Effect of wood shavings on the temperature profile of livestock waste during composting with daily turning

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Abstract: The use of bulking agents in the composting of livestock manure improves process characteristics and mitigates gaseous emissions. Measurements were conducted to assess the impact of wood shavings on the temperature profiles of cattle and pig manure during aerated composting. Cattle stomach waste and wood shavings were mixed in mass ratios of 100%:0%, 80%:20%, and 75%:25% and placed in three different chambers. Pig manure was also mixed with wood shavings in ratios similar to that of cattle stomach waste and placed in three different chambers. The piles were left to compost for 21 days after which the experiment was repeated. During composting, each pile's temperature and pH were measured daily. On each measurement day, the compost pile in each chamber was weighed and aerated by moving into an empty chamber. Compost samples were collected from each chamber twice a week for dry matter and volatile solid contents analyses. Results showed that composting pile temperatures increased with increasing levels of wood shavings added to manure. Pile temperature profiles followed a three-stage configuration; mesophilic, thermophilic, and curing stage. The duration of each stage depended on the type of livestock manure and the quantity of wood shavings used for amendment. The duration of the thermophilic stage for composting piles amended with wood shavings more than doubled that of piles not amended with wood shavings. Aerated composting of livestock manures significantly reduced the mass (by 56%-69% after 21 days) with a greater reduction favored for manure amended with wood shavings. Aerated composting reduced the moisture content of livestock manure from 77% to 45% after 21 days. The pH profiles indicated an increasing trend throughout the composting duration with values ranging from 3.08-6.69 at the start to 7.35-8.59 at the end of composting.

Keywords: aeration, composting, livestock, manure, temperature profile, wood shavings, Cameroon

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1 Introduction

Livestock manure is an important organic source of plant nutrients for many smallholder African farmers (Bayu et al., 2005). However, when livestock manure is not properly managed, it losses vital plant nutrients, becomes a source of greenhouse gases and odor (Ngwabie et al., 2010; Park et al., 2014; Ndambi et al.,

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2019). Composting is regarded as one of the favored manure management practices where aerobic microorganisms convert biodegradable material into compost, water vapour and carbon dioxide, while mitigating methane emissions (Lopez-Real and Baptista, 1996). Composting also considerably reduces manure volume (Michel et al., 2004; Febrisiantosa et al., 2018) and inactivates pathogens (Gurtler et al., 2018). Methane mitigation associated with composting may rather lead to increased emissions of ammonia, since composting increases pile pH and temperature, favoring the production of ammonia over ammonium (Li et al., 2008). As such, it has been shown that ammonia emissions increase exponentially with process temperature during the thermophilic stage of composting, and increase linearly with temperature during the curing stage of the composting process (Pagans et al., 2006).

Amongst other factors such as moisture content and carbon/nitrogen ratio, temperature is considered an important factor affecting composting due to its influence on the activity and growth of microorganisms (Poincelot, 1974; Liang et al., 2003). The temperature profiles of composts piles generally follow a three-stage configuration; a mesophilic, thermophilic, and curing stage (Pagans et al., 2006; Huang et al., 2017; Febrisiantosa et al., 2018). The amendment of livestock manure with wood shavings increases the dry matter content and carbon/nitrogen ratio, thus providing energy for microorganisms and their activities (Groenestein and Van Faassen, 1996). This is expected to enhance the composting process and further increase pile temperature compared to manure that is not amended with wood shavings.

Adequate information on pile temperature profile during composting is therefore important to monitor the efficiency of the decomposition process. As such, the objective of this study was to assess the impact of wood shavings on the temperature profile of cattle and pig manure during composting with daily turning of the pile. In addition, changes in compost pile mass/dry matter and pH were also analyzed.

2 Materials and methods

2.1 Composting facility

Composting of cattle stomach waste and pig manure with and without wood shavings was carried out in a roofed facility consisting of seven chambers (Figure 1), located in the campus of the University of Buea-Cameroon. Each chamber consisted of three walls constructed with cement blocks and a concreted floor. The dimensions of each chamber was 0.9 × 0.7 × 1 m (L×W×H) as shown in Figure 2.

