Evaluation of composting performance of mixtures of chicken blood and maize stover in Harare, Zimbabwe

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Abstract

Background: Chicken processing results in the production of a lot of blood which if disposed on land poses environmental hazards in terms of land pollution. The aim of the study was to develop an aerobic composting process for chicken blood to produce a nitrogen-rich soil amendment for use in agriculture. The study involved composting of blood and maize stover of different proportions (10%, 30%, 70% and 100% maize stover) in compost bins over 72 days and determining which proportions would yield compost with greater potential to support plant growth.

Results: The performance of the different compost mixtures was evaluated by monitoring internal temperature, mineral N (NH_4^+-N and NO_3^--N), C/N ratio, pH, electrical conductivity and total cations. The concentration of ammonium N decreased by 8.75%, 50.5%, 33.5% and 18.8% for the 10%, 30%, 70% and 100% stover treatments, respectively, with composting time. Nitrate N peaked to 1.93 and 1.06 mg/kg for the 30% and 70% treatments, respectively, on day 43, while it peaked to 1.54 and 0.54 mg/kg for the 10% and 100% treatments, respectively, on day 50. The C/N ratios decreased significantly ($p < 0.001$) for all treatments.

Conclusion: The 10% and 30% treatments had better composting performance than the 70% and 100% treatments as they reached and maintained thermophilic temperatures for at least 8 days. The 10% and 30% treatments appeared to have the greater potential of supporting crop growth.

Keywords: Aerobic composting, C/N ratio, N mineralisation, Poultry processing wastes, Waste management

Introduction

Consumption of poultry products in Zimbabwe has steadily increased without being impaired by either religious considerations or culinary practices. Poultry production has increased in recent years by 16% to 19%, and this is expected to continue because of the high demand for poultry products (WATTAgNet 2011). In the processing of chickens, a lot of wastes are produced as companies aim to produce a good-quality final product and its intermediates. The centralisation of poultry processing plants has increased the problem of poultry waste management. The volume of waste produced during processing is large enough to develop techniques for processing the waste and presents possibilities for future use (Biely et al. 1972). Waste treatment is costly; therefore, most companies use direct land application to dispose of waste. Stewart (1980) estimated that 73% of manure and slaughterhouse wastes is directly applied on land. Plant, animal and human disease outbreak, fish kill and foul odour are potential results of uncontrolled land application of waste, and some researchers have shown that composting can suppress diseases (Veeken et al. 2005).

In some poultry processing systems, the poultry waste is converted to poultry feed by ensilation, dehydration, chemical treatment and fermentation to yield protein biomass (El Boushy and van der Poel 1994). In Zimbabwe, some of the waste produced during chicken slaughter is generated into animal feed in rendering plants (Bhengesa 2004). The excess waste finds its way to landfills for a price charged by environmental agencies or municipal authorities. Recent food controversies including incidence of salmonella outbreaks, bovine spongiform encephalopathy or mad cow disease and the advent of new variants, Creutzfeldts-Jakobs disease, prions, transmissible mink encephalopathy and

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transmissible spongiform encephalopathy due to feeding animals with feed of animal origin, has stirred great confusion and panic in Great Britain (DEFRA 2012). This has led to the voluntary withdrawal of stock feeds of animal origin from ruminants in many countries including Zimbabwe. As a result, blood demand has declined. The blood from slaughterhouses is therefore held in lagoons or holding tanks or dumped in landfills (DEFRA 2012). This results in environmental pollution problems such as the presence of pathogens, eutrophication, groundwater pollution, acid deposition and high ammonia and nitrate concentration in water and soil (Edwards and Daniel 1992). This is costly for companies as they have to pay for a disposal permit and also provide transport to disposal sites. There is a need to find alternative waste management strategies for the excess waste that is both feasible and environmentally sustainable.

Composting is a controlled biological decomposition process that converts organic matter into a stable, humus-like product (Kozark 2001). Bary et al. (2001) did a demonstration project on the composting of offal from chicken slaughter and found that composting can be used successfully to manage chicken offal, but compost quality was not determined.

The aim of this study was to develop an aerobic composting process as an alternative waste management strategy for poultry processing systems that are facing challenges with waste disposal in developing countries. It also aimed at determining the types of chicken slaughterhouse wastes and to evaluate the composting performance of chicken blood and maize stover mixed at different rates.

Methods

Characterisation of waste types produced by poultry processing companies

A survey was conducted to determine the type of waste produced in poultry meat processing. Structured questionnaires were given to key informants at local chicken processing companies in Harare, Zimbabwe. The key informants included the production managers, environmental officers and plant operators. The survey aimed at determining the type and amount of slaughterhouse waste produced at the different companies. It also aimed at establishing how the different companies manage slaughterhouse waste and the challenges they face in dealing with this waste. A total of 20 questionnaires were administered at two local companies.

Preparation of compost material and composting procedure

Maize stover and chicken blood were used as the composting raw materials. The maize stover was collected from the Department of Crop Science, Faculty of Agriculture at the University of Zimbabwe. The chicken blood was collected in drums from a local chicken processing company in Harare. Maize stover was chopped into small pieces of particle sizes ranging from 3 to 5 cm. The chopped maize stover and chicken blood were mixed manually on a polythene sheet spread on the ground using garden forks. The maize stover and chicken blood were mixed in proportions of 10% maize stover, 30% maize stover, 70% maize stover and 100% maize stover to make a total of four treatments on a weight-to-weight basis. To ensure thorough mixing of raw materials, the mixing was repeatedly done from one end of the spread polythene sheet to the other. The materials were packed into wooden compost bins measuring 1.2 × 1.0 × 1.0 m and raised 20 cm above the ground. The bins were made from wooden planks about 15-cm wide, and 1- to 2-cm gaps were left between planks on all bin sides to allow aeration during composting. The bins were filled to a height of 1.0 m. The treatments were replicated three times, and the bins were arranged in a randomised complete block design. Composting was done over a period of 72 days. Moisture adjustments were done whenever the moisture dropped below 40%.

