Variability of physiochemical properties of pig manure with added wood shavings during open-air dumping and Windrow Composting

ABSTRACT

Background:
Effective composting management practice through monitoring of composting governing parameters is very crucial in ensuring the safety and effectiveness of the composting process and hence the quality of the compost.
Aims: To assess the variability of the different physiochemical properties (pH, pile temperature, mass, VS, TS and TOC) during open-air dumping and windrow composting of raw pig manure and shavings amended pig manure with wood.
Study design: Field and laboratory experiment
Place and Duration of Study: Waste-to-resource project site and project laboratory of the Department of Environmental Science of the University of Buea, Cameroon between February and March 2022.
Methodology: Two sets of pig manure and wood shavings were mixed in mass ratios of 100%:0% and 90%:10% and placed in four different chambers. One set was dumped in an open-air situation while the other set was left to compost for 40 days. Piles were monitored after every next day for pH, temperature,mass loss, EC, MC, TOC, TS and VS analyses.

Results: The highest composting temperature (63.4℃) was experienced in the 90:10 % while the lowest (39.4℃) was experience in the 100%. All 100% treatments had an acidic starting pH (5.04 and 5.58) while 90:10% treatments had a more basic pH (6.76 and 6.82), there was a significant difference in EC between the open-air dumped and windrow compost piles *(P* = 0.000). Mass significantly reduced by 64% and 75% (100% and90:10% compost respectively), 51% and 56.5% (100% and 90:10%dumping respectively). Significant difference existed in MC (*P* = 0.010). Both VS and TC decrease acrossall treatments, the highest VS and TOC were observed in all 100:0% treatments.
Conclusion: Open-air dumping and Composting of pig manure with woods shavings should be promoted since it enhances physiochemical properties, but more emphasis should be on composting than on open-air dumping.

Keywords: open-air dumping, pig manure, physicochemical properties windrow composting, wood shavings.

1. INTRODUCTION.

Pork is considered to be one of the most widely consumed meat in the world [8] [26][6]. Due to the rapid economic growth in populous countries such as China and India over the past 20 years, the demand and consumption of pork is expected to increase by up to 40% by 2050 [21].

Pig manure is a common organic waste generated from pig farming that is often stockpiled (dumped) in open spaces not far from residential areas in most developing countries like Cameroon. Poor pig manure management can create adverse environmental effects such as pollution from various nutrients and organic compounds, emission of ammonia and other greenhouse gases, leading to health risks for human and animals. Therefore, it is necessary to find a suitable alternative to reduce the environmental problems associated with management of pig manure [31]. Composting of pig manure with added wood shavings have been identified as a promising approach for managing pig manure to produce a valuable soil amendment [15]. Windrow composting of pig manure with added wood shavings has the potential of significantly reducing the cost of manure disposal and improve the nutrient content of the final product (compost), leading to potential savings on fertilizer costs, improves soil fertility and crop yield, leading to potential economic benefits for farmers.

However, effective compost management practices, as well as consideration of potential environmental and human health risks, are crucial to ensuring the safety and effectiveness of the composting process. The variability of physicochemical properties of pig manure with added wood shavings amendments during composting can have significant implications for the quality and safety of the final compost product.

According to [30] the addition of wood shavings to pig manure during open-air dumping and windrow composting significantly affects its physicochemical properties. [28] and [13] reported that composting leads to a decrease in pH, volatile solids (VS) moisture content (MC), mass, total nitrogen, carbon-to-nitrogen (C/N) ratio and total organic carbon (TOC), while the electrical conductivity and available phosphorus are increased over time during the composting process. These changes in physicochemical properties have serious implications on the quality and stability of the final compost product.

Effective composting management practice through monitoring of composting governing parameters such as pH, temperature, mass, Electrical conductivity (EC), MC, VS, TOC, mixing ratios [6], turning frequency [30], composting method, and bulking agents [13] is therefore crucial in ensuring the safety and effectiveness of the composting process and hence the quality of the end product (compost manure). This research was therefore carried out to assess the variability of the different physiochemical properties (pH, pile temperature, mass, volatile solids contents (VS), total solids (TS) and total organic carbon (TOC)) during open-air dumping and windrow composting of pig manure with and without the use of wood shavings as a bulking agent.

