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## Composting as an alternative for the disposal of *Loxodonta africana* and *Ceratotherium simum* manure

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### Abstract

This investigation was conducted to evaluate composting as a means of disposal of manure from two large species of Zoo herbivores. Manure from a African Elephant (*L. Africana*) (EM) and a white rhinoceros (*C. simum*) (RM) were each mixed with yard trimmings (YT) as a bulking agent, in the proportions, 3EM or RM: 1 YT by weight, and placed either in three composting bins (1 $ft^3$) or in a pile, under roof and on a concrete floor in both cases. Temperature of each compost was recorded daily to determine when the first and second heat cycles occurred. Chemical analysis was carried out on samples taken on 0 d, at the peak of the first and second heat cycles, and at 0, 20, 40, and 60 d of maturation (7 phases). Data were analyzed according to a completely randomized design using ANOVA. Results obtained with the bin method are described as follows: only nitrogen content showed increased percentage concentration from initial observation to 60 d of maturation (EM, 1.08 to 2.16; RM 1.34 to 1.61). Corresponding decreases in carbon and organic matter concentrations were: EM, 38.3 to 28.8; RM, 34.9 to 33.9 and EM, 68.9 to 51.8; RM, 62.9 to 61.1. Logically, C:N ratio also declined (EM, 35.6 to 13.4; RM, 26.2 to 20.5). A shift from more to less alkaline or slightly acid pH was observed (EM, 8.45 to 7.41; RM, 7.55 to 6.49). Thermophillic temperatures were noted continuously for 22 days, reaching a maximum of 137.6 and 132.6 F for EM and RM. Weight of composted material (Kg) decreased (EM, 42.2 to 27.9; RM, 44.3 to 32.3). With compost produced piles the results in terms of chemical composition were similar to those reported above. The present data lend support to the use of composting as an effective means of reducing this type of organic residue while obtaining an organic fertilizer of suitable characteristics

### Resumen

Se llevó a cabo esta investigación para evaluar la composta como medio para disponer el estiércol de dos especies grandes de herbívoros de zoológico. El estiércol de un elefanta africano (*L. africana*) (EE) y un rinoceronte blanco (*C. simum*) (ER) se mezcló por separado con residuos de jardinería (RJ), como material absorbente en las proporciones ponderales, 3 EE o ER: 1 RJ y se coloco en 3 recipientes de 1 $pie^3$ o en una pila, bajo techo y encima de un piso de hormigón en ambos casos. Se noto la temperatura de cada composta diariamente para determinar cuando ocurría el primer y segundo ciclo de calor. Se realizo análisis químico de muestras tomadas el DIA cero, al pico del primero y segundo ciclo de calor y a los 0, 20, 40 y 60 d de maduración (7 fases). Los datos se analizaron según un diseño completamente aleatorizado usando ANOVA. Se obtuvieron los siguientes resultados con el método de recipientes: solo el contenido de nitrógeno mostró un aumento en su concentración porcentual desde la observación inicial hasta los 60 d de maduración (EE, 1.08 a 2.16; ER, 1.34 a 1.61, respectivamente). Reducciones correspondientes de carbono y materia orgánica fueron: EE, 38.3 a 28.8; ER, 34.9 a 33.9 y EE, 68.9 a 51.8; ER, 62.9 a 61.1. Lógicamente, la razón C:N también decreció (EE, 35.6 a 13.4; ER, 26.2 a 20.5). Se observo un cambio en los valores pH de mas a menos alcalino o levemente acido (EE, 8.45 a 7.41; EE, 7.55 a 6.49). Se notaron temperaturas termofílicas continuamente durante 22 días, que alcanzaron máximas de 137.6 y 132.6 F para EE y ER. Decreció el peso (kg) del material comportado (EE, 42.2 a 27.9; ER, 44.3 a 32.3). Al hacer composta en las pilas, los resultados obtenidos en términos de composición química se asemejan mucho a los arriba descritos. Los datos presentes dan apoyo al posible uso de la composta como medio efectivo para mermar el volumen de este tipo de residuos orgánicos a la vez que se obtenga un fertilizante orgánico de características apropiadas.