During the composting period, temperature measurements were taken three times a day from the centre of the compost in three different positions along the middle of the compost cells at equal intervals using a type T, DualLogR thermocouple thermometer (Model 91100–50, Cole Parmer Instrument Company, Vernon Hills, IL, USA). The ambient temperature was also noted every time internal compost measurements were taken. The composts were turned weekly, ensuring thorough mixing.

Sampling and analysis

Compost samples were collected weekly at turning from every bin by pooling five sub-samples collected from random positions. The samples were analysed for mineral N within 4 h of sampling or were refrigerated for analysis later. Mineral N was extracted from the compost sample by shaking 10 g of fresh compost in 100 ml of 0.5 M K_2SO_4 on a reciprocal shaker for 1 h. The mixture was filtered through a Whatman no. 42 filter paper. Ammonium N (NH_4^+-N) was determined in an aliquot (0.2 ml) of the filtrate after colour development with sodium nitroprusside, and nitrate N (NO_3^--N) was determined in a separate aliquot (0.5 ml) after colour development with 5% salicylic acid using a spectrophotometer (Okalebo et al. 2002).

Total N, P, Ca, Mg, Na, K, organic carbon and ash were determined using oven-dried compost samples. These samples were ground to pass through a 2-mm sieve. Total N and P were extracted by wet digestion using concentrated sulphuric acid, selenium powder, lithium sulphate and hydrogen peroxide mixture (Anderson and Ingram 1996). Total N was determined in an aliquot of the digest after colour development with sodium nitroprusside using a spectrophotometer. The concentration of P was determined

by the molybdenum blue colouration method (Okalebo et al. 2002). Ash and organic matter were determined as residual mass and weight loss on ignition at 550℃ for 12 h in a muffle furnace. Total cations (Ca, Mg, Na and K) were determined from the ash using the atomic absorption spectrophotometer. Electrical conductivity and pH were determined from water extracts (1:10 air-dried compost raw material/water) as outlined by Anderson and Ingram (1996).

Statistical analysis

Genstat 7.2 (Discovery Edition, Lawes Agricultural Trust, Harpenden, UK) and SPSS 8.0 (SPSS Inc., Chicago, IL, USA) statistical package were used in the statistical analysis of data. Descriptive statistics were used to show patterns of the parameters measured through the use of mean profiles. Although the compost mixture treatments were arranged in a randomised complete block design, a split plot in time ANOVA was used to analyse repeated measurements, that is, measurements taken at different times during composting. In this case, the main plot was taken as the compost mixture treatment, and sub-treatments were the different sampling times. Least significant differences (LSD) were used to compare treatments at $p = 0.05$ significance.

Results and discussion

Types of wastes produced during poultry processing

Chicken processing produces a lot of wastes which include blood, feathers, offal, settling/sludge, manure, dead and rotten birds and paper. Similar responses were obtained from the two poultry processing companies during the key informant survey. Table 1 shows the type of waste produced during processing, the management strategy in place and the challenges faced by each management strategy. Shortages of coal and electricity are the greatest challenge faced by local poultry processing companies in Zimbabwe. These are necessary in the production of the render meal used to produce pet food. The wastes used need to be boiled for at least 4 h at very high temperatures, which they are unable to reach due to poor-quality coal and electrical power cuts. It was, however, difficult to determine exactly how much waste was produced as they did not weigh the waste produced (Mukombachoto 2006, personal communication). However, an average of 45,000 chickens are slaughtered per day at each of the poultry companies visited during this study. From laboratory work done, a live weight of 1,000 kg put in the slaughterhouse will give a blood yield of 37 kg (El Boushy and van der Poel 1994). This is, however, based on laboratory experiments using a bleeding time of 90 s such that this value can be greater than the actual amount collected in industry (El Boushy and van der Poel 1994). It can, however, be estimated that on

average, 1,665 tonnes of blood is produced daily from one company. Thus, blood is a major chicken slaughterhouse waste which requires innovative waste management strategies to prevent pollution of the environment, and composting is one such strategy.

Characterisation of raw materials and the composting process

The chemical characteristics of the different raw materials used in the study are shown in Table 2. Chicken blood had very high N contents, indicating that they could be used to reduce the C/N ratio of maize stover as shown by the 10%, 30% and 70% maize stover treatments. The pH of maize stover was about 7 as opposed to that of chicken blood which was low (<6). The electrical conductivity of chicken blood was more than double than that of maize stover (<2 mS/cm), indicating a high concentration of basic cations.

The compost parameters that affect stability/maturity, that is, temperature, ash content, total cations (Na, Mg, Ca and K), mineral, total N and total carbon (Wang et al. 2004), were monitored in this study because an unstable compost can have detrimental effects on plant growth. Mathur et al. (1993) highlight that the successful use of compost in agriculture is dependent on its maturity, and unstable composts can cause poor plant growth and damage plants by causing phytotoxicity or by competing for oxygen due to insufficient decomposition of organic matter.