Figure 1 Roofed composting facility showing empty composting chambers, each with three walls and one open side

2.2 Manure sample preparation

Cattle stomach waste and pig manure (Figure 2) were collected locally in plastic buckets and transported by car to the composting facility. The samples were collected early in the morning and composted the same day. Cattle stomach waste was collected from a slaughterhouse during the slaughtering process, while pig manure was collected from the concrete floor of a privately owned farm located in Buea, the headquarters of the South West Region of Cameroon. At the composting facility, a scale balance (Analog Hanging Scale, Shangzing Quan Heng, China) was used to subsample 100, 80 and 75 kg cattle stomach waste into chambers 1, 2 and 3 respectively (Figure 2). Twenty and 25 kg wood shavings obtained from a saw mill processing *Swietenia* were added to the waste in chambers 2 and 3 respectively to enable the contents of each chamber to be 100 kg (Table 1). The wood shavings and waste in each chamber were then homogenously mixed manually (Figure 2). Similarly, pig manure and wood shavings were subsampled into chamber 4 (100 kg), chamber 5 (80 kg pig manure and 20 kg wood shavings) and chamber 6 (75 kg pig manure and 25 kg wood shavings) as seen in Table 1, with the contents of each chamber homogenously mixed. Chamber 7 was reserved for daily mixing events to aerate the composting piles. The contents in each chamber were composted for 21 days in May (Experiment 1). The entire experiment was repeated for another 21 days in June (Experiment 2) with new cattle stomach waste, pig manure and wood shavings all collected from the same locations as in the May experiment. The measurement duration of 21 days was determined when average compost pile temperatures during the curing stage were similar to pile temperatures at the start of composting. During both experiments, water was not added to the composting piles.

Table 1 Manure and wood shavings ratio in different composting chambers

Cattle stomach waste: wood shavings (kg)	Pig manure: wood shavings (kg)
Chamber 1. 100:0	Chamber 4. 100:0
Chamber 2. 80:20	Chamber 5. 80:20
Chamber 3. 75:25	Chamber 6. 75:25

Figure 2 Livestock manure and wood shavings and the mixture used in the composting process

2.3 Composting pile data collection

During the composting process, data relating to temperature, pH and mass of the compost pile were measured daily at 8 a.m. Composting pile temperature in each chamber (Figure 3) was measured at three different locations using a compost thermometer (TFA Dostmann, Wertheim, Germany). The three locations for temperature measurement were chosen along the edge and in the middle of the pile. Instantaneous compost pile temperature in each chamber was the average of the three readings. Composting pile pH in each chamber was measured in-situ using an AL10pH meter (Buch & Holm A/S – Marielundvej, Denmark) and recoded as the average of three readings from different locations measured. After measuring the temperature and pH, the contents in each chamber were weighed and turned by moving them to the next empty chamber. For example, the contents in chamber 6 were moved to the empty reserved chamber 7, thereby freeing up chamber 6 to receive the contents of chamber 5.

Figure 3 A mixture of manure and wood shavings undergoing decomposition in a chamber

Samples were collected from the composting pile in each chamber twice a week after turning events. The samples were collected into duplicate vials for analyses of the dry matter and moisture content using method 1648 of the U.S. Environmental Protection Agency (Telliard, 2001, Ngwabie et al., 2018).

Ambient air temperature and relative humidity were measured under the shade of the composting facility using a Tinytag data logger (Gemini Data loggers, Chichester, UK) at 5 min intervals.

2.4 Statistical analyses

All statistical analyses were performed using the R package for statistical computing. The Analysis of Variance (ANOVA) test was used to assess differences in compost pile temperatures for various manure to wood shavings mixtures at a *p*-value of 0.05. When a significant difference was observed, a post-hoc analysis was carried out using the TukeyHSD test to assess comparisons between temperature profiles of specific groups of manure to wood shaving mixtures.

3 Results and discussion

3.1 Ambient conditons and composting pile characteristics

During the first measurement duration in May, the air temperature was in the range of 19-35 ℃ with a mean value of 25 ℃±3 ℃ while the relative humidity was in the range of 42%-99% with a mean of 85%±11%. In June, the air temperature was in the range of 20 ℃ -31 ℃ with mean a value of 25 ℃±3 ℃ while the relative humidity was in the range of 59%-99% with a mean of 88%±8%.

The characteristics of the cattle stomach waste and pig manure measured during the first day of sampling are presented in Table 2 as well as that of the wood shavings. Composting of the cattle stomach waste and pig manure with or without wood-shavings significantly reduced the mass by 56%-69% after 21 days, with details presented in Table 3. Loss in mass during composting has also been reported in other studies and has been attributed to energy utilized in the decomposition process, loss on water and evaporation of volatiles compounds (Breitenbeck and Schellinger, 2004; Rom and Zhang, 2010). Although there was no clear pattern in mass reduction based on the level of added wood shavings, a higher reduction is expected for amended manure as added wood shavings are associated to greater changes in the bulk density and free air space (Michel et al., 2004).