## Introduction

Approximately 500 pounds of herbivore manure is produced daily at the Dr. Juan A. Rivero Zoo of Mayaguez, Puerto Rico. Most of this manure is produced by the *L. Africana* (African elephant) and two *C. simum* (White rhinoceros) (Hernández, 2004). These organic residues require an expensive treatment for disposal to reduce the environmental contamination that they cause. Also, the possible presence of pathogenic bacteria in the manure could affect the health of other animals, employees and visitors to the zoo. A possible alternative under consideration to dispose of this manure is the elaboration of compost, which would reduce and stabilize these organic residues by biological decomposition causes by their disposal.

The Zoo of Puerto Rico is not the only one in the world at which this type of process is being evaluated. The Woodland Park Zoo in Seattle, Washington is using this procedure to dispose of the manure of herbivore animals and also residues of food. Not only are they using the solid portion of the residues, they also make use of the liquid fraction obtain during the composting process, selling it as fertilizer (E & A Environmental Consultants, Inc., 2000). The production of compost at the Zoo of Puerto Rico would reduce the cost presently incurred for disposal of the manure, while the compost could be used as fertilized in the Butterfly Nursery and in the green areas of the Zoo itself. The objective of this investigation is to evaluate the method of composting as an alternative to dispose of the manure of *L. africana* and *C. simum* generated at the Zoo of Puerto Rico Dr. Juan A. Rivero.

## Materials and Methods

The organic residues to be composted were *L. Africana* (EM) and *C. simum* (RM) manure obtained from the Dr. Juan A. Rivero, Zoo located in Mayaguez, Puerto Rico. Used as absorbing materials were yard trimmings (YT) from the composting facilities located at the Alzamora Farm, University of P.R., Mayagüez Campus. EM compost and RM compost were chemically analyzed during each composting phase. For the elaboration of the compost, each organic residue was placed in between two layers of equal weight of YT. The two treatments were YT:EM and YT:RM. Each treatment was triplicated and placed in identical $3ft^3$ composting bins. Also, each treatment was composted in a pile to compare this method with the composting bins. Thus a total of eight composts were included in the study. The initial layer of YT was weighted after obtaining a layer 12" high. With this weight, the amount of excrement needed to make a 3:1 ratio (excrement: YT) was calculated. The composts were hydrated to obtain an initial moisture content of 60% and this characteristic was monitored during every stage of the process to maintain an acceptable level. In order to control humidity more effectively, the composting bins and the piles were located under a roofed area with a concreted floor.

For both treatments, the temperature was monitored daily with composting thermometers. As shown in Figure 1 the composting process was divided into seven phases which were determine by changes in temperature of the material. The typical composting process has mainly two heat cycles. During these cycles, temperature increases markedly due to the metabolism of the bacteria while using as substrates nutrients obtained from the material. As these resources start decreasing, temperature decreases proportionally. The first two phases are completed when the temperature decreases ten degrees F from the maximum value registered in each cycle. The third phase is considered to finish when the temperature decreases until reaching that of the atmosphere. This phase is designated as the start of maturation of the compost. Subsequently, three more samples were obtained during maturation (20, 40 and 60 days) in order to monitor evolution of the compost throughout the process.