Temperature

Temperature is a very important factor in the decomposition of organic substrate (de Bertoldi et al. 1983), and therefore, it was monitored daily during this study (Figure 1). Generally, the temperature profiles obtained in the composting experiments showed a very short active composting phase for the 10% and 30% maize stover treatments. Temperatures reached the thermophilic range (>45℃) on the second day for the 10% and on the third day for the 30% maize stover treatments, with the highest temperatures being of 60.6℃ and 59℃, respectively (Figure 1). This puts the treatments into the active stage of composting. The internal compost temperatures remained above 55℃ for at least three consecutive days and, according to Haug (1980), achieved adequate pathogen kill. At these high temperatures, pathogens such as *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtillus* are killed. However, moisture was lost, some microbes became inactive, and microbial activity declined and thus required moisture adjustment. Microbial activity could also have been lowered by a decrease in easily biodegradable compounds (Paredes et al. 2000; Garcia-Gomez et al. 2002). This reduction in microbial activity resulted in the rapid cooling of the composts. The active

Table 1 Types of chicken slaughterhouse wastes, management strategies and challenges/problems faced in disposing the waste

Type of waste	Management strategy	Challenges or problems
Feathers	-Produce render meal	• Amount per day is more than cooker capacity; thus, waste accumulates.
	-Excess dumped in landfills	• Power cuts result in waste accumulation as generator cannot be used for both cold rooms and rendering plant.
		• Shortage of fuel for transporting wastes
Blood	-Produce render meal	• Blood exceeds cooker capacity, and when blood bank is full, the excess has to be dumped, creating more wastes.
		• Power cuts result in waste accumulation as generators cannot be used for both cold rooms and rendering plant.
		• Shortage of fuel for transporting wastes
Offal	-Sold to local market	• Offal supply is actually short for the market.
	-Ingredient for the render meal	
Settling/sludge and wastewater	-Wastewater is pre-treated to remove blood.	• Shortage of pre-treatment chemicals
	-Spread over land as manure	• Water used for irrigating lawn produces an unpleasant odour.
	-Disposed at council treatment plant	• Due to shortage of pre-treatment chemicals, not all the blood is removed from the waste water.
	-Blood-free wastewater is used to irrigate lawns and is channelled to water bodies.	
Manure	-Spread over land	• Blockage of drains
	-Sold to locals	
Other	-Waste paper and plastic are recycled by the city council.	• High transportation costs
	-Dead-on-delivery birds are used as pet food or sold to crocodile farms	• Shortage of markets
	-Rotten products not fit for pets and render meal are dumped at the city's dump site.	• High cost for the transportation of waste to dumpsite

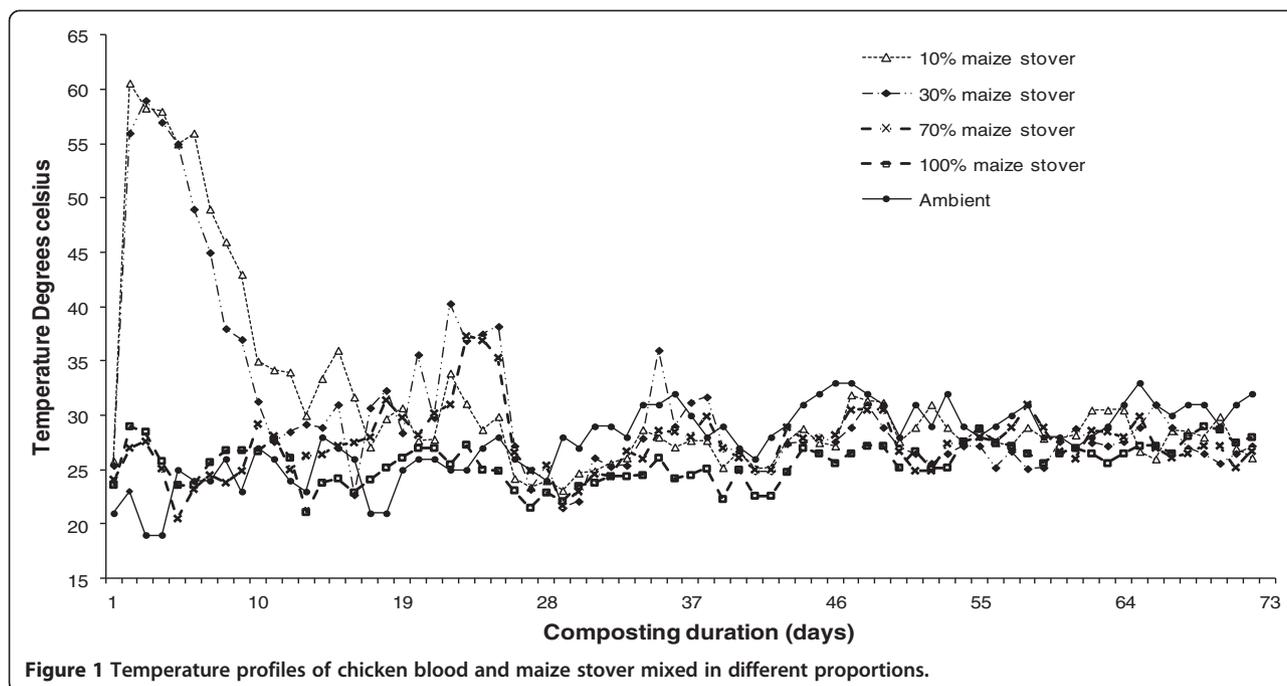Identified from key informant surveys (*n* = 20).

phase was, however, short lasting for 8 days. This could have been due to low ambient temperatures and a decrease in the compost pile volume and thus possibly reduced microbial activity. The internal temperatures for the 10% and 30% maize stover treatments remained above ambient temperatures for 26 days. The 70% and 100% maize stover treatments, however, did not get to the active

phase of composting, with the highest temperatures recorded being 37.3°C (day 23) and 29°C (day 2), respectively. These treatments did not achieve adequate pathogen kill. Slow decomposition results in gradual heat generation that is lost to the environment at a rate greater than heat accumulation in the compost (Hankin et al. 1976), and this is suspected to have occurred in the 70% and 100% maize stover treatments.

