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Effect of method of storing cattle faeces on the physical and chemical characteristics of the resultant composted cattle manure

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Abstract

The growing population of dairy cows in urban and peri-urban areas coupled with improvement in feeding is generating more manure, which if properly conserved can become an input to crop/ fodder production. The objective of this study was to investigate whether the method of storing faeces excreted by cows fed on *Pennisetum purpureum*–legume foliage diets affects the manuring quality of the resultant manure. Four diets comprising sole *Pennisetum* fodder, *Pennisetum* + *Calliandra*, *Pennisetum* + *Centrosema* and *Pennisetum* + *Desmodium* were fed to cows. Faeces excreted were subjected to four methods of storage for three months as follows: Placing faeces in pits and covering with soil (T1), wrapping faeces in polythene sheets and placing them in pits (T2), placing faeces in pits and leaving the pits open (T3), and stockpiling faeces on open flat ground (T4). Composts derived from faeces subjected to T3 and T4 methods exhibited maturity. Apart from nitrogen in the compost derived from faeces of cows supplemented with *Calliandra*, the nitrogen, phosphorus and potassium concentrations in all the composts significantly declined. Organic matter losses from composts got from T3 and T4 were significantly greater than that of T2. It was concluded that storing cow's faeces using T3 method would be the most appropriate and low-cost management intervention for improving cattle manure nutrient conservation.

Key words: *Calliandra*, *Centrosema*, composted cattle manure, *Desmodium*, faeces, *Pennisetum purpureum* fodder

Introduction

Land for farming in urban and peri-urban (UPA) areas is becoming very scarce requiring the adoption of intensification-oriented technologies on the spaces available (FAO-COAG, 1999). However, intensification has led to net negative soil nutrient balances, especially in places where appropriate soil management practices are lacking (Lal, 2001).

Replenishing soil fertility either using organic materials, inorganic fertilizers or a combination of both has been singled out as the best option that is likely to reverse the situation (Sanchez *et al.*, 1997). However, the use of inorganic fertilisers by smallholder farmers is still low due to socioeconomic constraints. Therefore, organic materials particularly livestock manure will continue to serve for

some time as a key resource in reversing this trend (Fresco and Steinfeld, 1998).

The number of exotic and crossbred dairy cattle reared in Kampala District has continued to increase steadily over the years (Kibombo, 2007). Increased animal numbers coupled with improvement in feeding is generating more manure – a waste product, which if well managed can become an input to other production enterprises, such as biogas and crop/fodder production. To maximize the value of livestock manure as a soil amendment resource, there is need to improve its collection and conservation (Murwira *et al.*, 1995). Dairy cattle reared in Kampala District are kept in stalls and the excreta are scrapped off the floor daily and stockpiled on bare ground by the side of the stall, from where it is later transported to the fields. When left exposed to the atmosphere, nutrients in the excreta are lost through volatilization (especially N), runoff and leaching (Eghball *et al.*, 1997). As a result small quantities of nutrients are potentially recyclable through manure within the farm system.

Making the most efficient use of livestock manures depends critically on improving manure handling and storage. In their review on nitrogen cycling, Rufino *et al.* (2006) observed that most publications on organic matter (OM) transfer and utilisation centred on the livestock and soil–crop sub-systems, and there was a distinct lack of information regarding manure handling and storage to maintain its quality. In order to maintain the consistency of livestock manure quality, it is necessary to design efficient management strategies that can address nutrient losses during manure handling and storage. Therefore, this study was intended to identify the most effective method of storing cattle faeces which will lead to production of compost with better manuring quality.

Materials and methods

Location and experimental design

This study was conducted at Makerere University Agricultural Research Institute Kabanyolo (MUARIK) located 19 km north of Kampala at 0° 28" N and 32° 37" E and an altitude of 1204 m. The experimental design was a two factor randomised complete block design comprising four types of faeces excreted by dairy cows and four methods of faecal storage. Four lactating Friesian (*Bos taurus*) x Zebu (*Bos indicus*) crossbred cows from the MUARIK herd, which were in early lactation were used. They were housed individually in concrete-floored stalls equipped with feed and water troughs.

Four types of faeces were obtained by feeding four different diets to cows in a 4 x 4 switchover Latin square design. The diets comprised *Pennisetum* fodder fed *ad libitum* as a control, *Pennisetum* + *Calliandra*, *Pennisetum* + *Centrosema* and *Pennisetum* + *Desmodium*. Legume supplements were offered at 0.52% of the animal body live weight and all the cows received 2.68 kg DM (0.52% body live weight) of dairy meal daily to ensure that the treatment diets contained 11–13% crude protein (CP) required for moderate levels of production (ARC, 1980).