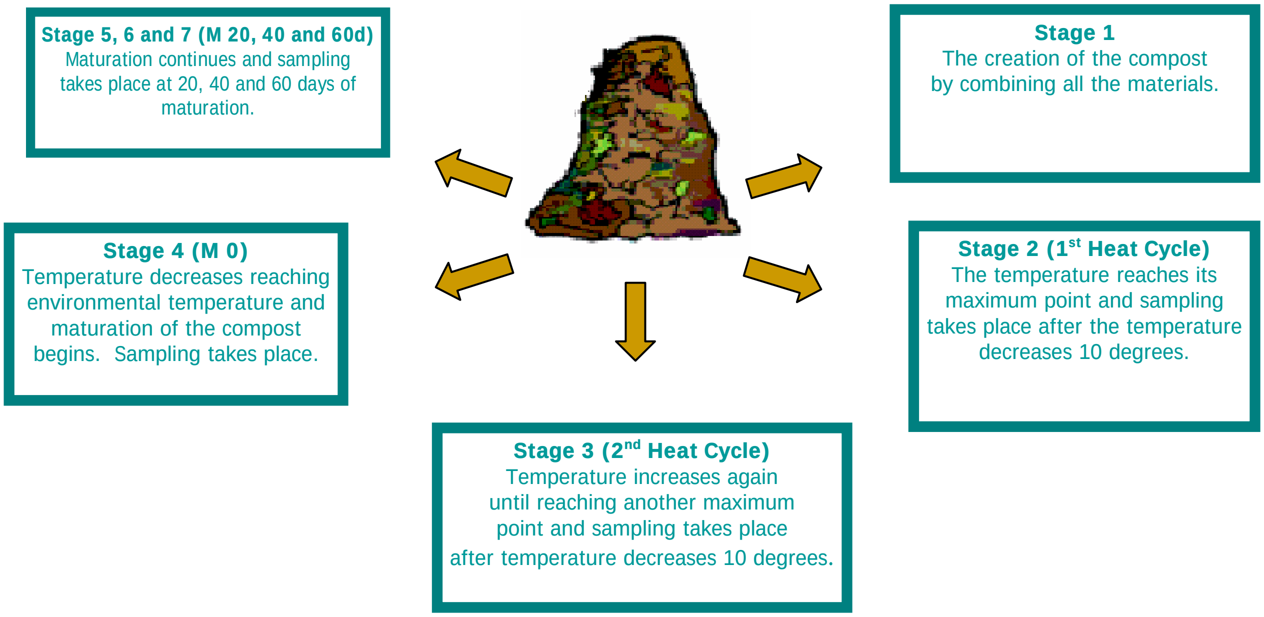


Figure 1. Sampling times during the composting process

At stage 0 samples of each original material where obtained in order to determine the initial pH, C:N ratio, and organic matter (OM) inorganic matter (IM), and nitrogen (N) concentration. These values were obtained using standard procedures (AOAC, 1990). In each phase (Figure 1), the compost was weighted, turned and four random samples were collected to obtain a representative sample. This sample was later chemically analyzed for the same components as mentioned above. Data were analyzed according to a completely randomized design using the ANOVA procedure of SAS. Treatment means showing significant difference in the ANOVA were ranked using the Tukey test of SAS (1990). All statements of significance are based on the probability level of .05, unless otherwise noted.

## Results and Discussion

Results obtained showed that there was no significant difference in chemical compostin between both methods of composting. The pH results for the bin method (Table 1) involve an interaction between type of manure and composting phases. The pH in the EM compost differed ($p<0.05$) between phases varying from slightly alkaline (phases 1 and 2), to neutral (phases 3, 4, 5, 6). The pH in the RM compost differed ($p<0.05$) between phases varying from neutral (phases 1, 2, 3) to slightly acid (6.72, 6.59, 6.49).

Table 1. Values of pH for EM and RM composts in the seven composting stages by the bin method

| | | Treatments | |
|---|---|---|---|
| Component | Composting Stage | EM compost | RM compost |
| pH | 1 | $8.45^{a}$ | 7.55 |
| | 2 | $8.22^{ab}$ | 7.86 |
| | 3 | $7.99^{abc}$ | 7.12 |
| | 4 | $7.74^{abc}$ | 6.72 |
| | 5 | $7.5^{c}$ | 6.59 |
| | 6 | $7.41^{c}$ | 6.49 |

