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Effect of Double-T and V-shaped Pipe Configurations and Perforations on the Quality of Chicken Litter Compost

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Abstract*:* Livestock waste management has received much attention because of the huge volume and instability. One of the good management practices adopted to address this menace is composting. This study examined the effect of specialized passively aerated composters on some physicochemical properties of chicken litter. The composter is made up of six double T and V shaped pipe with three different perforation diameters of 15, 20 and 25 mm. Pile configuration of the developed composters had marked effect on total nitrogen content ($p \leq 0.05$) of the compost subjected to 90 days composting time. The composters had uniform air distribution as pile temperature was not significantly affected by pile configuration, perforation size, and their interactions. Furthermore, both T and V shaped pipe structures reached a thermophilic temperature of 49.0 and 67 ^{o}C respectively and the compost stabilized in the 12th week. From the agronomic point of view, V-shaped pipe outperformed double inverted T pipes with perforation sizes of 15 and 20 mm. Overall result from this study suggests that double-T and V-shaped composters are feasible composting systems that can enhance biodegradation, maturation, and stability of chicken litter.

Keyword: compost, litter, composter, double-T, pile, perforation.

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1 INTRODUCTION

Wastes pose serious environmental and health concerns; promotes insect vector proliferation, causes odour problem and a nuisance to sight. Its deposition in water bodies equally enhances aquatic weeds development and flooding. Other environmental impact categorisations are global warming, depletion of abiotic resources, acidification and eutrophication, hence the management is imperative. In Nigerian cities, waste management is a major environmental quandary, which is as a result of population increase, limited fiscal resource, low technical know-how on waste management (Martins, 2005). Also, indiscriminate industrial planning, increased urbanization, poverty and lack of willpower by both environmental agencies and individuals seem to have had marked impact on the massive level of pollution from waste generated in Nigeria (Ogunwande, 2010).

Solid waste generation in Nigeria is in the range of 0.44 to 0.66 kg/ capita /day and about 25 million tonnes/annum, with household and commercial centres contributing about 70% of total urban waste burden (Okwesili, 2016). About two-thirds of household and municipal wastes are indiscriminately dumped on the streets and in the drains thus posing severe environmental and health hazards. Hence, solid waste management intends to govern the generation, collection, storage, transfer and transportation, processing, and disposal in harmony with public health, economics, engineering, conservation, aesthetics, and other environmental considerations. This can practically be achieved by employing solid waste management methods such as waste minimisation, reuse, recycling and recovery. Composting falls into the recycling category (Akpenpuun et al., 2016).

Composting is the microbial decomposition of organic matter under controlled conditions. Some composting technologies have been developed to convert organic solid wastes into compost and organo-mineral fertilizers. Composting improves waste handling characteristics through volume or weight reduction, pathogens death, nutrients and organic matter stabilization (Barrington et al., 2003). Hence, conversion of organic solid wastes into compost and organo-mineral fertilizers is a practical approach to tackling the rising solid waste concerns.

The major problem in livestock industries, particularly poultry, is the large-scale of wastes generated on a daily basis. The accumulation of these wastes poses a high hazard to the environment. Hence, the disposal of these wastes using environmentally and economically sustainable waste management technologies and techniques is a conceivable panacea (Asuquo et al., 2012). However, some waste generated by the livestock industries are currently utilised on agricultural land as a source of nutrients and soil amendment, despite this, a considerable volume remains unused. Hence, a significant gap exists between waste generation and use that has resulted in giant heaps of livestock wastes, predominantly from poultry farmlands (Akpenpuun et al., 2017). The continuous accumulation of these wastes leads to environmental pollution. This study investigated the effects of configuration and perforation size on some physio-chemical properties of chicken litter using passive aeration composting to address this challenge.