2. MATERIAL AND METHODS

2.1 Substrate collection.

Pig manure used in this study was collected in Buea, the regional capital of the South West Region of Cameroon. Fresh pig manure was obtained from a local concreted slatted floor pig farm located about 2 km of the University of Buea, the farm consisted of fattening pigs that were fed with crushed pellets (Piggfor, Origo 522) manufactured by LantmännenLantbruk® (Linköping Sweden). The feed contained 129 g/kg crude protein and 12.4 MJ/kg metabolical energy. The manure was considered fresh because the pit at the farm where the manure was collected was usually emptied daily to an external storage/dumping area. The wood shavings that were used was sourced locally from a saw mill located in Molyko (not more than 4 km from the University of Buea). The wood shavings were a combination of flakes from 30 50 years eucalyptus tree (30%), 45% Naucleadiderrichii (opepe) and 25% Enantiachlorantha (African whitewood).

2.1.1 Composting facility

This study was carried out in a shaded yard at the Waste-to-Energy Resource project site at the University of Buea. The project site is made up of 18 composting chambers; each having a dimension of 0.7 X 0.9 X 1 m. Each chamber has three closed walls with an open front and top, the closed walls are made of solid cement bricks to a height of 1 m from ground and a concreted floor. The floor of each chamber slopes very gently to the open front where it meets with a drainage channel through which leachates from the compost was collected. The entire composting site is covered with a solid roof of about 3 m from ground surface (Fig. 1).

2.2 Experimental set-up.

800 kg of fresh pig manure of not more than one day old was collected in empty rice bags and brought to the composting facility where two sets of 400 kg of manure were weighted using a scale balance (Type: Analog Hanging Scale, Shangzing QuanHeng, China). One of the sub-samples (400 kg) was homogenously mixed mechanically with wood shavings in the ratio 90:10 manure: wood shavings, while the other sub-sample was left unaltered (100% pig manure). Each of these subsamples were further divided into two sub-samples of 200 kg each and was used for composting and open-air dumping experiments respectively.

Fig. 1. Composting facility located in the University of Buea where measurements were conducted.

Manure subsample designated for open air dumping (stock piling) were placed in the first two chambers while manure samples designated for aerated composting were placed in the 3rd and 4th chambers respectively while the 5th chamber served as a reserve chamber used during mixing for aeration and mass reduction data collection (Fig. 2). Manure samples designated for aerated composting were turned after every 1 day (Mondays, Wednesdays, Fridays and Sundays) throughout the 40-days composting period while those designated for open air dumping were not mixed throughout the experiment. During mixing, manure in the 4th chamber was weighed and moved to the 5th, that in the 3rd was moved to the 4th and the process was reversed on the following days (Fig 2). As such, it is expected that the manure in chambers 3 and 4 where mixed and aerated. Daily mass reduction data was collected only for the manure samples designated for aerated composting, mass of the dumped manure was taken at the end of the 40 days period.