*Means with different superscripts differ (P<.05)*

Data for chemical composition of the bin method compost showed no difference between types of manure but differences among composting stages were detected. In both EM and RM the DM percentage increased (P<0.05) throughout the composting phases but stayed within the limits of 55-60% (Figure 2). The initial C:N ratio of the materials used was within recommended limits (20:1 to 40:1; Rynk, 1999). In both types of manure it decreased with time, reaching a final value of 13.43 for the EM compost and 20.52 for the RM compost (Figure 3). C:N ratios of approximately 20 in the compost are favorable for its use as a fertilizer, since plants can use efficiently the nutrients applied. If the C:N ratio were too high there would be competition for nutrients between the plant and the microorganisms in the soil. C and OM contents (Figures 4 and 5) decreased (P<0.05) with time, but the variation among phases was significant only in the case of EM. Conversely, the IM content increased (P<0.05) throughout the composting process for both treatments. These results represent the expected pattern of C and OM decrease due to the microorganism acquiring nutrients for their metabolism. Nitrogen concentration increased (P<0.05) in the EM compost until the end of the composting process, but remain similar over time for RM compost (Figure 6).

Thermophillic temperatures were reached in both EM and RM and maintained throughout 22 days, reaching a maximum of 137.6°F for EM and 132.6°F for RM (Figure 7). The weight of the composting material decreased from 42.21 and 44.33 kg at stage 0 to 27.94 and 32.29 kg at the end of maturation for EM and RM compost, respectively (Figure 8). This decreasing weight is due to the microbial degradation of material used as substrates. Both EM and RM original materials were completely decomposed. Table 2 shows the results obtained for the pile method of composting which are very similar to those obtained by the bin method.

Figure 9 presents photographs of the two different composting procedures.

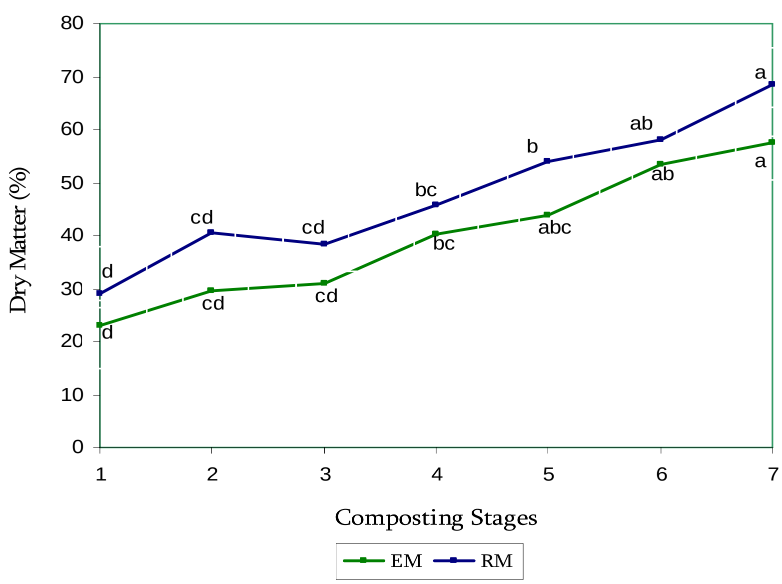


Figure 2. Dry matter percent of the EM and RM composts in the seven composting stages by the bin method
*Means with different superscripts differ (P<0.05)*