Feeding management

Legume forages were harvested at once before commencement of the study, dried and ground to pass through a 3 mm sieve and kept in jute bags. This was done to ensure that the chemical composition of legumes fed to the cows was the same throughout the experiment. *Pennisetum*

purpureum fodder was harvested daily, chopped into 3-5 cm pieces and fed to cows by filling the troughs three times daily to ensure *ad libitum* supply. Dairy and legume meals were offered to cows only in the morning. Drinking water was provided *ad libitum*. Experimental diets were maintained for 14 days for adjustment and 14 days for data collection.

Treatment of faeces

During the 14 days of data collection, all the faeces excreted daily by each cow were scooped from the floor, weighed and kept in a metallic drum to minimize nutrient losses. After 14 days of collection, the faeces of each cow were emptied from drums and mixed thoroughly and a 500g sample was taken. Faeces of each cow were then divided into four equal portions and subjected to four storage methods for three months. The storage methods were: Placing faeces in pits (0.6 m deep and 0.6 m wide) and covering with soil after placing dry grass over the faeces to avoid contamination by soil (T1); Wrapping faeces in polythene sheets and placing them in pits (T2); Placing faeces in pits and leaving the pits open (T3); and Stockpiling the faeces on flat ground and leaving them uncovered (T4). The faecal storage methods were replicated four times and completely randomized. These storage methods were designed to reflect the potential and farmers' conventional methods of storing cattle manure in the UPA areas of Uganda. The majority of smallholder dairy farmers stockpile cattle excreta in the open just adjacent to the stall (T4 method). Covered versus uncovered treatments were used to capture the effects of precipitation and solar heating.

Sampling procedure and treatment of manure samples

After three months of storage, the faeces henceforth referred to as composted cattle manure were sampled. Sampling the manure in each pit and stockpile consisted of taking core samples from top to the bottom of pit using a 6 cm diameter plastic tube from four different locations. The four core samples were then mixed thoroughly and a 500g sample was taken. In addition, the texture, colour, smell and biological activity of samples were assessed following procedures as Lekasi *et al.* (2003a) to judge the maturity and quality of the composted cattle manures.

Chemical analysis of manure samples

Composted manure samples were analysed for OM contents, total N, P, K and NH_4-N (Okalebo, 1985). The pH values of manure samples were determined using a pH meter on a 1:1 by volume of water:faecal solution.

Statistical analysis of data

The data collected were analysed using the Statistical Analysis Systems (SAS, 2004) and following the model outlined below.

$Xij = \mu + \alpha i + \beta j + \alpha\beta ij + \varepsilon ij;\ i$ and $j = 1$ .....a

where, Xij = the jth observation on the response variable under the ith treatment
μ = Mean
α = Dietary treatment effect
β = Faecal storage treatment effect
$\alpha\beta$ = Interaction between dietary and faecal storage treatment effects
ε = Random error effect

The concentrations of N, P, K and pH in faeces at the start of storage period were used as covariates. The means were separated using the least significant difference (LSD) at the probability level of 5%.

Results

Physical properties of composted cattle manures

The compost derived from faeces which were stored in pits and covered with soil (T1) had a fairly coarse texture and mottled appearance (Table 1). The outer layers were at advanced stages of decomposition than those inside the pile. Faeces that were wrapped in polythene sheet and stored in pits (T2) had not changed in appearance, texture and smell. The compost derived from faeces which were stored in open pits (T3) and that from faeces stockpiled on flat ground (T4) were at advanced stages of decomposition and exhibited features of maturity, namely fine texture, homogeneous colour, inoffensive smell and presence of macroorganisms.

The ammonium concentrations, C:N ratios and changes in the chemical properties of composted cattle manures

The interaction between the effect of supplementing *Pennisetum* diet with legume foliage and the effect of faecal storage methods did not significantly ($P \geq 0.05$) influence any of the parameters that were measured. The ammonium (NH_4-N) concentrations and C:N ratios were treated independently of the other chemical properties because, this study aimed at determining the treatment(s) where these two would decline to the lowest levels. This is one way of determining the maturity of the resultant compost (Zucconi and de Bertoldi, 1987). Supplementation of *Pennisetum* diet with legume meal did not have a significant ($P \geq 0.05$) effect on the C:N ratios and NH_4-N concentrations in the composted cattle manures (Table 2). Apart from the concentration of N in the compost derived from faeces excreted by cows supplemented with *Calliandra*, the concentrations of N, P and K in all the other composts declined. Nitrogen losses from composts obtained from *Centrosema* supplemented diet were similar to those of the control but higher ($P \leq 0.05$) than those of the compost got from *Calliandra* supplemented diet.