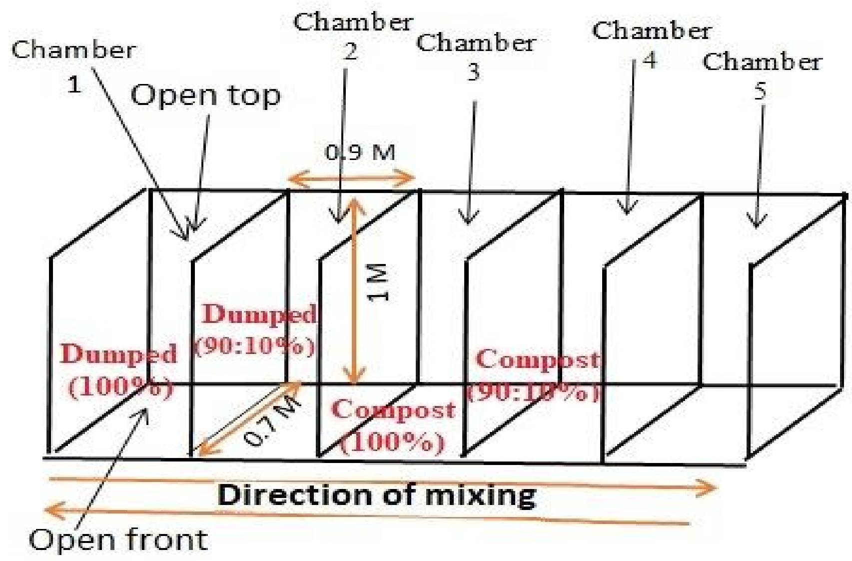

Fig 2. Schematic view of the windrow composting facility indicating pig manure to wood shavings mass mixing ratios.

2.3 Measurement of physiochemical parameters

Pile temperature and pH were measured in-situ (both for composting and open-air dumping) on every monitoring day (at 10 AM) by placing a compost thermometer (TFA Dostmann, Wertheim, Germany) and an AL10pH portable pH meter (Aqualytic, Dortmund, Germany). The sensors were placed on the manure at three different locations and depths, with the average readings considered to be the temperature and pH of the pile. Samples were collected from the dumped and composting piles in each chamber, this was done after turning of composting manure on every sampling day. Samples were collected into duplicate vials for the analyses of EC, moisture content (MC), total solids (TS), and VS using method 1648 of the U.S. Environmental Protection Agency [26] [18] [19]. Total organic carbon (TOC) was calculated according to [31].

2.3 Statistical analysis

Statistical analyses of the data were carried out using MINITAB version 21. Analysis of Variance (ANOVA) test was used to assess differences in the various physiochemical parameters in the different dumped and windrow compost piles at a p-value of 0.05. Where significant differences were observed, a post-hoc analysis was carried out using the TukeyHSD test to assess comparisons between the various physiochemical parameters profiles of specific groups of manure to wood shaving mixtures during dumping and windrow composting. Student T-test was used to compare means of physiochemical properties between raw pig manure and raw pig manure when amended with wood shavings under open-air dumping and windrow composting.

3. RESULTS AND DISCUSSION

3.1 Temperature Variation

Fig 3 shows the different trends in the pile temperature during dumping (storage), windrow composting of pig manure with different levels of amendments.
The temperatures in all the treatments both in the dumping and composting experiments began with ambient temperatures, all treatment experienced sharp increase in temperatures after four composting days.

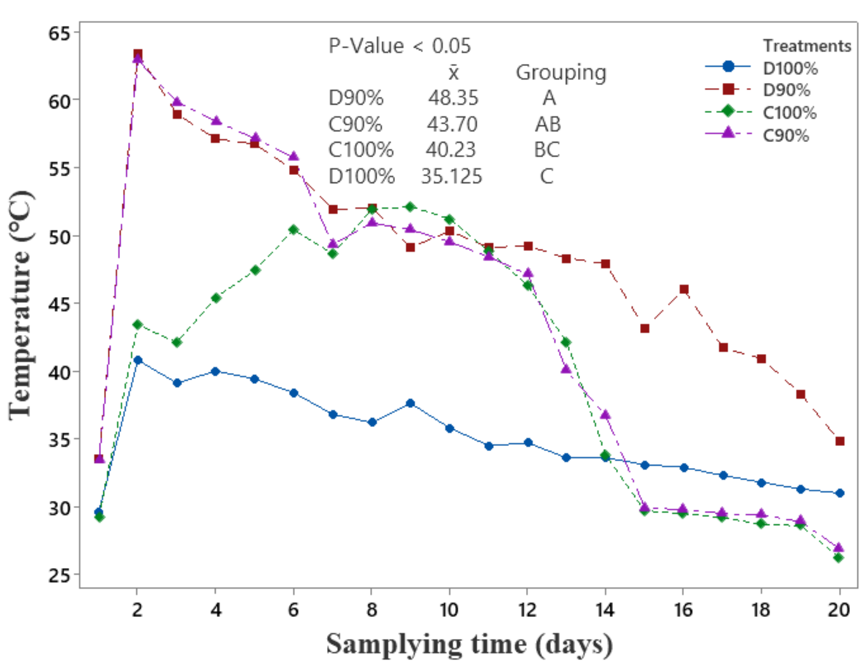

Fig 3. Variation in pile manure temperature of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings,