2 MATERIALS AND METHODS

2.1 THE CONFIGURATION OF COMPOST BINS

The experiment was carried out under a shaded area, to prevent abiotic factors interference, at the Department of Agricultural and Biosystems Engineering, University of Ilorin, Ilorin Nigeria. Physio-chemical data obtained from the experiment were subjected to statistical analyses using SPSS 20.0 version. Two-way analysis of variance (ANOVA) was conducted to compare disparities in compost properties, where significance was

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indicated at $p \leq 0.05$. The experiment set-up comprised six compost bins, each having a dimension of 410, 420 and 540 mm for height, top, and bottom diameter, respectively. The above dimensions were adopted from Ogunwande (2010). Both pipe configurations had 14 perforation sizes and were installed in the bins. Each configuration was triplicate for different perforation sizes of 15, 20, and 25 mm diameters. Perforations were covered with synthetic mesh to prevent chicken litter from dropping into the pipes.

The fresh chicken litter used for this research was sourced from an egg-producing poultry farm in Ilorin metropolis, Nigeria, while the bulking agent, sawdust, was collected from a sawmill plant in Ilorin metropolis, Nigeria. The aeration pipes were made from 30 mm inner diameter polyvinyl chloride (PVC) pipes. Shown in Figures 1 and 2 are the double-T and V pipe configurations.

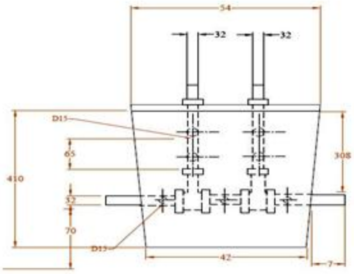

Fig. 1: Double-T Pipe Configuration

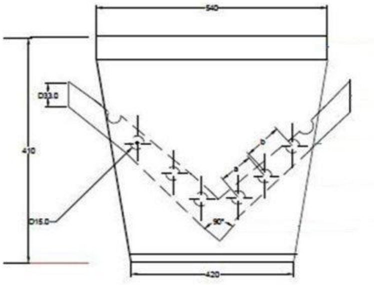

Fig 2: V Pipe Configuration

The weight of sawdust (a) needed for the desired C/N ratio was determined using equation 1.

$$a = \frac{\%N_b \text{ x } (\mathrm{R} - R_b) \text{ x } (1 - M_b)}{\%N_b \ (R_a - \mathrm{R}) \ (1 - M_a)} \qquad (1)$$

The quantity of water required to adjust the moisture content of the sawdust to 55% was determined using equation 2.

$$Quantity\ of\ water = \frac{\mathrm{M_b} - \mathrm{M}}{\mathrm{M} - 1.0} \qquad (2)$$

2.2 PARAMETERS INVESTIGATED

The pH and electrical conductivity (EC) were measured using a digital pH meter (Model 8000) and Conductivity TDS meter (Model YK – 22CT), respectively.

2.3 TEMPERATURE

The ambient temperature and temperatures within each pile were measured daily, using Lascar EL-WiFi-TH thermohygrometer (accuracy: ±0.3°C) and EL-WiFi-T+ (accuracy: ±0.1°C) at three levels (20, 30, and 35cm from the top). The temperatures readings were recorded at 08:00 and 10:00 am, when the ambient temperature was relatively stable.

2.4 MINERALS

Samples were collected biweekly at three levels before size reduction ground, a procedure recommended by Ogunwande (2010). Organic carbon, total nitrogen, pH value, phosphorous, and potassium content were tested and reported in their total. The total carbon (Ct) was calculated from the ash content using equation 3 (Mercer & Rose, 1968):

$$\mathrm{TC\%} = (100 - \text{Percentage Ash Content }\%) \times 1.8 \qquad (3)$$

2.5 ELEMENTAL LOSS

The initial (X_1) and final (X_2) ash contents were used to evaluate elemental loss. This estimation was carried out with piles as mass balance, the process considered pile weight reduction recommended by Ogunwande (2010).

$$Y_{loss} = \frac{X_1 Y_2}{X_2 X_2} \qquad (4)$$

where

Y = element (Organic carbon, total nitrogen, pH value, phosphorous, and potassium);

Y_1 and Y_2 = initial and final concentration of Y respectively.