The results obtained in this study were similar to those reported by Govera-Mhindu (2002), who observed a short active phase for household waste. The author attributed this to slow decomposition or heat generation by the recalcitrant constituents of the wastes in the compost. In a study by Warman and Termeer (1996), compost piles of racetrack manure and grass clippings peaked at 65°C to 70°C and maintained temperature above 50°C for 15 days, thus a long active phase. In the same study, larger compost piles stayed hot for longer periods of time, and compost temperatures remained above 40°C even longer when compost leachate was returned into the compost. This could be due to increased microbial activity as nutrients such as nitrates were replenished. In another study, Swinker et al. (1997) added more N as ammonium sulphate on day 37 of

Table 2 Chemical characteristics of compost mixtures, chicken blood and maize stover used as composting raw materials

Raw material	Total C (%)	Total N (%)	C/N ratio	pH	Electrical conductivity (mS/cm)
Chicken blood	48.9	12.5	3.9	5.8	4.01
Maize stover	53.8	0.8	67.3	7.1	1.69
10% maize stover treatment	51.4	3.3	15.6	5.8	4.40
30% maize stover treatment	54.1	1.7	31.8	6.6	2.60
70% maize stover treatment	55.0	1.2	45.8	7.2	2.10
100% maize stover treatment	53.3	0.8	66.6	7.0	2.00

Figure 1 Temperature profiles of chicken blood and maize stover mixed in different proportions.

composting a variety of horse bedding materials comprising of phone book paper, wheat straw or saw dust to keep the process active.

There are several factors that can determine the decomposition process and the thermophilic activity of composts. Mupondi et al. (2006) reported that a wide C/N ratio, high tannin levels and low pH can slow down the compost decomposition process. Sundberg et al. (2004) observed that low pH can be an inhibiting factor in the progression of compost to thermophilic phase. In this study, the 10% and 30% maize stover treatments attained thermophilic temperatures because of the high proportion of the N-rich chicken blood in the treatments (90% and 70% *w/w*, respectively) which lowered the C/N ratio. The

lower C/N ratio with higher N content indicates that the compost mixtures could probably be a good source of protein for microbes involved in the decomposition of the compost mixtures (Adediran et al. 2003). The C/N ratio is one of the most important parameters that determine the extent of composting and degree of maturity of the compost (Jeevan Rao et al. 2008). The 70% and 100% maize stover treatments failed to reach the thermophilic phase because of the wide C/N ratio.

Changes in cation concentration during composting
The nature and characteristics of the organic materials used in composting determine the nutrient concentrations in the final compost (de Bertoldi et al. 1983). There was an
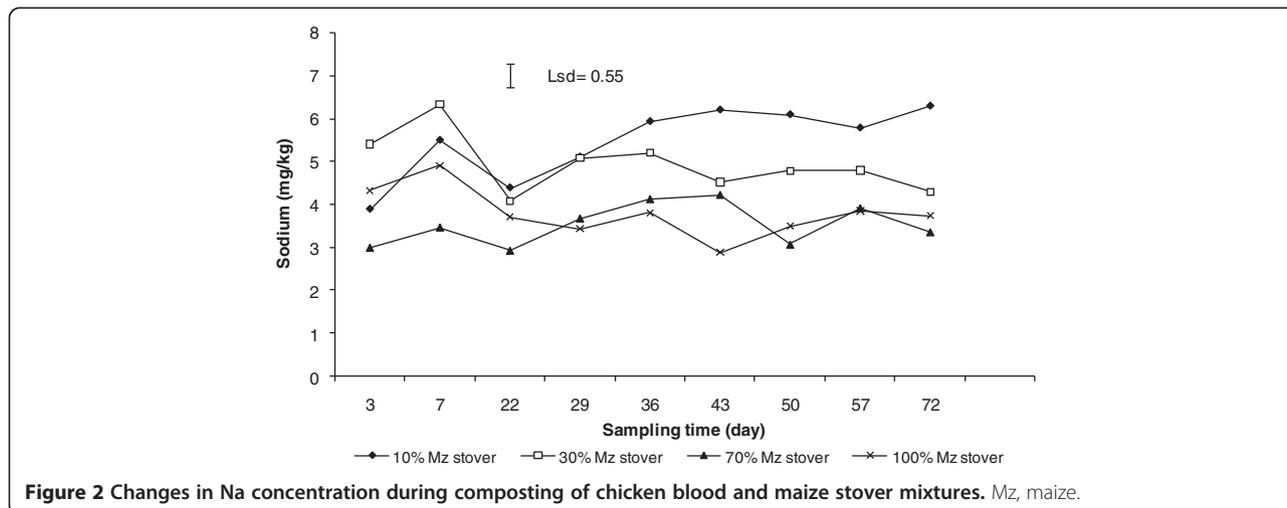
Figure 2 Changes in Na concentration during composting of chicken blood and maize stover mixtures. Mz, maize.
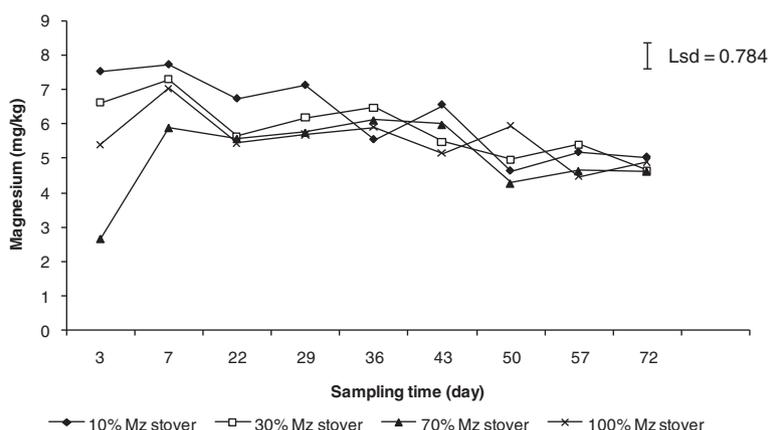
Figure 3 Changes in Mg concentrations during composting of chicken blood and maize stover mixtures. Mz, maize.