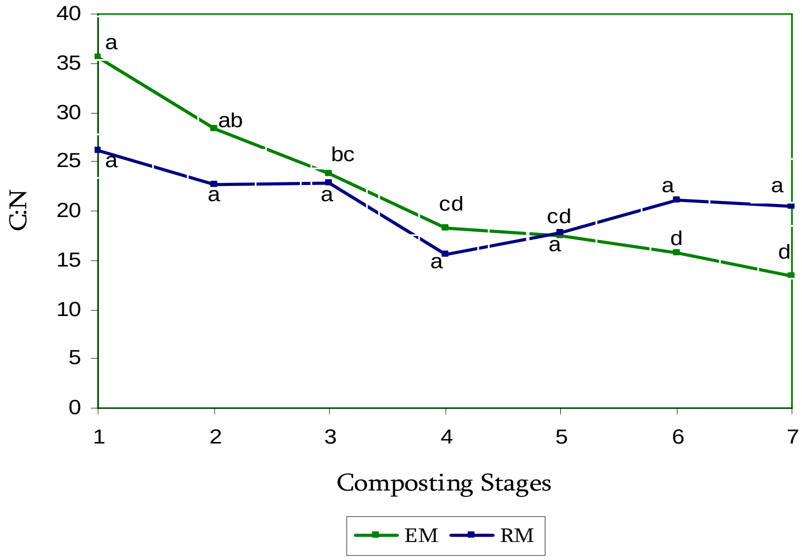


Figure 3. Carbon to nitrogen ratio of the EM and RM composts in the seven composting stages by the bin method
*Means with different superscripts differ (P<0.05)*

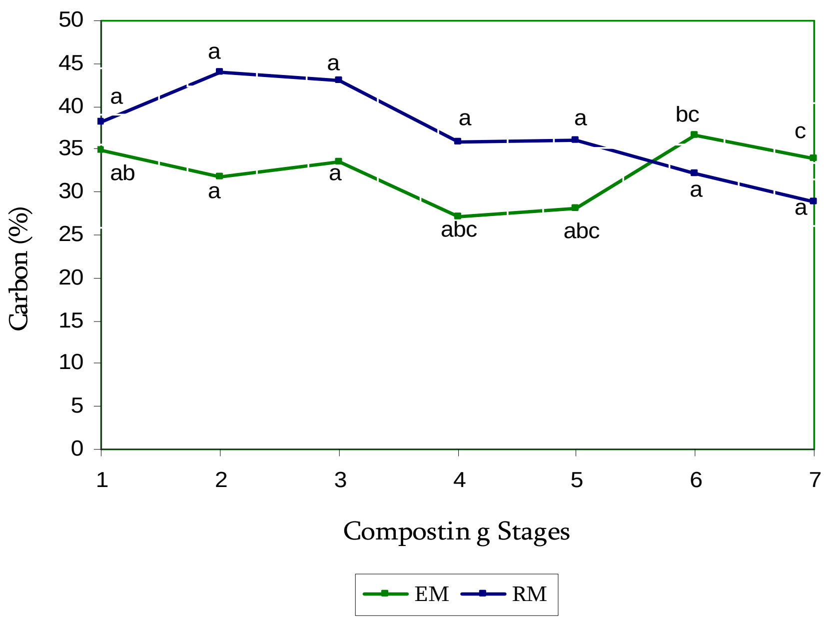


Figure 4. Carbon percent of the EM and RM composts in the seven composting stages by the bin method
*Means with different superscripts differ (P<0.05)*