The highest and the lowest peak temperatures we both experienced in the open-air dumping treatments. The highest peak temperature in the experiment (63.4℃) was experienced in the 90:10 % dumping (D90%) on the 2nd day of the experiment while the lowest (40.8℃) was experience in the 100% dumping (D100%) on the 2nd day of the experiment. The sharp increase in temperatures after four composting days can be attributed to the direct relationship that exists between microbial activities and temperature during composting [21], the high microbial activities at the opening phase of the composting leading to the rapid increase in temperature. The significant difference that existed between the temperature profiles in both dumped and compost piles is similar to [19]. When temperature profiles between open-air dumped (stored) manure and windrow compost pile were compared using the ANOVA test, it was observed that a significant difference existed between the treatments in both dumped and compost piles. A further pair-wise post-hoc analysis showed that significant differences occurred for temperature profiles between D90% and D100%, D90% dumping and 100:0% composting (C100%) and between 90:10 compost (C90%) and D90% (Table 1). It has been reported that when wood shavings is added to manure, it increases the dry matter and especially the carbon-to-nitrogen ratio there by increasing microbial activities and hence compost pile temperature [18][31][19]. This study also indicated that the rate of decomposition increased with increasing turning; thus, the shortest maturation time and the fastest drop in temperatures was observed in the windrow composting treatments where there was constant turning throughout the 40 days measurement period. This has also been reported by [9] where bins with highest turning frequency experienced temperature dropped rapidly and the compost reached its maturity in a relatively shorter period of time.

Table 1: ANOVA table on the comparison of different pig manure treatments

	Temperature	pH	EC	MASS	MC	VS	TOC
Factor			**Means**				
D100%	35.13 C	7.204 C	3.2410 C	119.35 A	64.15 A	57.63 A	32.02 A
D90%	48.35 A	7.737 BC	3.5145 BC	103.6 A	54.58 AB	51.93 A	28.85 A
C100%	40.23 BC	7.843B	3.987 AB	149.0 A	56.49 AB	49.01 A	27.23 A
C90%	43.70 AB	8.489 A	4.079 A	143.5 A	49.35 B	45.14 A	25.08 A

3.2 pH variation

The pH profiles as shown in Fig 4, indicates that all 100% treatments started with a lower pH (5.04 and 5.58) for dumping and windrow composting respectively while all 90:10% treatments had a more basic pH at the start of the experiments (6.76 and 6.82) for dumping and windrow composting respectively.

All treatments exhibited an increasing pH throughout the 40 days experiments period, this has been reported elsewhere [1][11][19]. The highest end pH (8.84) was recorded in C100% while the lowest pH (8.32) was recorded in D100% treatment. Despite the increasing pH trend, fluctuations were observed and could be the influenced of the buffering capacity of wood shavings [23] [19]. An implication of the observed increasing pH trend is an increase in ammonia production and the activity of proteolytic bacteria [15][23]. The pH values were relatively constant as the composting process proceeded to indicate compost stabilization [12]. The results of this research also showed that turning had an insignificant effect on pH during composting and open-air dumping of pig manure, it has also been reported by [20]. The difference in pH between 90:10% compost and the rest of the treatment can be explained by the combined effect of the wood shavings and frequent turning while the difference between 100:0% dumping and windrow composting can be explained by the effect of turning on the pH [9]