3 RESULTS AND DISCUSSION

3.1 PHYSIO-CHEMICAL PROPERTIES OF COMPOSTING SUBSTRATES

The piles stabilized within 90 days of composting which agrees with Bernal et al. (2013), who reported 90 – 117 days of poultry manure stabilisation period. Seepage losses were considered insignificant as there was no free flow of water from the piles. There were noticeable changes in the physicochemical properties of the compost throughout the experiment. Shown in Table 1 is the analysis of the effect of pipe configuration (PC) and perforation size (PS) on the compost. There was no significant effect in the physicochemical properties concerning the pipe configurations and perforation sizes.

Table 1. ANOVA showing the effects of PC and PS on compost properties

Parameter	Source	df	F	p
pH	PS	2	1.51	0.23
	PC	1	0.70	0.41
	PS * PC	2	0.18	0.84
EC	PS	2	0.51	0.60
	PC	1	1.19	0.28
	PS * PC	2	0.74	0.48
C_T	PS	2	0.22	0.79
	PC	1	1.19	0.28
	PS * PC	2	0.17	0.84
N_T	PS	2	1.53	0.23
	PC	1	6.67	0.01x
	PS * PC	2	0.09	0.91
P_T	PS	2	1.25	0.29
	PC	1	0.94	0.33
	PS * PC	2	0.39	0.67
C/N Ratio	PS	2	0.19	0.82
	PC	1	0.27	0.60
	PS * PC	2	0.04	0.95

However, the pipe configuration had marked effect on the total nitrogen content at ($p < 0.05$). This might be attributed to early colossal N_T loss from NH_3 volatilization compared with a minimal loss from other physicochemical parameters (Bernal et al., 2008).

3.2 PILE TEMPERATURE

The thermophilic temperature was reached between 72 - 110 hrs from the start of the experiment. This temperature could have destroyed most of the pathogens and weeds. This thermophilic stage was reached earlier than that reported by Ogunwande (2010), who investigated the perforated V-shaped pipes configuration.

Samples at 20 and 30 cm pile depths had the highest average temperatures. However, these were relatively close to other pile depth temperatures, an indication of proper air distribution within the piles. The variations in the pile temperature were as a result of local aeration as the temperature indicates that oxygen consumed by the micro-organisms is high. The ANOVA result showed that PC, PS, and the interaction of PC and PS (PC*PS) had no significant effect ($p>0.05$) on pile temperature. This indicates air distribution uniformity for all the pipes considered in this study (Ogunwande, 2010; Akpenpuun et al., 2017a). The high consumption of Oxygen further suggests that all the pipes irrespective of configuration and perforation diameter worked effectively with respect to temperature distribution. The daily temperature profiles obtained with the average of the temperature values recorded at the three levels (depth) within the piles during the composting processes are presented in Figures 3 to 6.

Thermophilic temperatures within the range of 49 and 67oC was observed within 48 – 72hrs of composting was an indication of high microbial activities (Bernal et al., 2008) and that the initial C:N ratio of 30:1, moisture content of 55% and the pile configuration were ideal for composting chicken litter. The effectiveness of each bin for producing uniform composting rate within the pile was evaluated by comparing the upper and lower level thermophilic temperatures. The results of the analysis showed that the temperature readings did not differ significantly ($p> 0.05$) in all piles (Table 1).