initial increase in the concentration of Na during the first week, with the 30% maize stover treatment having the highest concentration (Figure 2). On day 22, there was a drop in the Na concentration for all the treatments, followed by a gradual increase. After day 29, the 10% maize stover treatment had the highest Na concentration. The Na concentrations for the 10% and 30% maize stover treatments were significantly different ($p < 0.001$) throughout the composting period, while those of the 70% and 100% mixtures were not significantly different at the end of the composting period but were significantly different ($p < 0.05$) from the 10% and 30% treatments.

There was a general increase in Mg concentration for all treatments in the first week of composting, followed by a decrease (Figure 3). As composting proceeded, there were no significant differences in Mg concentrations for all the treatments. The final Mg concentrations were generally less than the initial concentrations for all treatments except for the 70% maize stover treatment. There

were no significant differences in the Mg concentrations of the final composts for all the treatments ($p = 0.05$).

For all the treatments, there was a general increase in the concentration of Ca (Figure 4). The Ca concentrations, however, fluctuated throughout the composting period. The 100% maize stover treatment had the lowest Ca concentration from day 22 to day 50. There were significant differences ($p < 0.05$) between the 10% maize stover treatment and the 100% maize stover treatment for most of the composting period; however, for all the treatments, there was no significant difference between the final composts.

The K concentration was significantly different for all treatments throughout the composting period (Figure 5). The 10% maize stover treatment had the highest K concentration, while the 100% maize stover treatments had the least K concentration for most of the composting period. The K concentration fluctuated for the 70% maize stover treatment in the first 5 weeks of composting. The
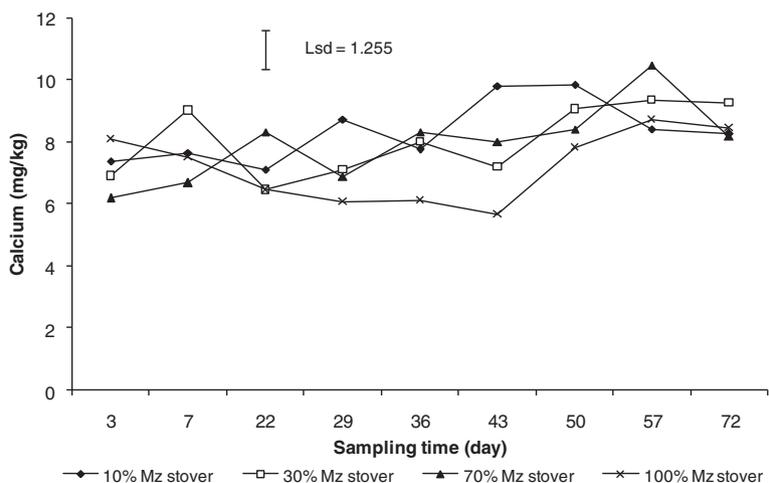
Figure 4 Changes in Ca concentration during composting of chicken blood and maize stover mixtures. Mz, maize.
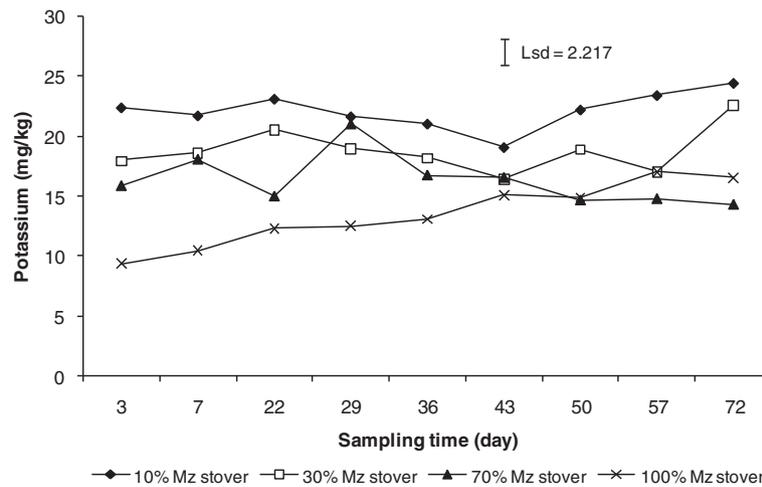
Figure 5 Changes in K concentrations during composting of chicken blood and maize stover mixtures. Mz, maize.

final compost for the 10% and 30% maize stover treatments were not significantly different, but both were, however, significantly different from the 70% and 100% maize stover composts.