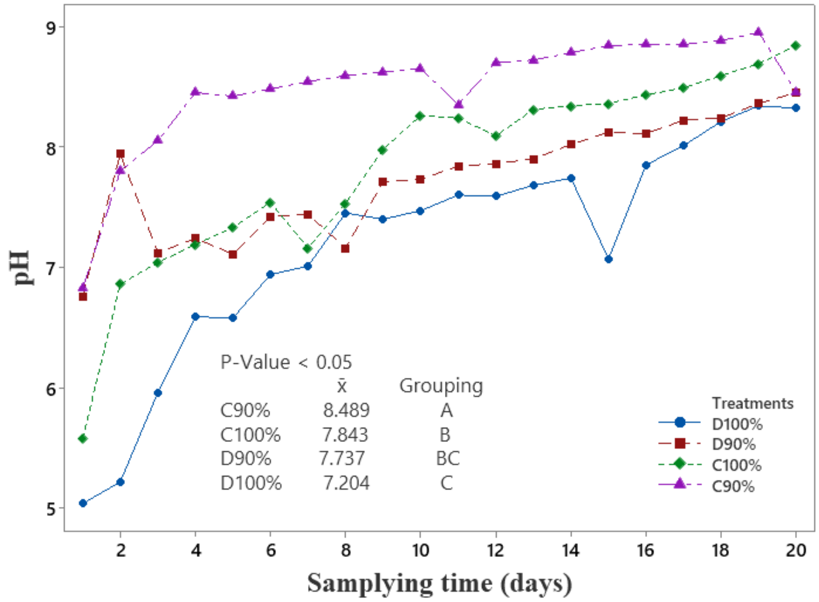

Fig 4. Variation in pH of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings.

3.3 Electrical Conductivity (EC) variation

The electrical conductivity of the windrow compost and dumped pig manure increased gradually during the composting and dumping period with a sharp decrease occurring between day 10 and 14 in all treatment. The lowest and the highest EC was recorded in C90% (1.95 µS/cm and 5.75 µS/cm respectively) on day 1 and day 10 of the experiment respectively (Fig 5). The steady increase in electrical conductivity of the windrow composting and dumped pig manure up to days 20 to 24 and the steady decrease thereafter in all treatments could be attributed to the release of mineral salts such as phosphates and ammonia ions through the decomposition of organic substances. The volatilization of ammonia and the precipitation of mineral salts could be the possible reason for the decrease in EC at the later phase of composting [28]. The greater increase in EC recorded by the windrow composting treatments was similar to [4], this can be attributed to the fact that frequent turning of the composting pile generally accumulates high concentration of salts and increases the electric conductivity (EC) in the compost [14]

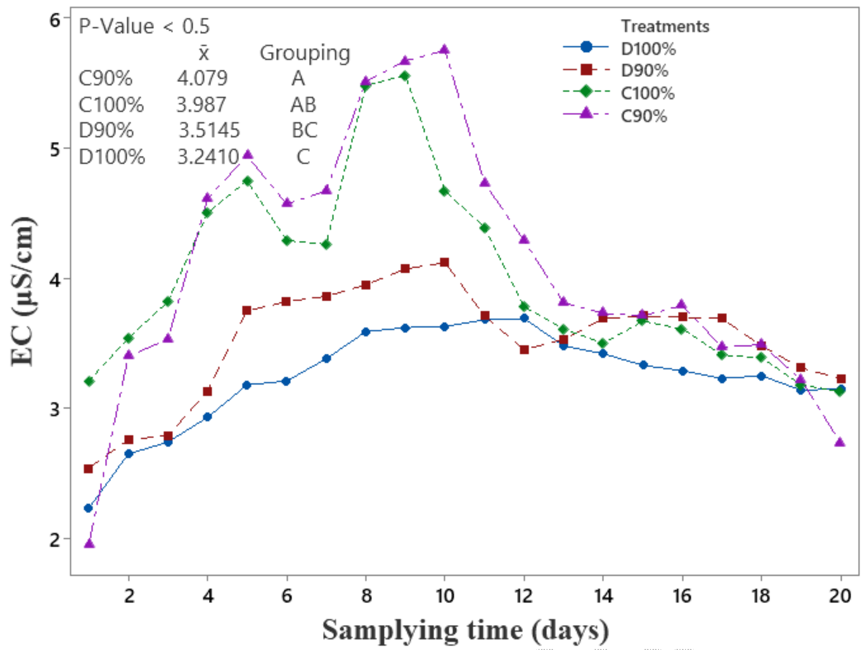

Fig 5. Variation in Electrical conductivity of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings

There was a significant difference in EC between the open-air dumped and windrow compost piles (P = 0.000) the Tukey's post hoc analysis further revealed that the differences existed between C90% and both D100% and D90% treatments while differences also occurred between the C100% and D100% (Table 1).