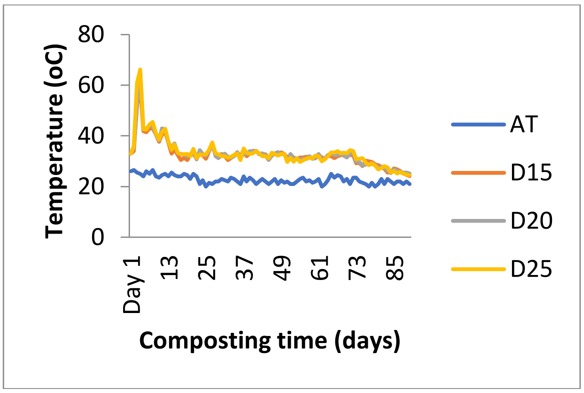

Fig. 3: Temperature vs. Time in Piles @ 8 am

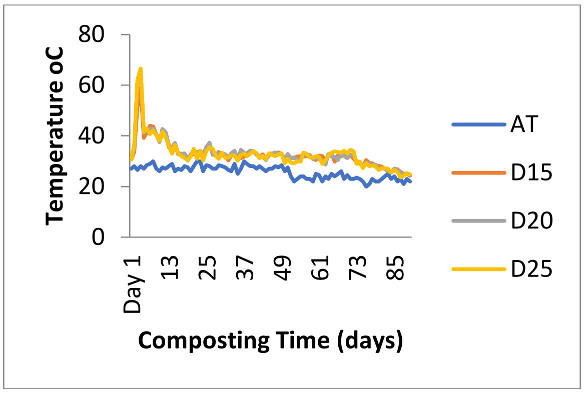

Fig. 4: Temperature vs. Time in Piles @ 10am

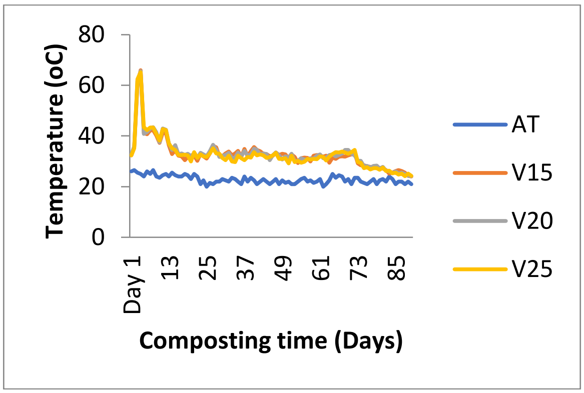

Fig. 5: Temperature vs. Time in Piles @ 8 am

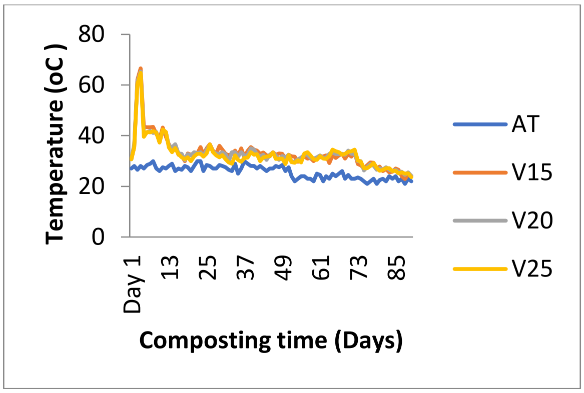

Fig. 6: Temperature vs. Time in Piles @ 10 am

3.3 pH

The chicken litter had an alkaline pH throughout the experiment. The initial values were within the range of 6.0 - 9.0 recommended for rapid composting. This could also be an indication of its buffering capacity. The pH of piles in double inverted tee pipe structure perforated with 20 mm perforation size (D20) and in V- shaped pipe structures with 20mm perforation (V20) were consistently the highest during composting in piles shown in Figures 7 and 8. The pH of pile D15 and V15 maintained a low profile while that of pile D20 decreased and increased remarkably. The pH of piles with Vs pipe followed nearly similar patterns shown by D20. Increase in pH was as a result of biodegradation of the organic acids, mineralization of organic compound and the following release of volatile NH_3. Bahman (2001) also reported increases in pH in cow dung composting. The drops in pH noticed in some piles in the early days of composting (V25- week 2) may have been due to the production of organic acids during decomposition of organic matter contained in the chicken litter. The decrease in pH towards the end of composting could be attributed to increasing nitrification process or an indication of maturity process. The final pH values (7.9 - 8.3) were within the range of 6.0 - 8.5 compatible with most composters and this result agreed with Bahman (2001) and Bernal et al. (2013), who reported on composting of cattle dung.

