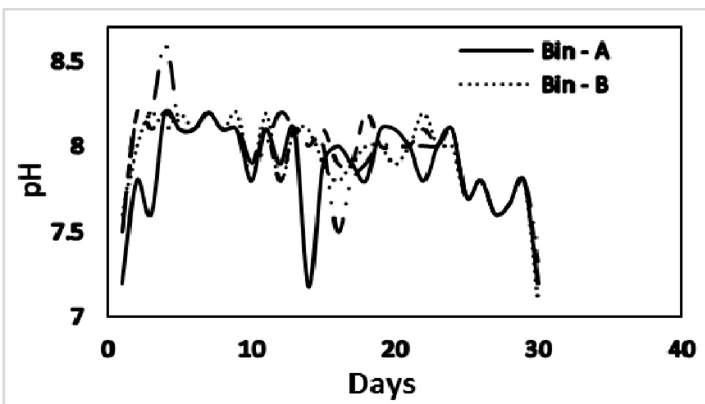

Fig 5. Variation of pH in the test run

The pH of the waste mass was within the range (7.2 and 8.6). The variation might be due to the presence of soluble carbon, monosaccharide, starch and lipids at different time in the process [14]. The pH was slightly alkaline in nature in raw waste due to the presence of calcium and magnesium salts in it. During the stocking period, the pH moved from alkaline zone to neutral. This could be attributed to the production of CO_2 and organic acids during pulverizing and stocking process. It may also be due to the mineralization of nitrogen and phosphorus into nitrates/nitrites and ortho-phosphates, respectively, and the conversion of organic matter into CO_2 and humic by microorganism [15]. The pH in the control bin shows high variation during the initial stage of the test run which might be due to the presence of high volume of microbial community in the bin mass and the absence of worms in the bin. Not much variation was recorded in the pH of the mass in all the bins, except a small fall of pH was recorded in bin A during the 15th day of the test. This might be associated with the active bio mass activity in the bin, since the bin was elatedly aerated.

E. Biomass growth rate vs waste volume reduction

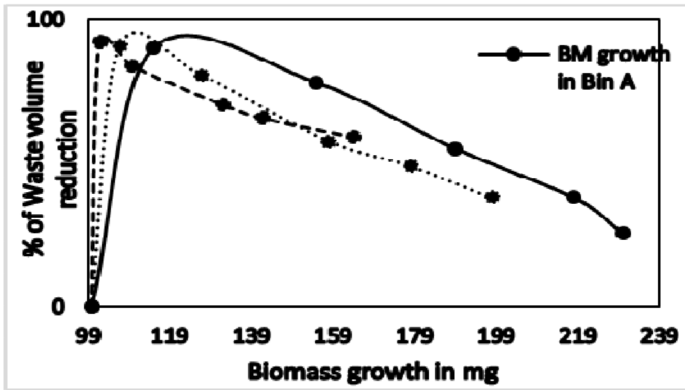

Fig 6. Biomass growth rate

Figure 6 represents the worm growth rate with respect to substrate volume reduction. Approximately 10% of volume reduction was achieved during the initial stage of the experiment. This might be due to bed consolidation during the moistening of beds. All the bins were loaded by equal biomass by weight (100 gm). It was well witnessed from figure that aerating the bins would benefit the biomass growth and in parallel it would aid in the substrate volume reduction. The growth of worms mainly depends on the rate of metabolic activity played with it [16]. Aerating the bins aid the mobility of worms and helps to invade the pool of micronutrients and microorganisms in it. Further, aeration of substrate will reduce the worm suffocation during the process.

In the conventional vermicomposting process, the worms' movement is restricted due to the natural consolidation of substrate mass. In aerated bins the pores are wide opened and excess moisture gets easily drained off. Comparing the two methods of aeration carried out in the study made, the elevated vertical aeration proves to be the best option as the biomass growth was high (234.4 gms). Apart from this, the recirculation of vermiwash also plays a significant role in waste volume reduction and biomass growth rate. High percent of growth rate is also associated with the recirculation of vermi wash, which hold high microbial population. This microbial population plays a predominant role in waste disintegration and biomass growth rate.

IV. CONCLUSION

The final outcome of this experimental study clearly shows that, process modification will help worms to actively participate in mannuring the waste. The modified process involved from converting the waste into stock (pulverizing and moulding) and augmenting air in the vermi bin followed by recirculation of vermiwash. Augmenting air will enhance the level of available oxygen in the vermi bed and recirculation of vermi wash will inject the drained microorganism. This will provide suitable environment for worm's growth in the system. And the same was evidenced from the final biomass weight in bins A and B. Out of the two aerated bins, the biomass rate in bin A was more than double the times of initial weight (110%) and it was around 97% in bin B. Where it was only 58% in bin C. Moreover Vermi wash collected in conventional process holds DO of 2.6 mg/l, while it was around 3.5 mg/l in bins aided with aeration. This proves that aiding the vermi bins with air and recirculating the vermiwash provide a sophisticated environment for the worms to disintegrate the solid waste and able to produce good quality of organic manure in short duration. Hence, the experimental study proves that aiding aeration and recirculating the vermi wash will speed up the biodegradation process and facilitate the biomass growth in the system.

ACKNOWLEDGEMENT

The authors wish to thank the Environmental laboratory of Civil Engineering department, Annamalai University, Chidambaram, India for rendering all the facilities to complete this study a great success.

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