3.4 Mass reduction

Fig. 6 shows mass reduction during windrow composting and dumping of pig manure. There was a general decrease in mass throughout the composting and dumping period. The highest mass lost (75.5%) was recorded in C90% treatment while the least mass reduction (51%) was recorded in D100% (Fig 6). Loss in mass during composting has also been reported in other studies and has been attributed to energy utilized in the decomposition process, loss in water and evaporation of volatiles compounds [5][24] [31] [19].

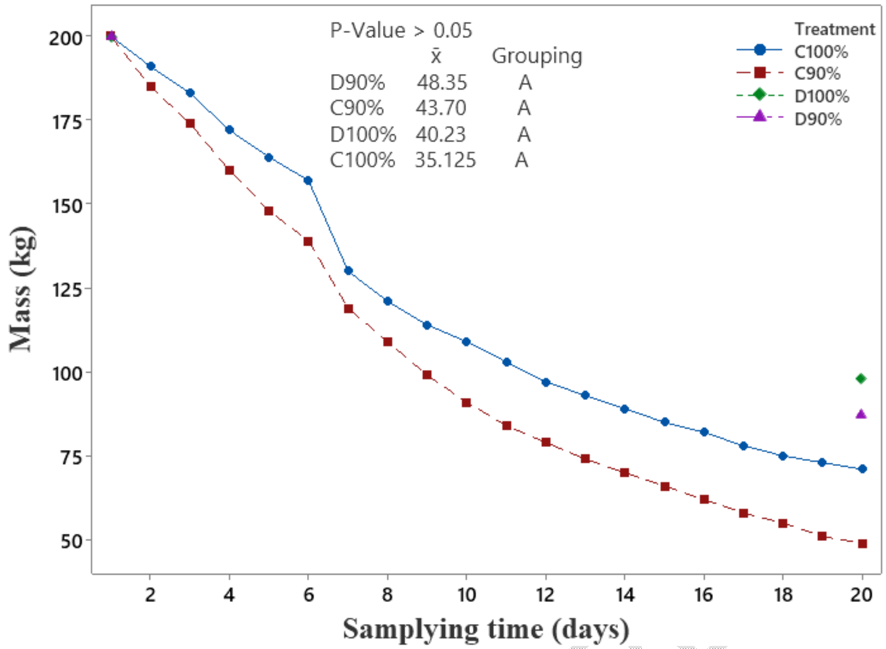

Fig 6. Mass reduction of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings

Composting and open air-dumping of pig manure with or without wood-shavings significantly reduced the mass by 64% and 75% (C100% and C90% respectively), 51% and 56.5% (D100% and D90% respectively) after 40 days and there was no significant difference between the various treatments (table 2). Higher mass reduction rates experienced in the amended manure treatment can be attributed to the added wood shavings which are associated to greater changes in the bulk density and free air space [17][33][19] while higher mass reductions observed in the composting treatment when compared to the open-air dumped treatment can be attributed to the frequent turning that increased the rate of decomposition.

Table 2: T-test results for comparison of means of physiochemical properties between raw pig manure and raw pig manure when amended with wood shavings under open-air dumping and windrow composting.

Variable	Temperature	pH	EC	MC	VS/TOC
D100% and D90%	Not significant	Not significant	Not significant	significant	Significant
C100% and C90%	Not significant	Not significant	Significant	Significant	Significant
D100% and C100%	Not significant	Not significant	Not significant	Not significant	Significant
D100% and C90%	Not significant	Not significant	Not significant	Not significant	Not significant
D90% and C100%	Not significant	significant	Not significant	significant	Significant
D90% and C90%	significant	Not significant	Not significant	Significant	significant

3.5 Moisture content variation

Treatments with wood shavings amendments (D90% and C90%) observed lower initial moisture content (76.47% and 76.56%) respectively for dumping and composting while treatments without wood shavings (D100% and C100%) observed higher initial moisture content (83.69% and 82.53%) respectively for dumping and composting (Fig 7.). Final MC on the other hand was lower in the composting treatments (34.92% and 25.53% respectively for C100% and C90%) than the open-air dumped treatments (45.11% and 40.31% respectively for D100% and D90%).
Significant difference existed in MC between the open-air dumped and windrow compost piles (*P* = 0.010). A Tukey's post hoc analysis further revealed that the differences existed between C90% and D100% (Table 1).