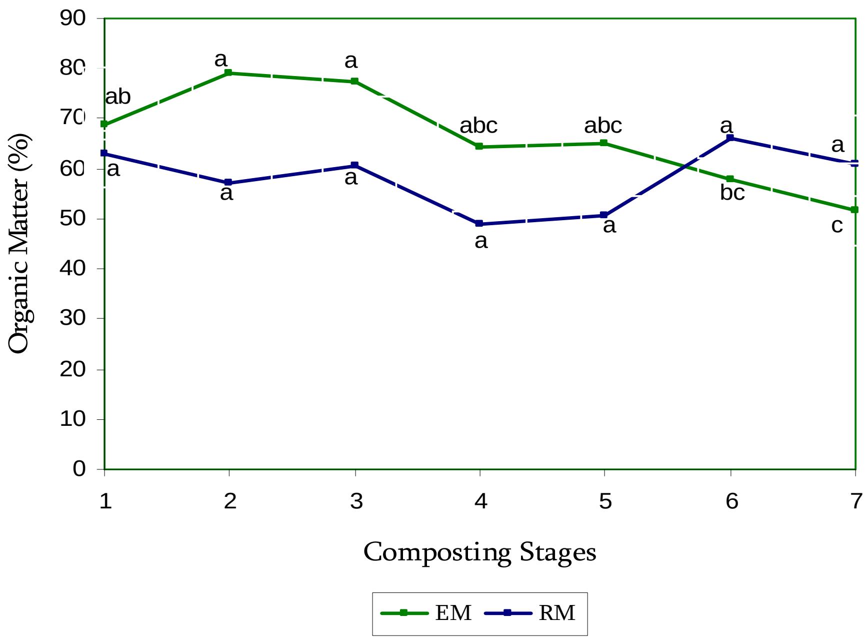


Figure 5. Organic matter percent of the EM and RM composts in the seven composting stages by the bin method
*Means with different superscripts differ (P<0.05)*

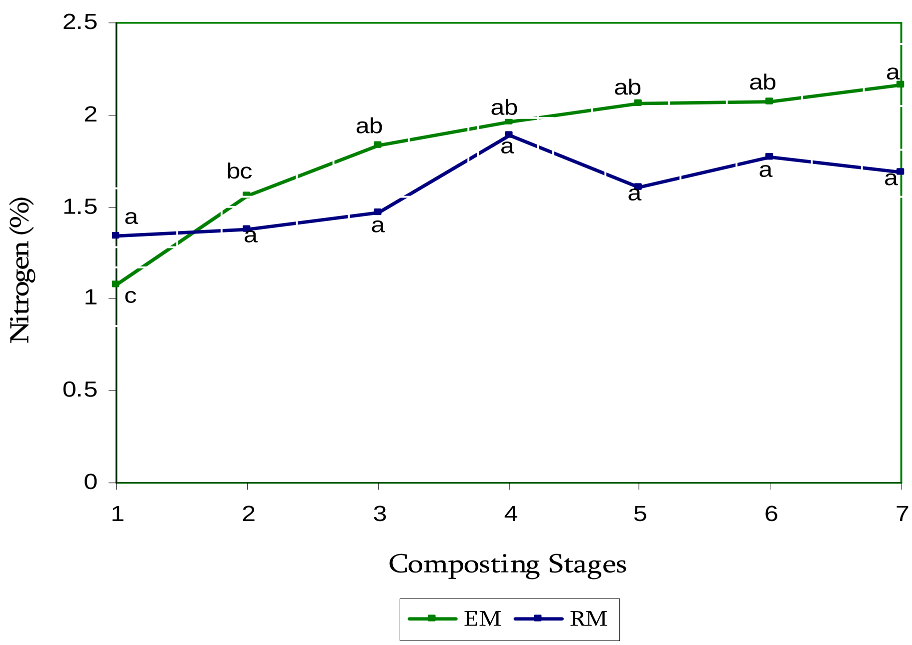


Figure 6. Nitrogen percent of the EM and GM composts in the seven composting stages by the bin method
*Means with different superscripts differ (P<0.05)*