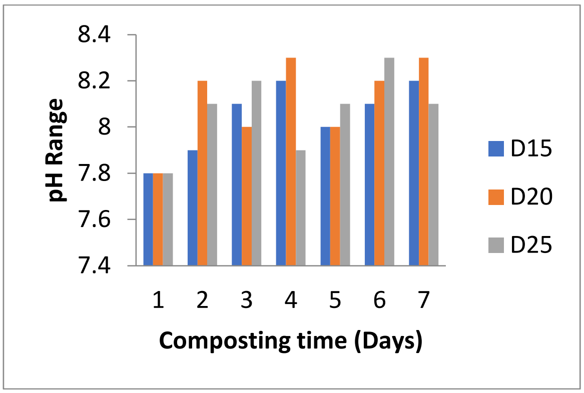

Fig. 7: pH vs. time in Piles (DIT-shapes)

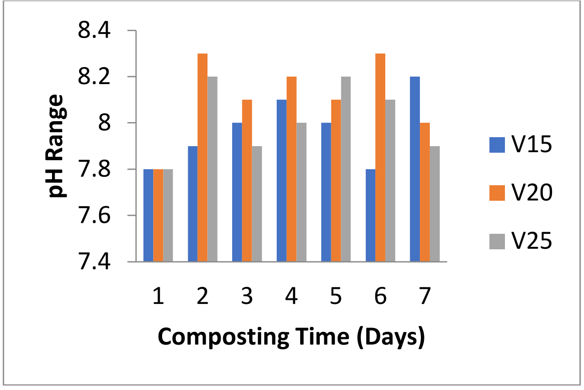

Fig. 8: pH vs. time in Piles (V-shapes)

3.4 TOTAL CARBON

The result of the ANOVA revealed no significant loss of total carbon (C_T) ($p > 0.05$). However, there was a higher loss of total carbon in piles with Vs (V15, V20, & V25) pipes, probably as a result of the losses during the thermophilic phase which was higher in piles with Vs pipes (24.7 - 53.7%) than in piles with DIT (D15, D20, & D25) pipes (24.5 - 51.2%). The C_T losses, which increased gradually to final values between 53.4% and 76.1%, Figures 9 and 10, could be attributed to bio-oxidation of organic matter resulting in the evolution of CO_2 and heat. The high losses in the early days of composting indicated a high level of organic matter biodegradation in the piles. This result follows the trend reported by Okwesili (2016) in the utilisation and biological indicators of soils.

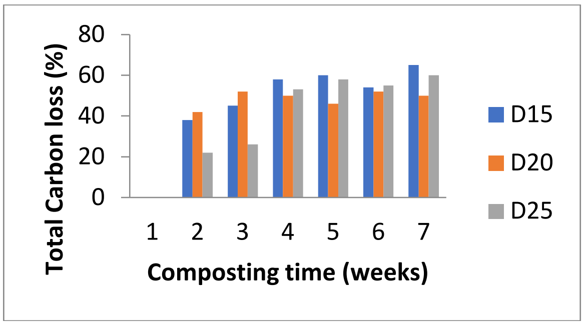

Fig. 9: Total Carbon loss vs. Time (DIT-shapes)

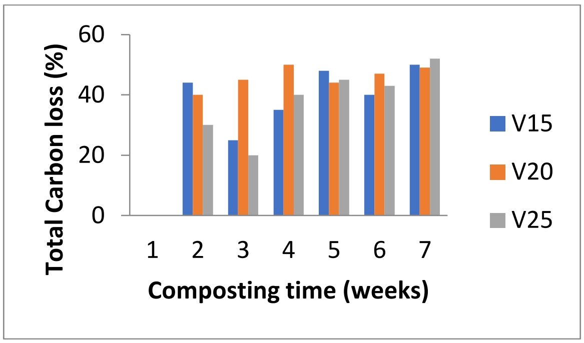

Fig. 10: Total Carbon loss vs. Time (V-shapes)

3.5 TOTAL NITROGEN

The N_T concentration increased gradually with time during the composting process; a phenomenon reported in previous composting studies conducted by Bernal et al. (2013). This increase in N_T was due to the concentration effect caused by the weight loss as organic matter was biodegraded and production of CO_2. The results of the ANOVA showed that neither PC/ PS nor the interaction had significant effect ($p<0.05$) on the loss observed in the piles (Table 1). Nevertheless, the mean values showed that the losses were more significant in piles with Vs pipe and piles with 25 mm diameter perforations. The final losses (0.30 - 25.2%) recorded in this study were lower than 45 - 92% reported by Ogunwande (2010), probably as a result of the passive aeration method used (Figures 11 and 12). Furthermore, most nitrogen loss documented was as a result of seepage, and since seepage was insignificant in this experiment, this justifies the low final losses (Bernal et al., 2008).