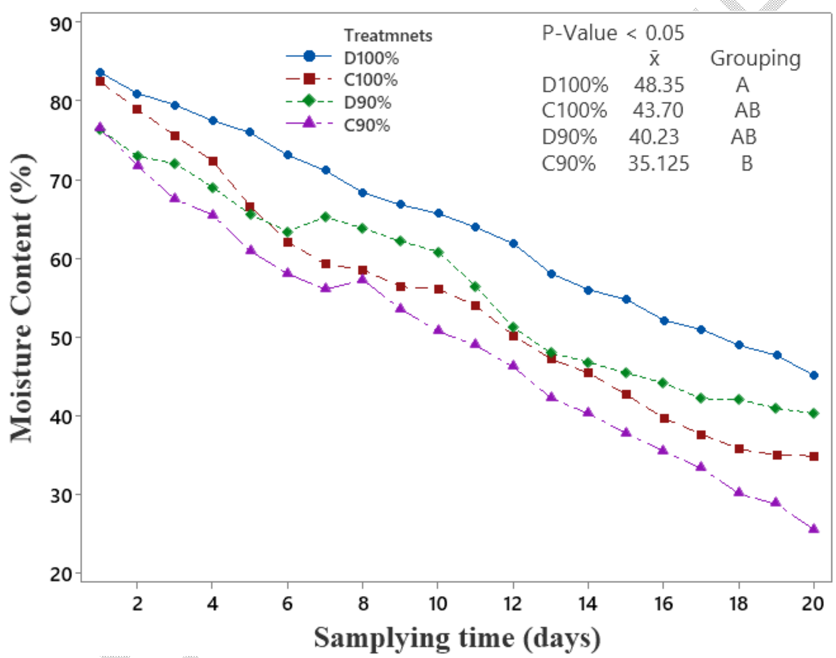

Fig 7. Moisture content variation of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings.

Variation in the Moisture content between Windrow composting and open-air dumping process can be viewed as an index of decomposition rate, since the heat generated during decomposition leads to vaporization, reasons for lower moisture contents in the windrow compost treatments. Greater aeration by turning and wood shavings amendments during windrow composting intensifies the activities of microorganisms, shortens the period of active stabilization [31].

3.1.6 Volatile solids (VS) and Total organic carbon (TOC) variation

Both VS and TC generally decreased across all livestock manure treatments (Fig 8). Both VS and TC values were not significant different along the treatments (*P*=0.152). This study showed that the bulking agent (wood shavings) had a significant role to play in the decrease in VS and TOC during the composting process with maximum decrease occurring during the mesophilic phase and between the most aerated treatments.