Table 2 Characteristics of raw cattle stomach waste and pig manure

Characteristics	Cattle stomach waste		Pig manure	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
Moisture content (%)	87	84	81	79
pH	6.95	6.98	3.08	7.35
Dry matter (%)	13	16	19	21
Volatile solids (%)	85	81	91	89

Table 3 Reduction in the mass of livestock manure when composted with different levels of wood shavings

Mass ratio of manure to wood shavings (kg)	Cattle stomach waste mass reduction (%)		Pig manure mass reduction (%)	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
100:0	66	69	62	61
80:20	67	69	56	65
75:25	68	69	66	66

Note: Experiment 1 was carried out in May while experiment 2 was carried out in June.

The reduction in mass shown in Table 3 corresponded to a reduction in the moisture content in each pile as presented in Figure 4. The moisture content of the experiment with cattle stomach wastes was on average 81% at the start and 45% at the end of the composting process. The moisture content of the experiment with pig manure was on average 77% at the start and 45% at the end of the composting process.

The range of pH values for the different livestock manure with and without wood shavings are presented in Table 4. It was observed that pH values were different not only between cattle and pig manure, but also between samples of the same livestock manure. The pH profiles are shown in Figure 5, indicating an increasing trend throughout the aerated composting duration of 21 days as has been reported elsewhere (Abdullah et al. 2013, Huang et al., 2017). Despite the increasing pH trend, fluctuations were observed and could be influenced by the buffering capacity of wood shavings (Rich et al 2018). An implication of the observed increasing pH trend is an increase in ammonia production and the activity of proteolytic bacteria (Li et al., 2008, Rich et al 2018). The pH values were relatively constant as the composting process proceeded to indicate compost stabilization (Jain, et al. 2019). It was noted that the initial pH values for the pig manure doubled from experiment 1 to experiment 2. This could be influenced by a mixture of feed and/or urine content in the manure that was collected on the concreted floor.