Losses of P in the composts derived from faeces excreted by cows on legume supplemented diets did not differ ($P \geq 0.05$) from that obtained from faeces of cows fed on the control diet. Among the supplemented diets, loss of P was greatest ($P \leq 0.05$) in the compost obtained from faeces of cows supplemented with *Centrosema* compared with the compost obtained from faeces of cows fed on *Calliandra*. On average, P losses varied between 49.6 and 57.4% of the initial amounts.

Losses of K ranged from 29.5 to 55.7% of the initial amounts, with the highest loss occurring in the compost derived from faeces of cows fed on the control diet (Table 2). Similarly, K losses occurred in composts derived from faeces of cows whose diet was supplemented with *Desmodium* and *Centrosema*, but these losses were lower ($P \leq 0.05$) than that of the compost obtained from faeces of cows fed on the control diet.

The faecal storage methods significantly affected the NH_4-N concentrations and C:N ratios and also caused significant changes in the chemical attributes of the composted cattle manures

Table 1. Physical properties of the composted cattle manures

Faecal storage method	Parameters that were sensually evaluated			
	Texture	Colour	Odour	Biological activity
Faeces stored in pits and covered with soil **(T1)**	Fairly coarse textured. Faeces at various stages of decomposition covering fresh faeces in the centre	Mottled appearance with colours ranging from that of fresh faeces to dark brown	Smell of putrefaction indicating that decomposition was occurring	Not yet invaded by any macrofauna
Wrapped in polythene sheet and stored in pits **(T2)**	Coarse textured material that looked like fresh animal faeces.	Colour of fresh faeces with no visible sign of decomposition taking place	Strong smell of ammonia which is characteristic of fresh animal faeces	Not yet invaded by any macrofauna
Stored in pits and left uncovered **(T3)**	Fine textured and at an advanced stage of decomposition	A homogeneous material, with uniform black colour.	A mild and inoffensive smell like that of soil.	Earthworms, beetles and termite tunnels present
Stockpiled on flat ground and left uncovered **(T4)**	Fine textured and at an advanced stage of decomposition	A homogeneous material, with uniform black colour.	A mild and inoffensive smell like that of soil.	Many earthworms, beetles, tunnels of termites observed.

Table 2. The ammonium concentrations, C:N ratios and changes in the chemical properties of composted cattle manures as affected by legume supplementary feeding to dairy cattle offered Pennisetum purpureum fodder

Legume meal supplements	NH_4-N content (g kg^{-1})	C:N ratio	OM	Total N	Total P	Total K	pH rise
			Change (g kg^{-1})				
Calliandra calothyrsus	0.48	26.4	-60.93	+0.18^{c}	-3.01^{b}	-9.75^{b}	1.8
Centrosema pubescens	0.44	28.2	-99.63	-1.39^{ab}	-3.96^{a}	-7.51^{bc}	1.7
Desmodium intortum	0.48	29.1	-73.71	-0.05^{bc}	-3.39^{ab}	-6.20^{c}	1.6
Control	0.53	28.6	-107.6	-1.80^{a}	-3.61^{ab}	-13.72^{a}	1.6
$LSD_{(0.05)}$	0.13	4.4	56.55	1.44	0.69	2.36	-

^{abc}Means within the same column having different superscripts are significantly ($P \leq 0.05$) different

Table 3. The ammonium concentrations, C:N ratios and changes in the chemical properties of composted cattle manures as affected by faecal storage methods

Faecal storage methods	NH_4-N content (g kg^{-1})	C:N ratio	OM	Total N	Total P	Total K	pH rise
			Change (g kg^{-1})				
Pit and soil cover (T1)	0.40^{b}	30.5^{a}	-79.53^{ab}	-1.62^{a}	-4.25^{a}	-9.10^{b}	1.7
Pit and polythene (T2)	0.76^{a}	29.5^{a}	-38.23^{b}	-1.10^{a}	-3.75^{a}	-6.84^{b}	1.3
Pit and not covered (T3)	0.34^{b}	24.4^{b}	-100.54^{a}	-1.08^{b}	-3.03^{b}	-8.28^{b}	2
Piled on flat ground (T4)	0.43^{b}	28.0^{ab}	-123.53^{a}	-1.43^{a}	-2.95^{b}	-12.95^{a}	1.7
$LSD_{(0.05)}$	0.13	4.4	56.55	1.44	0.69	2.36	-