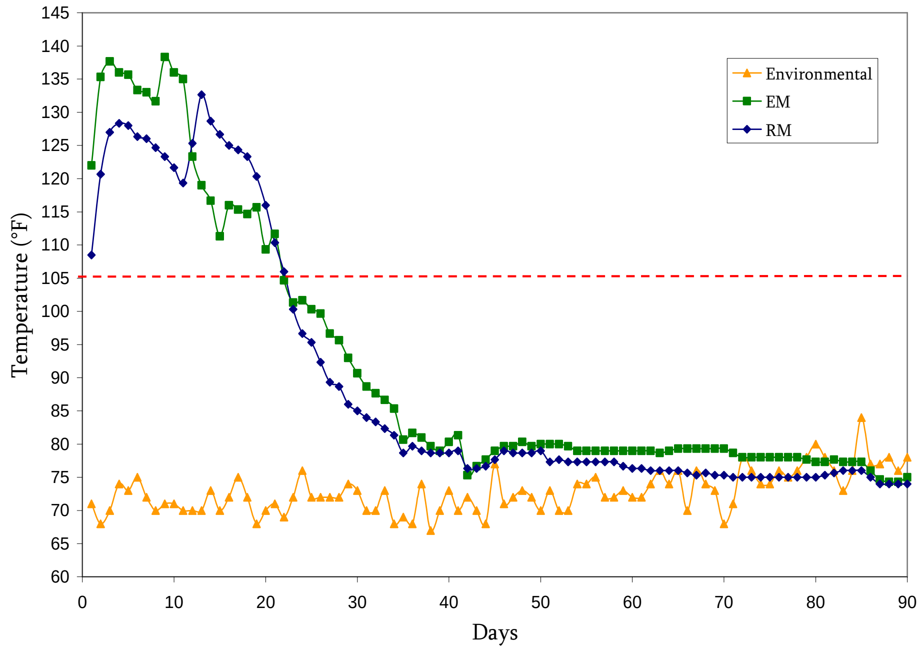


Figure 7. Temperature of the EM and RM composts in the seven composting stages by the bin method

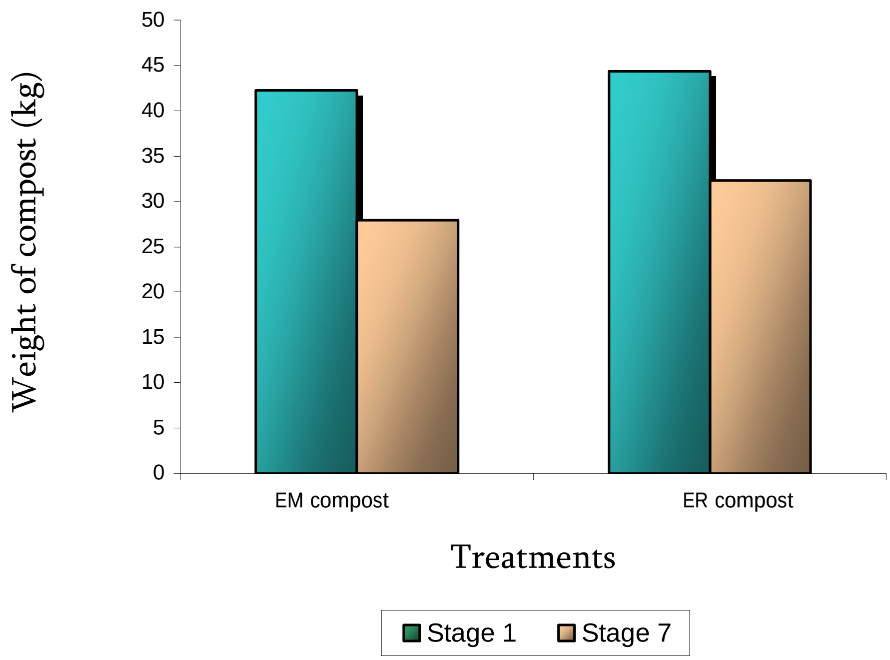


Figure 8. Difference in weight of material for EM and ER composted by the bin method in initial and final stages

Table 2. Results for EM and RM composts in the seven composting stages by the pile method