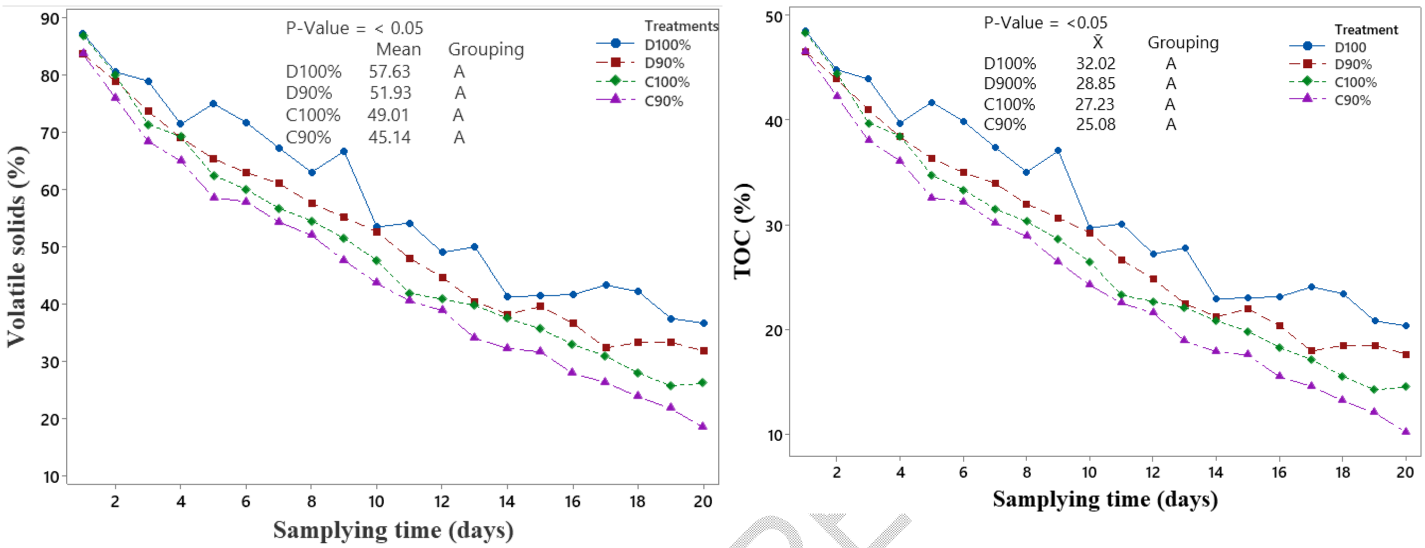

Fig 8. Volatile solids (VS) and Total organic carbon (TOC) variation of different manure and woodshavings mixing ratios during composting and dumping. D100: dumped raw manure, D90: 90% raw manure dumped with 10% woodshavings, C100: composted raw manure, C90: 90% raw manure composted with 10% woodshavings

This trend is likely to be due to loss of carbon as CO2 during open-air dumping and composting. Since the decomposition process was the fastest and most aerated treatments, the highest carbon loss was observed in these treatments while the lowest carbon loss was observed for pile with the least aeration. Decrease in carbon content with increasing turning frequency was also reported by [2][3] [20]. Organic matter mineralized recorded after open-air dumping and composting was mostly due to the degradation of easily degradable compounds such as proteins, cellulose and hemicellulose, which are utilized by microorganisms as C and N sources. While degrading organic compounds, microbes convert 60–70% carbon to CO2 and utilize remaining 30–40% into their body as cellular components [3].

4. CONCLUSION

The findings showed that increased aeration and turning speed up the rate of decomposition, resulting in shorter maturation time and faster temperature drop. Temperature was directly related to microbial activity, with wood shavings enhancing microbial activities and leading to higher temperatures. pH fluctuated during composting but stabilized as the process advanced, indicating compost stabilization. Initial mineral salt release increased electrical conductivity, which later decreased due to ammonia volatilization. Mass loss occurred during windrow composting and open air dumping, primarily due to energy usage, water loss, and evaporation of volatile substances. Wood shavings amendment improved bulk density, free air space, and accelerated mass reduction rates. Moisture content differed between open-air dumping and windrow composting, reflecting decomposition rates, with windrow composting experiencing reduced moisture due to evaporation. Aeration, facilitated by turning and wood shavings, increased microbial activity and reduced active stabilization time. Wood shavings also reduced volatile solids and total organic carbon throughout composting. Controlling composting processes is crucial for enhancing microbial activity, temperature control, pH stability, nutrient release, and mass reduction. Regular mixing of pig manure with wood shavings is recommended to improve physiochemical parameters and shorten decomposition time, resulting in high-quality compost with reduced environmental impact.

The authors acknowledge support from all the pig farmers and the saw mill owner who provided livestock manure and wood shavings used in this research. We equally thank the HOD of the Department of Environmental Science of the University of Buea-Cameroon for granting us access to both the waste to resource project site and the Laboratory.

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