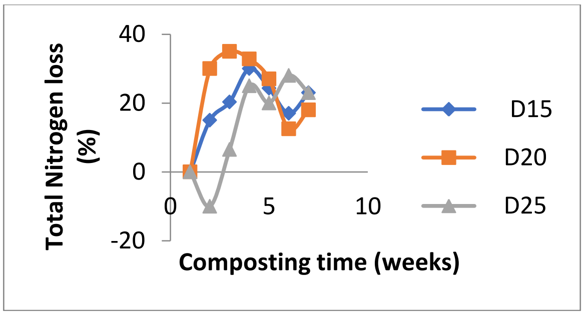

Fig. 11: Nitrogen loss vs. Time (DIT-shapes)

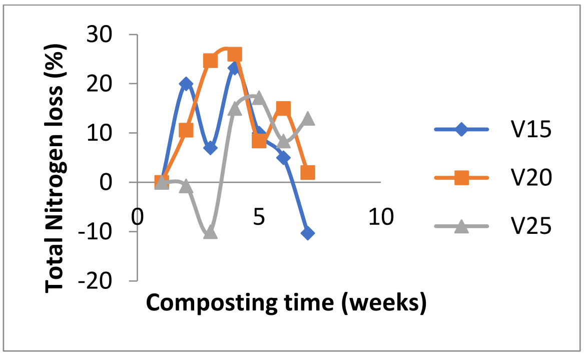

Fig. 12: Nitrogen loss vs. Time (V-shapes)

3.6 TOTAL PHOSPHORUS

The P_T concentration increased during composting, a situation that was attributed to the net loss of dry mass as a result of a decrease in the organic matter content (Bernal et al., 2008; Ogunwande, 2010). The results of the ANOVA showed that PS affected ($p<0.05$) P_T during composting. The P_T variation in each pile followed a sinusoidal pattern and was characterised by gain and loss in P_T content (Figures 13 and 14). The final values showed that all the piles had gained in P_T content. The final gains revealed that pipe Vs20 was equally as effective ($p> 0.05$) as pipe DIT15 in minimizing P_T loss.

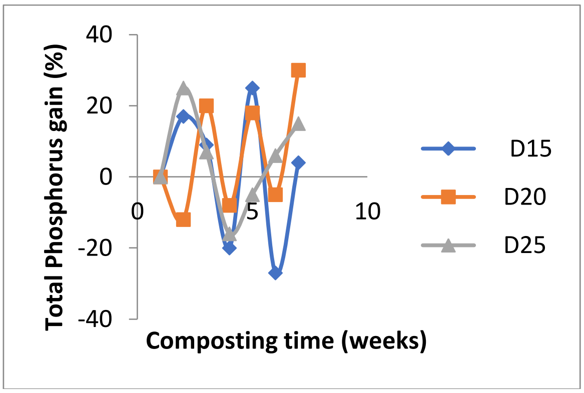

Fig. 13: Total Phosphorus vs. Time (DIT-shapes)

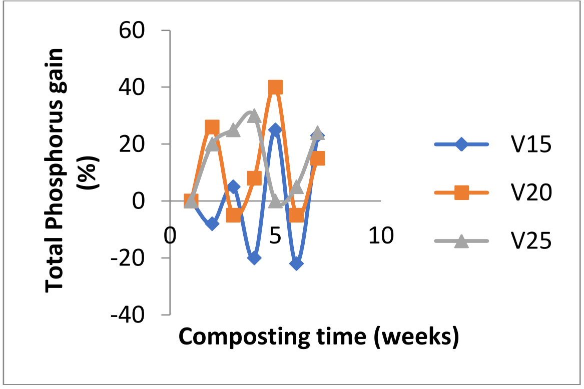

Fig. 14: Total phosphorus vs. Time (V-shapes)