^{ab}Means within the same column having different superscripts are significantly different ($P \leq 0.05$)

(Table 3). The NH_4-N concentration in the compost obtained from T2 was higher ($P \leq 0.05$) than those in the composts derived from other storage methods. The C:N ratios of composts derived from T3 and T4 storage methods were similar, but that of the compost derived from T3 was lower ($P \leq 0.05$) than those of composts derived from T1 and T2. The reduction in OM contents from composts obtained from T3 and T4 methods were greater ($P \leq 0.05$) than that of T2. With the exception of the compost derived from faeces subjected to T3 whose N content increased by 7.4%, the concentrations of N in the composts derived from faeces which were subjected to other storage methods declined. The decline in P concentrations was greater ($P \leq 0.05$) in composts obtained from faeces subjected to T1 and T2 storage methods, while the decline in the concentration of K was greater ($P \leq 0.05$) in the compost derived from faeces which were subjected to T4 method (Table 3).

Discussion

Physical properties of the composted cattle manures

Changes that occur in the physical properties of cattle manure during storage and are easily recognizable using the senses of touch, sight and smell can be used to predict the maturity and quality of composts (Lekasi *et al.*, 2003a). During storage, decomposition gradually transforms the coarse textured organic materials into a fine, loamy material called compost. Therefore, by carefully using the sense of touch a farmer can tell whether or not the compost material is ready for use as soil amendment. In this regard, therefore, the composts obtained from faeces stored in open pits (T3) and those that were stockpiled on flat ground and left uncovered (T4) were mature.

Changes in the colour of compost can also be used to determine its maturity. Cattle faeces that are not fully decomposed consist of a more heterogeneous mixture with a mottled appearance. This was observed in the compost derived from faeces stored in pits and covered with soil (T1). Mottling was attributed to the fact that the outer layers decomposed at a faster rate than those inside the pile. The whole faecal mass had not fully decomposed, and thus required more storage time to decompose and turn into mature compost with a more homogeneous black colour. The composts derived from faeces stored in open pits (T3) and those that were stockpiled on flat ground (T4) had turned into a uniform black colour indicating that they had reached maturity.

Fresh animal manure and other organic wastes usually emit a strong smell of ammonia and putrefaction during the early stages of decomposition. Also, when there is shortage of oxygen, the composting process shifts from aerobic to anaerobic decomposition which is slow and releases foul odours due to formation of sulphur compounds (Thomsen, 2000; Cooperband, 2002). At maturity, the resultant compost has a mild and inoffensive smell like that of soil, which is attributed to the presence of humic substances (Bernal *et al.*, 1998). Therefore, the composts that were got from faeces subjected to T1 and T2 methods whose smell was offensive had not matured, while those obtained from faeces subjected to T3 and T4 methods had reached maturity.

The invasion of decomposing cattle faeces by macroorganisms also serves as an indicator of compost maturity. The OM

in fresh animal excreta is decomposed by the successive action of bacteria, fungi and actinomycetes. As compost matures after the thermophilic stage, various macroorganisms such as earthworms and beetles colonize the decomposing material at different times and keep displacing each other until stable humus is produced (Cooperband, 2002). The invasion by macroorganisms which was observed in the composts derived from faeces that were subjected to T3 and T4 storage methods was an indication that these composts had reached maturity.

The ammonium concentrations, C:N ratios and changes in the chemical properties of composted cattle manures

The differences in changes of N contents in the composted manures were attributed to the levels of polyphenols in the legume supplements. *Calliandra* contains higher levels of polyphenols than *Centrosema*, and it has been reported that polyphenols reduce protein digestibility by forming complexes with CP in feeds, which in turn result in excretion of larger amounts of N in faeces (Delve *et al.*, 2001). The results of this experiment indicated that polyphenols continue to exert their influence on the decomposition and release of N (and other nutrients) from faeces, hence producing N- (nutrient-) rich compost. However, this influence would adversely affect the growth of crops if N and other nutrients are not released for crop use at the time of need. Handayanto *et al.* (1997) observed a strong relationship between N recovery and the protein-binding capacity of polyphenols, which suggested that protein-binding by polyphenols was responsible for reduced N recovery from the slow N release legume tree prunings applied to soils.