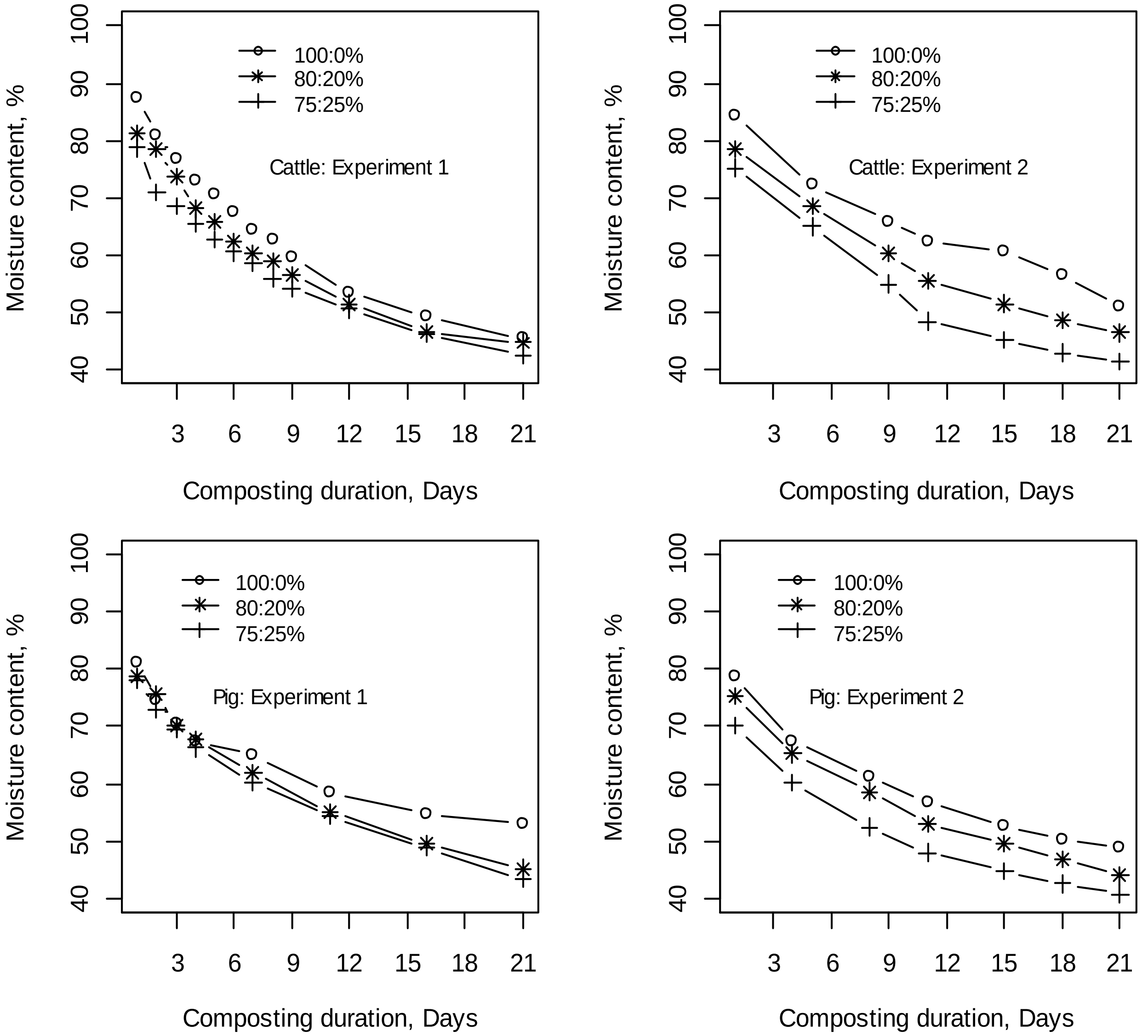

Figure 4 Profiles of moisture contents for cattle stomach waste and pig manure when composted with different levels of wood shavings

Note: Percentages represent the mass ratio of manure to wood shavings in the mixtures.

Table 4 Range of pH values during the composting of livestock manure with different levels of wood shavings

Mass ratio of manure to wood shavings (kg)	Cattle stomach waste		Pig manure	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
100:0	6.20-8.57	6.96-7.89	3.08-7.65	6.67-8.19
80:20	5.92-8.48	6.94-8.13	3.61-7.48	6.48-7.88
75:25	5.77-8.59	6.92-8.20	3.25-7.35	6.52-7.94

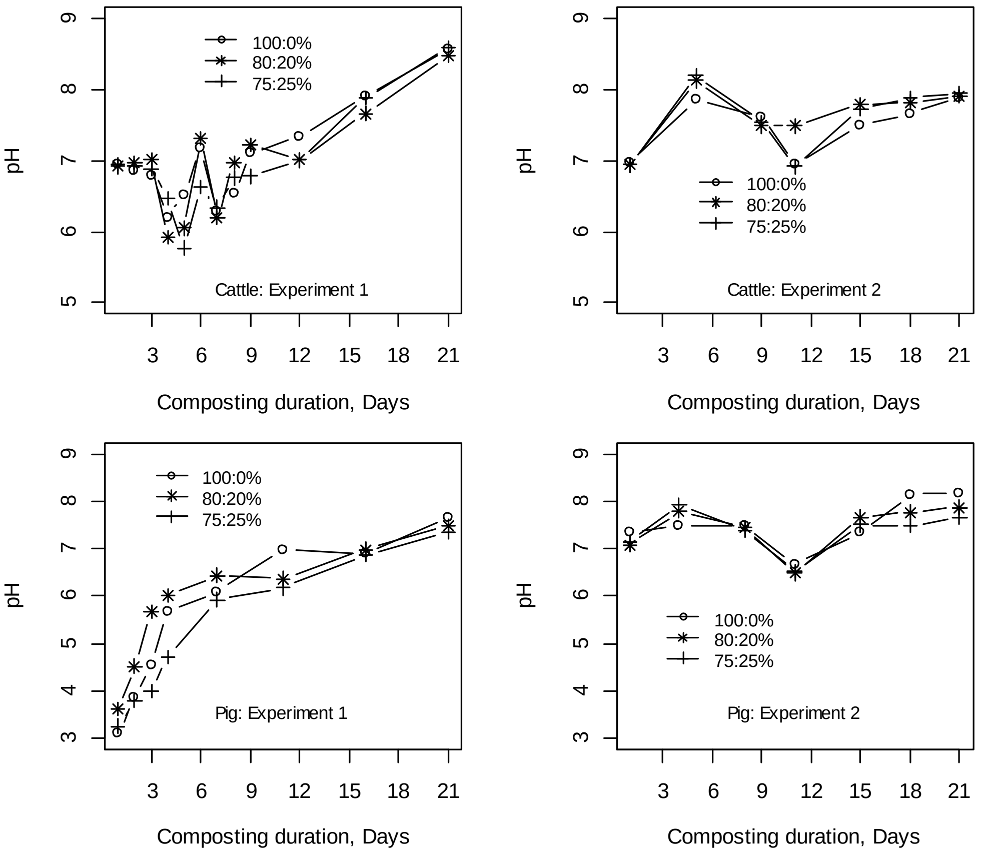

Figure 5 Profiles of pH for cattle stomach waste and pig manure when composted with different levels of wood shavings.