3.7 C/N ratio

The initial C/N ratio (32:1) of the chicken litter was within the range of 20:1 - 35:1 recommended by Ogunwande (2010) for rapid composting. It was observed that neither PC nor PS had significant ($p> 0.05$) effect on the C/N ratio of composting piles, Table 1. A gradual decrease was noticed in all the piles in Figures 15 and 16 due to the mineralization of organic matter presents in the chicken litter and increase in total N concentration resulting from concentration effects as C is biodegraded. The decrease in C/N ratio with time has also been reported in previous composting studies (Bahman, 2001; Lawal, 2004). The final C/N ratios ranged from 10.3:1 to 13.5:1. These values were within the range of 12:1 to 16: 3 for final composts, and an indication of compost stability and compost maturity (Ogunwande, 2010)

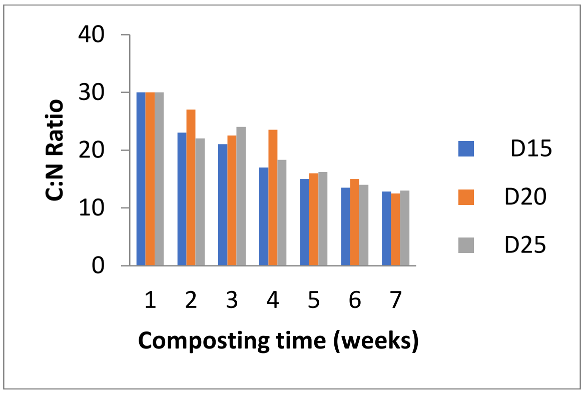

Fig. 15: C/N Ratio vs. Time (DIT-shapes)

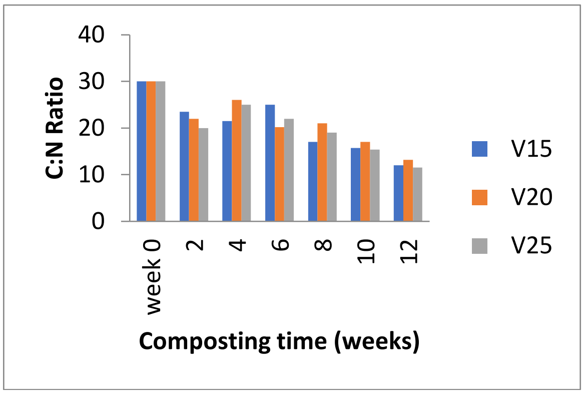

Fig. 16: C/N Ratio vs. Time (V-shapes)

4 CONCLUSION

The effect of the incorporation of a double-inverted-T and V-shaped pipes with three perforation sizes (15, 20 and 25 mm) were examined for chicken litter composting. Uniform air distribution was enhanced through the introduction of these pipes with the composts reaching maturation within 12 weeks. It was established that the final C/N ratios for all the composts were within the recommended limit (10.3 to 13.5/1). Furthermore, all the piles attained thermophilic temperatures for effective biodegradation. This study has established a low cost, aerobic, and effective chicken litter treatment via composting. The inclusion of the double inverted T-shaped pipe with 25 mm perforation sizes and all the V-shaped pipes considered in this study in chicken litter compost is both feasible for compost maturation cum stability and equally applicable for the agronomic purpose.

5 NOMENCLATURE

D_{15} Double Inverted T-pipe with 15mm diameter perforations

D_{20} Double Inverted T-pipe with 20mm diameter perforations

D_{25} Double Inverted T-pipe with 25mm diameter perforations

V_{15} V-shaped pipe with 15mm diameter perforations

V_{20} V-shaped pipe with 20mm diameter perforations

V_{25} V-shaped pipe with 25mm diameter perforations

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