High NH_4-N concentration in the compost derived from T2 method was due to anaerobic conditions created by the polythene sheet, which favoured anaerobic decomposition (Thomsen, 2000). It is indicative of an unstabilised material that is still undergoing decomposition, and not fit for use as organic amendment (Gómez-Brandón *et al.*, 2008). In the earlier stages of composting, NH_4-N is produced by the decomposition of nitrogenous compounds. As the compost matures, the NH_4-N content drops because of being oxidized into nitrate by the action of ammonium-oxidizing bacteria. The NH_4-N concentrations in the composts derived from T1, T3 and T4 methods were similar to that (0.4 g kg^{-1}), which is the maximum limit suggested by Zucconi and de Bertoldi (1987) for the compost that is mature and ready for use as soil amendment.

Usually, as the decomposition of organic materials proceeds, the carbon contents gradually fall while the concentrations of mineralized N increase leading to the reduction of C:N ratios (Lekasi *et al.*, 2003b). This occurs because each time the organic compounds are consumed by microorganisms, two-thirds of the carbon is given off as carbon dioxide. While investigating the effect of storage methods on the properties and degradability of cattle manure, Atallah *et al.* (1995) observed that stockpiling or composting of cattle manure led to significant carbon losses of 17.1 and 26.4% and relative N gains of 25 and 32.7% for stockpiled and composted manure, respectively. As a result, the C:N ratio decreased with increasing time of storage. The reduction in the C:N ratio continues with ageing of

compost, finally reaching a value which is characteristic of a stable mature compost.

Because of its influence on decomposition and nutrient release (especially N and P), the C:N ratio is one of the chemical characteristics that can be used to define the manuring quality of organic soil amendments (Palm *et al.*, 2001). By using the C:N ratio as a measure of manure quality, the compost derived from T3 method would be considered superior as a soil amendment over the composts got from faeces subjected to T1 and T2 methods. Composts with lower C:N ratios decompose faster and supply N and other nutrients to the growing crops, whereas composts with high C:N ratios partially immobilise N, making it unavailable to the plants for sometime (Delve *et al.*, 2001).

Decomposition of OM during the composting process is characterized by changes in the residual rate (i.e., the percentage of OM which remains compared with the original amount). The significant decline in the OM contents of composts obtained from T3 and T4 methods was attributed to exposure of faeces to the atmospheric air, rainfall and temperature, and microbes, which accelerated the decomposition process (Somda *et al.* (1995). Covering with a polythene sheet in T2 cut off air supply to the faeces, which caused a shift from aerobic to anaerobic decomposition which is a slow process (Cooperband, 2002). The reduction in OM contents of cattle manure and other organic wastes during storage and composting has been reported by Rufino *et al.* (2007), Bernal *et al.* (1998) and Atallah *et al.* (1995). These researchers attributed the reduction in OM contents to the evolution of CO_2, evaporation of water and particle-size reduction.

The results showed an increase in the concentration of N in the compost derived from faeces that were subjected to the T3 method. Studies conducted by Rufino *et al.* (2007) and Bernal *et al.* (1998), revealed that at the onset of decomposition, N losses are greater than those of carbon leading to a reduction in the concentration of N. But as the decomposition process proceeds, the concentration of N increases because the rate of OM reduction (loss of carbon in form of CO_2) becomes greater than the loss of N. Therefore, in the T1 and T2 methods where the concentrations of N were still declining, the decomposition process had not yet reached the turning point where the rate of OM reduction becomes greater than that of N. This means that faeces stored using T1 and T2 methods take longer to decompose into mature compost. An increase in the concentration of N could have also occurred in the compost obtained from T4 method which experienced aerobic conditions as in T3. However, since the compost in T4 was more exposed to the atmosphere than in T3, higher losses of N through volatilisation and erosion occurred leading to reduction in the concentration of N. Similarly, erosion caused by rain was responsible for the decline in the concentration of K in the compost derived from faeces subjected to T4 method.

Conclusion

This experiment demonstrated that the method of storing faeces excreted by stall-fed dairy cows following removal from the stall affects the time taken to turn into mature compost and the conservation of nutrients therein, which in turn affects the manuring quality of the resultant manure compost. Storing faeces excreted by dairy

cows in open pits (T3 method) would be the most appropriate, simple and low-cost management intervention for improving cattle manure nutrient conservation.

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