Note: Percentages represent the mass ratio of manure to wood shavings in the mixtures

3.2 Pile temperature profile

The range of pile temperatures recorded during the composting duration is presented in Table 5. Details of the composting pile temperature profiles are shown in Figure 5 for cattle stomach waste and pig manure. The lowest temperature in each manure to wood shavings mixture was measured either on the first or last days of composting. In fact, measurements in the current experiment lasted for 21 days because compost pile temperatures on day 21 were similar to compost pile temperatures on the first day (Figure 6). Results showed that higher instantaneous temperatures were measured in compost piles amended with wood shavings when compared to compost piles without wood shavings. Peak temperatures increased with the level of wood shavings added to the livestock manure as presented in Table 5. For example, peak pile temperatures were 52℃, 59℃ and 61℃ as wood shavings added to cattle stomach wastes were 0%, 20% and 25% respectively in experiment 1.

The temperature profiles of composts piles presented in Figure 6 generally followed a three-stage configuration; a mesophilic, thermophilic, and a curing stage in line with other studies (Abdullah et al., 2013; Huang et al., 2017; Febrisiantosa et al., 2018). The duration of each stage depended both on the waste type and the level of amendment with wood shavings. Apart from cattle stomach waste in experiment 2 (Figure 6), the temperature within compost piles amended with wood shavings increased rapidly during the first three days of composting from the mesophilic range (20 ℃-45 ℃) to the thermophilic range with temperatures above 45 ℃. Manure that was not amended with wood shavings generally took about twice longer to reach thermophilic temperatures compared to manure with added wood shavings. It was also observed that for compost piles that reach thermophilic temperatures, the duration of the thermophilic stage for amended compost was more than double that of compost piles that were not amended with wood shavings.

Table 5 The range of pile temperature (℃) values achieved during the composting of cattle stomach waste and pig manure with different levels of wood shavings

Mass ratio of manure to wood shavings (kg)	Cattle stomach waste		Pig manure	
	Experiment 1	Experiment 2	Experiment 1	Experiment 2
100:0	24.9-52.3	26.9-38.7	25.7-47.8	28.8-48.8
80:20	25.7-58.5	28.3-44.1	27.0-53.5	27.4-52.7
75:25	25.1-61.3	28.1-46.1	26.3-55.8	27.0-52.7

Table 6 Post-hoc analysis of specific temperatures of groups of manure to wood shaving mixtures

Pairs of manure to wood shaving mixtures	Cattle stomach waste	Pig manure
	Experiment 2	Experiment 1
80:20 versus 100:0	NS	NS
75:25 versus 100:0	SD	SD
75:25 versus 80:20	NS	NS

Note: Non significant difference, SD: Significant difference

When compost pile temperatures between different manure to wood shaving mixtures were compared using the ANOVA test, it was observed that a significant difference existed between the mixtures of experiment 2 for the cattle stomach waste as well as the mixtures of experiment 1 for the pig manure. A further pair-wise post-hoc analysis showed that the significant differences occurred only for temperature profiles of manure to wood shaving mixtures of 75:25 and 100:0 for cattle and pig manure respectively (Table 6). This indicates that the temperature profile during composting is affected more with increasing proportions of wood shavings added to manure.

A significant difference in the temperature profiles was observed between the compost piles with no wood shavings and that with the highest quantity of added wood shavings. This indicates an increase in compost temperature with increasing quantity of added wood shavings added to manure. It has been reported that wood shavings is added to manure, its increases the dry matter and especially the carbon-to-nitrogen ratio there by increasing microbial activities and hence compost pile temperature (Poincelot, 1974; Ngwabie et al., 2010).