The slight increase in the concentration of most total cations with composting could be attributed to the concentrating effect of composting. Decomposition results in the loss of organic constituents, leaving behind the inorganic nutrients.

Changes in electrical conductivity and pH during composting

The electrical conductivity of all treatments generally increased with composting. The highest electrical conductivity (EC) values were recorded in the 10% maize stover treatment, and the least were in the 100% maize stover treatment. Electrical conductivity values were in the order 10% > 30% > 70% > 100% (Figure 6). The 70% and 100% maize stover treatments were not significantly different ($p = 0.05$) for the first 36 days but differed significantly thereafter. There were significant differences between the initial and final EC values for all the treatments except the 100% treatment. The results obtained in this study were similar to those reported by Sanchez-Monedero et al. (2001) and Mupondi et al. (2006). They attributed an increase in the EC of composts to organic matter mineralisation that resulted in the release of cations responsible for increasing EC (Bertran et al. 2004; Mupondi et al. 2006). The greatest EC values were observed for the 10% and 30% maize stover treatments for which mineralisation was highest. These treatments also had high concentrations of total basic cations as they initially had more chicken blood.
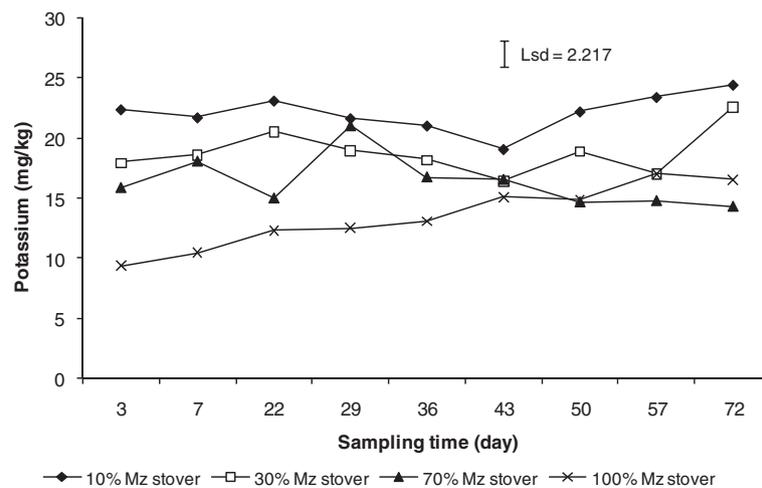
Figure 6 Changes in EC during composting of chicken blood and maize stover mixtures. Mz, maize.
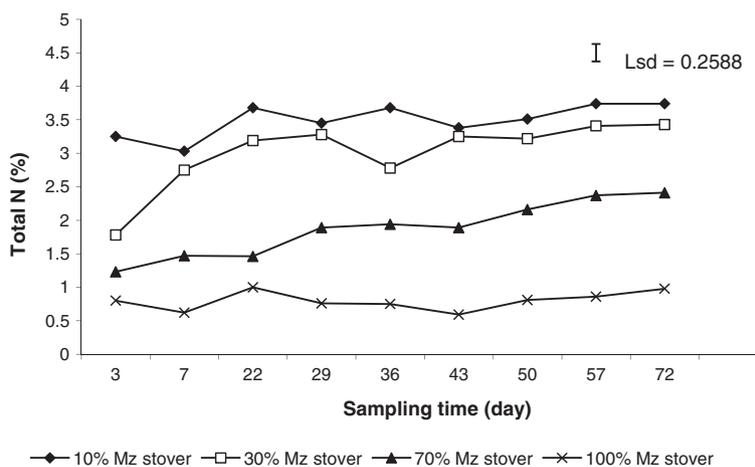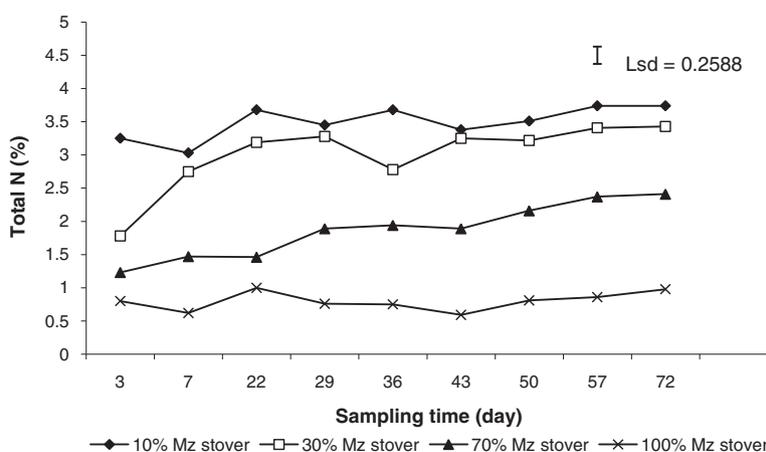
Figure 7 Changes in pH during composting of chicken blood and maize stover mixtures. Mz, maize.

During the study, the pH of all the treatments did not significantly change with composting time (Figure 7). The pH was, however, significantly different among treatments ($p < 0.001$). The pH recorded was in the order 10% < 30% < 70% < 100% throughout the composting period (Figure 7). The slight increase in pH could be attributed to decomposition of organic acids to release alkali and alkali earth cations previously bound by organic matter (Smith and Hughes 2002; Mupondi et al. 2006). The results, however, differ from those reported by other researchers like Adediran et al. (2003), who reported an initial decline in pH followed by an increase to a slightly constant pH. They reported this trend when they co-composted tobacco waste, sawdust and wood shavings with cow dung, pig dung, poultry manure and cabbage waste, ingredients different from what was used in this study. They attributed the initial drop in pH to the production of organic acids during the early stages of decomposition. pH was lowest for the 10% treatment throughout the

composting period, and this could be attributed to the low pH of the blood (Table 2).