| Component | Type of Manure | Composting Stage 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| pH | EM | ND | 8.38 | 8.37 | 7.56 | 7.53 | 7.51 | 7.37 |
| | RE | ND | 7.77 | 7.78 | 7.40 | 7.10 | 6.53 | 6.40 |
| MS | EM | 22.96 | 28.68 | 28.30 | 37.36 | 53.92 | 67.49 | 63.86 |
| | RM | 28.99 | 37.50 | 36.64 | 34.09 | 44.95 | 46.79 | 49.74 |
| MO | EM | 68.89 | 69.37 | 65.87 | 62.00 | 67.39 | 40.00 | 66.00 |
| | RM | 62.88 | 70.69 | 54.29 | 54.22 | 41.53 | 51.12 | 60.63 |
| N | EM | 1.08 | 1.42 | 1.57 | 2.06 | 2.19 | 2.32 | 2.29 |
| | RM | 1.34 | 1.14 | 0.97 | 1.77 | 1.49 | 1.61 | 1.51 |
| C | EM | 38.27 | 38.54 | 36.59 | 33.44 | 37.44 | 22.22 | 36.67 |
| | RM | 34.93 | 39.27 | 30.16 | 30.12 | 23.07 | 28.40 | 33.68 |
| C:N | EM | 35.57 | 27.14 | 23.31 | 16.23 | 17.09 | 9.58 | 16.01 |
| | RM | 26.15 | 34.45 | 31.09 | 17.02 | 15.48 | 17.64 | 22.30 |

ND= Not Determined

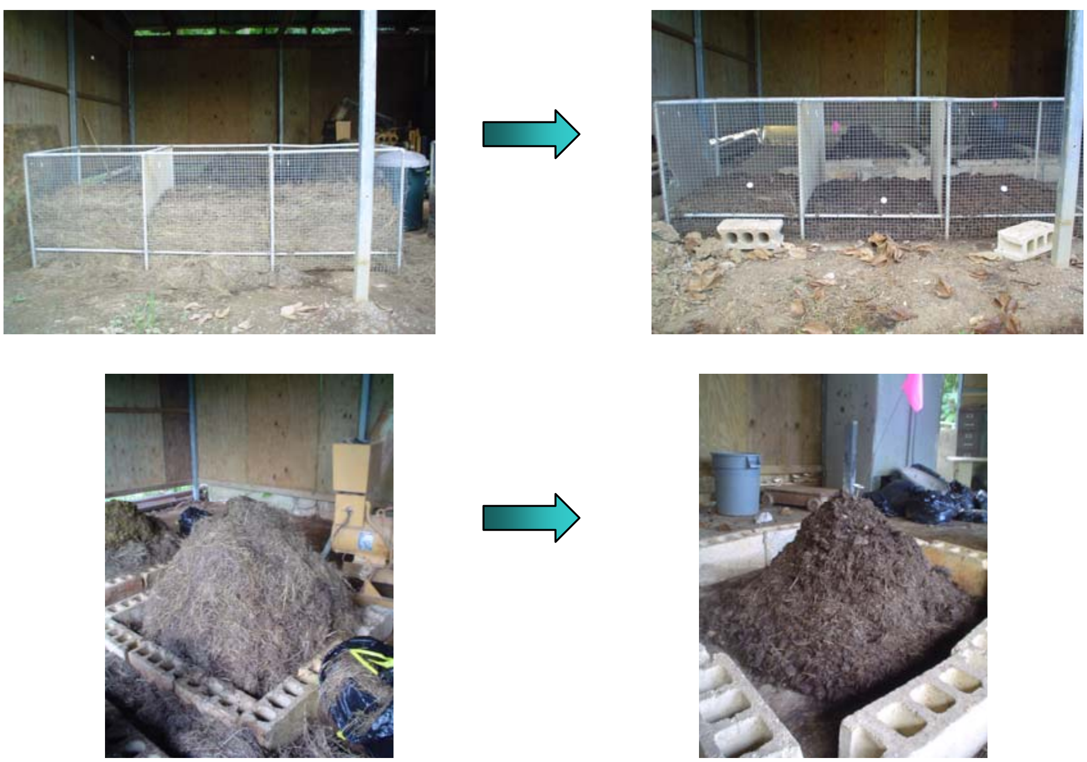

Figure 9. Contrast between bin and pile methods of composting showing initial and final stages

## Conclusion

The composting process is considered an environmentally safe way to reduce diverse types of organic waste materilas. The present results suggest that this process can be a suitable alternative to reduce *L. africana* y *C. simum* manure efficiently. Both, the bin and pile methods were shown to yield similar products with characteristics that suggest that they could be used as organic fertilizer.

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