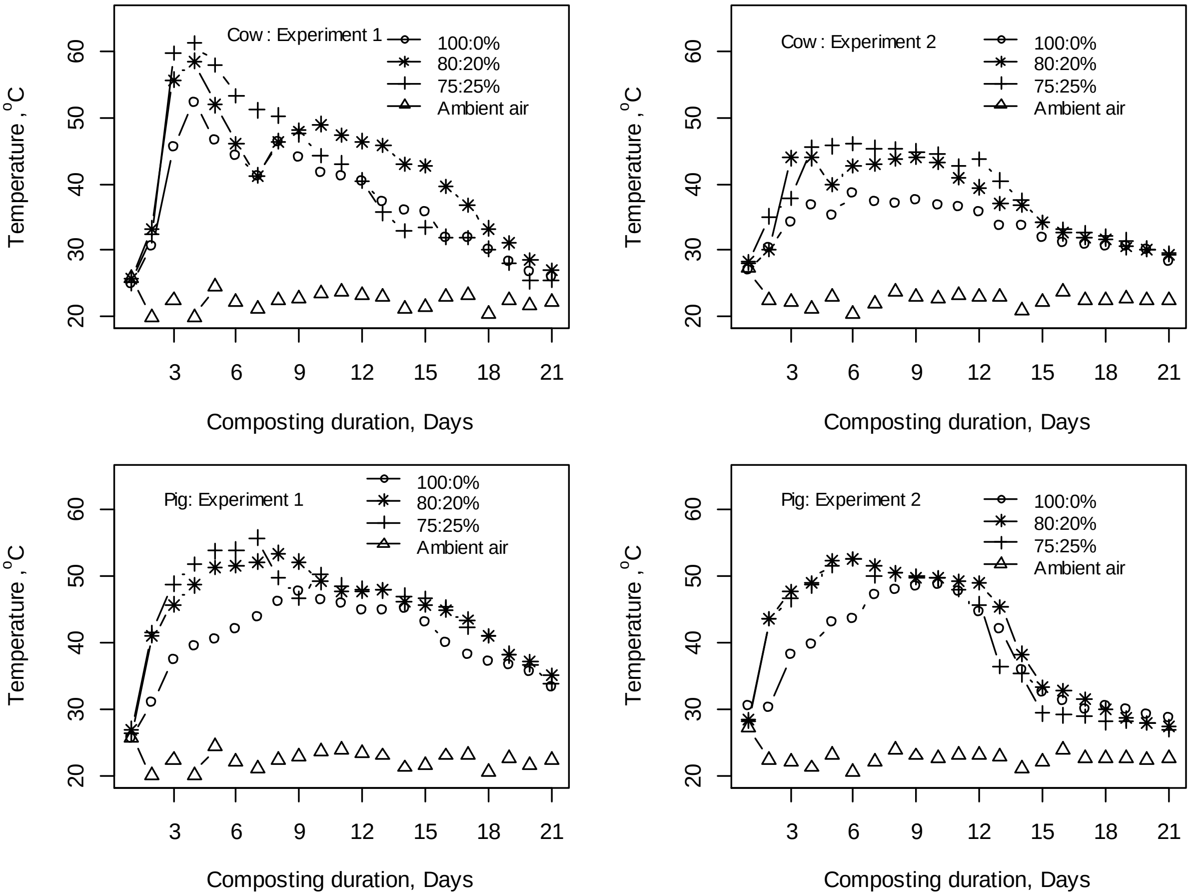

Figure 6 Temperature profiles of cattle stomach waste pile during aerated composting with wood shavings

Note: Percentages represent the mass ratio of manure to wood shavings in the mixtures.

4 Conclusions

The amendment of livestock manure/waste with wood shavings during composting provides better composting conditions while also mitigating gaseous emissions. Measurements were conducted to assess the impact of wood shavings on the temperature profiles of cattle and pig manure during aerated composting. Changes in compost pile mass, and pH were also analyzed. Composting pile temperatures increased with increasing levels of wood shavings added to livestock manure. Composting pile temperature profiles followed a three-stage configuration; mesophilic, thermophilic, and a curing stage, with the duration of each stage depending on the type of livestock manure and the quantity of wood shavings used for amendment. Temperatures within composting piles amended with wood shavings increased rapidly reaching the thermophilic level within the first three days of composting, while manure not amended with wood shavings generally took about twice longer to reach thermophilic temperatures. The duration of the thermophilic stage for composting piles amended with wood shavings more than doubled that of composting piles not amended with wood shavings. Aerated composting of livestock manure with or without wood-shavings significantly reduced the mass (by 56%-69% after 21 days) with a greater reduction favored for manure amended with wood shavings. Aerated composting also reduced the moisture content of manure from 77% to 45% after 21 days Composting pile pH profiles indicated an increasing trend throughout the composting duration. Although the amendment of wood shavings to manure during composting is highly recommended, the ratio of manure to bulking agent should be well determined for optimal process conditions.

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