Changes in nitrate N, ammonium N and C/N ratios during composting

There was a general increase in the total N concentration for all the treatments (Figure 8). The increase in total N was, however, not significant for the 100% maize stover treatment, while it was significant for all the other treatments ($p < 0.05$). The 10% and 30% maize stover treatments did not show any significant difference, but both were significantly different from the 70% and 100% maize stover treatments which were also significantly different ($p < 0.05$). The 10% maize stover treatment had the highest nitrogen percentage throughout the composting period, followed by the 30% maize stover treatment. The 100% maize stover mixture recorded the least total N concentration throughout the composting period. The concentration of NO_3-N was generally low for all the treatments (below 1 ppm) up

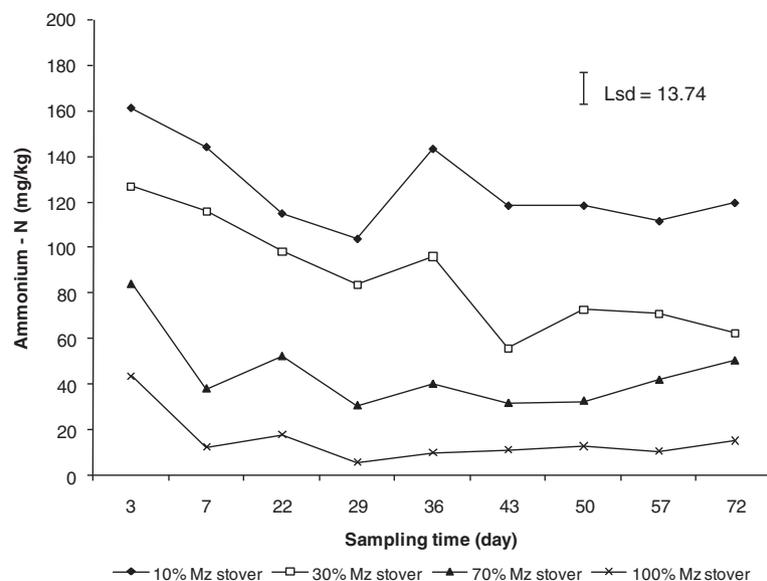**Figure 8 Changes in total N concentration during composting of chicken blood and maize stover mixtures.** Mz, maize.
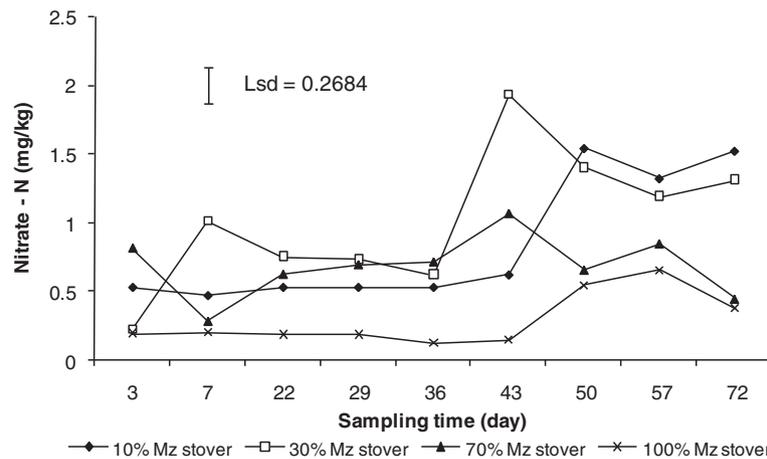
Figure 9 Changes in NO₃-N concentration during composting of chicken blood and maize stover mixtures. Mz, maize.

to day 36, after which it peaked to 1.93, 1.54, 1.06 and 0.65 ppm for the 30%, 10%, 70% and 100% maize stover treatments, respectively (Figure 9). Treatment means were significantly different after day 36 ($p < 0.05$). After day 50, the 10% and 30% maize stover treatments were not significantly different, and for the same period, the 70% and 100% maize stover treatments were also not significantly different. Nitrate N peaked when ammonium N was low, suggesting a conversion of the ammonium to nitrate. Similar trends have been observed in other studies (Eklind 1998; Canet and Pomares 1995).

There was a general decrease in the amount of NH_4-N during the first 29 days for all the treatments (Figure 10). This was followed by an increase which peaked at day 36. The NH_4-N concentration became relatively stable

after day 43 for all the treatments. The concentration of NH_4-N was stable for the 100% maize stover treatment from day 29 to the end of the composting period. Throughout the composting period, all the treatments were significantly different ($p < 0.05$). The concentration of NH_4-N was in the order 10% > 30% > 70% > 100% maize stover during the composting period. The general decrease in ammonium N during the first 3 weeks was probably due to microbial immobilisation and ammonia volatilisation especially during the active stage when internal compost temperatures were high. A decrease in internal compost temperatures corresponded with an increase in ammonium N concentration (Figures 1 and 10). This trend is similar to those observed by Govera-Mhindu (2002). Ammonia volatilisation could have

Figure 10 Changes in NH₄-N concentration during composting of chicken blood and maize stover mixtures. Mz, maize.

Table 3 Chemical characteristics of the final composts

Chemical parameter	10% maize stover	30% maize stover	70% maize stover	100% maize stover
Ammonium N (mg/kg)	146.9	62.34	55.9	35.4
Nitrate N (mg/kg)	1.52	1.31	0.44	0. 37
Sodium (mg/kg)	6.29	4.28	3.34	3.73
Calcium (mg/kg)	8.27	9.29	8.21	8.48
Potassium (mg/kg)	24.4	22.56	14.22	16.5
Magnesium (mg/kg)	5.03	4.65	4.63	4.89
Total N%	3.74	3.43	2.41	0.98
C/N ratio	13.82	13.92	22.84	52.5
Organic matter (%)	84.62	84.57	84.94	84.4
pH	6.03	6.52	6.52	7.47
EC	4.05	3.46	2.58	2.14

occurred as steam was observed escaping the 10% and 30% composts especially during the active stage. Many researchers have reported that the greatest loss of nitrogenous compounds during composting is through ammonia volatilisation (Martins and Dewes 1992; Tiquia and Tam 2000; Hong and Park 2005). Mineralisation could also have been slowed done as decomposition occurred. The high temperatures observed during the active stage could have killed some microorganisms responsible for ammonification. The final ammonium N concentration for all composts was higher than the nitrate N concentration (Table 3), indicating that more time than the 72 days was required for the composts to reach maturity.

The initial C/N ratios were 15.6, 31.4, 45.0 and 67.3 for the 10%, 30%, 70% and 100% maize stover compost treatments (Figure 11). The C/N ratios decreased to 13.5, 13.9, 22.8 and 52.5 for the 10%, 30%, 70% and 100% maize stover treatments in the final compost (Table 3). The final C/N ratios of the 10% and 30% maize stover treatments were not significantly different (Table 3). The 100% maize stover treatment had the highest C/N ratio which was significantly different ($p < 0.05$) from the other three treatments. Similarly, the final C/N ratio of the 70% maize stover treatment was significantly different ($p < 0.05$) from the other three treatments. Only the 10% and the 30% maize stover treatments had C/N ratios below the threshold of 25 (Brady and Weil 1999) but were above 12, indicating that the final compost from the 10% and the 30% maize stover treatments can be applied to soil but with some risk of immobilisation. The chicken blood which had a high N content was able to reduce the C/N ratio of the final compost when mixed in the right proportions with maize stover.
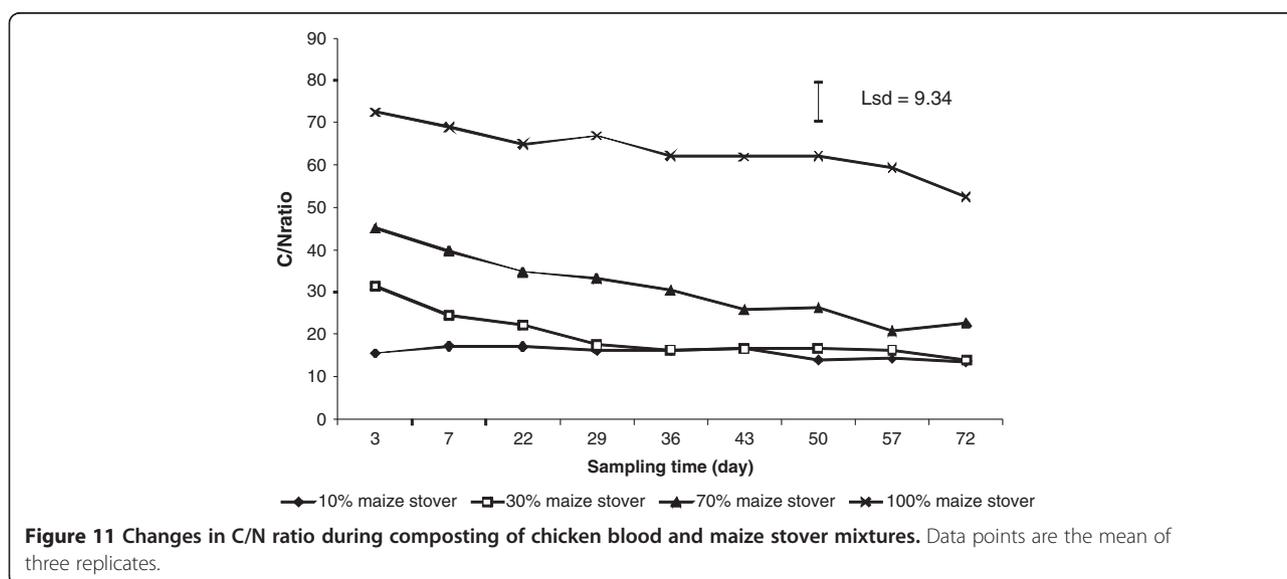
Figure 11 Changes in C/N ratio during composting of chicken blood and maize stover mixtures. Data points are the mean of three replicates.

Conclusions

The composting performance of the 10% and 30% maize stover treatments was better than that of the 70% and 100% treatments because they achieved the important active phase of composting. The changes in mineral N, C/N ratio and EC also showed that the 10% and 30% maize stover treatments performed better than the 70% and 100% treatments. The 10% and 30% composts were, however, not mature after 72 days of composting as they had C/N ratios greater than the critical 12 and an ammonium N and nitrate N ratio greater than 0.20. Composting, however, can still be employed as a management strategy for chicken blood as long as proportions used are able to attain thermophilic temperatures for pathogen kill and the composting done over a longer period.

Authors' contributions

CP was the student and main author, did the field and laboratory work, and drafted the manuscript. MW was the supervisor and participated in drawing up the project draft proposal, some field work, the statistical analysis and in correcting the manuscript. All authors read and approved the final manuscript.

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