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Chemical characterization of fresh and composted livestock manures

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Abstract

Effect of composting on the extractability of plant nutrients in organic wastes is essential for their recycling in sustainable soil fertility management. Therefore, an experiment was carried out to determine the concentrations of total C, total N, extractable P, K, Na and B in five types of fresh and composted manures (namely buffalo, camel, cow, goat and poultry). Laboratory results showed that the extractability of elements varied considerably with the type of composted manure. Total C varied in the order cow > goat > buffalo > poultry > camel while total N was in the order buffalo > poultry > cow > camel > goat. Total C, total N, extractable K and Na decreased with composting, whereas extractable P and B increased. Goat manure had higher pH and EC values than cow and poultry manures whether in fresh or composted samples. A marked increase in the EC value was observed in composted manures, whereas pH was reduced with composting.

Keywords: Chemical characterization; composted manure; fresh manure

1. Introduction

Continued disposal of large amounts of raw manure may result in soil and water contamination via leaching of toxic elements, nutrient imbalances and phytotoxicity in crops (Milan and Fernandes, 1996). Composting has become a preferred method for a variety of processing organic byproducts for application as soil conditioners and amendments (Butler *et al*., 2001). One of the most important advantages of using composted manure for agricultural purposes is its stability and maturity Application of undecomposed wastes or non-stabilized compost to land may lead to immobilization of plant nutrients and cause phytotoxicity due to insufficient biodegradation of organic matter (Butler *et al*., 2001). Hue and Liu (1995) also associated the application of immature compost with the release of phytotoxic compounds during composting. Composted manure is preferred because of its reduced volume and ease of handling due to smaller particle size that facilitates more uniform application (Eneji *et al.*, 2001; Larney and Blackshaw, 2003; Richard and Choi, 1999).

The introduction of appropriate management technologies could mitigate the health and environmental risks associated with the over production of organic wastes derived from the livestock industry by stabilizing them before their use or disposal. The management of livestock manures with consideration for environmental quality should be an important goal when recycling farm wastes as soil amendments (Eneji *et al.*, 2003a; Bolan *et al*., 2004).

Composted materials have gained a wide acceptance as organic amendments for sustainable agriculture, as they have been shown to increase soil organic matter levels, improve soil physical properties and modify soil microbial communities, thereby enhancing microbial biomass, activity and diversity. Composting is considered as a viable and environmentally sound method of waste management that hastens the decomposition of the organic waste under controlled conditions, thereby reducing its volume (Eneji *et al.*, 2001). The final product of this process is a stable, phytotoxicity-free and enriching-humus material known as compost, which is characterized by a high content of available-plant nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium (Eneji *et al.*, 2001). It is a microbial driven process, during which microorganisms utilize the decomposable organic waste both as a source of food and energy (Chefetz *et al*., 1998).

It is of great importance to provide further information regarding the nutritional and toxicity status of manure amendments, as a wide range of physico-chemical and biochemical changes do occur during composting. For instance, Eneji *et al.* (2001) found an increase in humic acid and acid-extractable phosphorus along with a decline in the levels of carbon and nitrogen. Since the total concentration of elements in manures may not provide the best indication of their bioavailability, evaluating the effects of composting on the extractable forms of elements in wastes is essential for the sustainable nutrient management of crops. Eneji *et al*. (2001) reported the physico-chemical changes during aerobic composting. The nutrient loss through runoff is related to the eutrophication of water bodies and it can become a major problem, especially in areas with an intensive animal husbandry. Therefore, the characterization of farm wastes compost should enable us to predict the behavior and fate of elements when compost is used as a soil amendment and also to identify sustainable field management practices to reduce possible nutrients losses.

Several studies have been conducted on the release of major constituents from manures during composting. However, research into the extractability of nutrient elements from fresh and composted manures of different livestock have been insufficiently reported. Therefore, an experiment was carried out to compare the concentrations of total C, total N, extractable P, K, Na and B in fresh and composted manures from five animal sources (i. e., buffalo, camel, cow, goat and poultry manure).

2. Materials and Methods

The different sources of manure (buffalo, camel, cow, goat and poultry manure) were collected from various locations in the district Abbottabad and composted for 112 days (16 weeks) under room temperature during summer in loosely folded black plastic bags. The manure samples were replicated thrice. Moisture in the manure was maintained at 20% and occasionally samples were turned at weekly intervals and mixed. Additional water was added as required. The compost temperature was measured daily at 1500 hours until it equaled that of the ambient. After composting, the manure samples were thoroughly mixed. The samples were dried (60 ^{o}C), ground, and screened via a 0.5-mm sieve for various analyses. For the determination of water extractable nutrients, 10 g manure samples were added 100 mL of distilled water and the samples were shaken on a mechanical shaker and thereafter filtered. Total carbon content was determined by dry- combustion using the method proposed by Nelson and Sommers (1982). Total nitrogen content was determined following the method of Winkleman *et al.* (1984). Phosphorus (P) was measured with a spectrophotometer according to the phosphomolybdate blue method (Olsen and Sommers, 1982). Potassium (K) was measured with a flame photometer (Soltanpur and Workman, 1979). Boron (B) was determined with a spectrophotometer at 420 nm following the method of Rashid *et al.* (1994). The pH of manure suspension with manure:water ratio of 1:10 was determined using a pH meter (Model: HANNA HI 8520). Electrical conductivity (EC) in the manure suspension was measured by an electrical conductivity meter (Model: 4320 JENWAY). Data were statistically analyzed using Statview software (SAS, 1999) and results were expressed on oven-dry basis. Mean separation was done using LSD at $p < 0.05$.

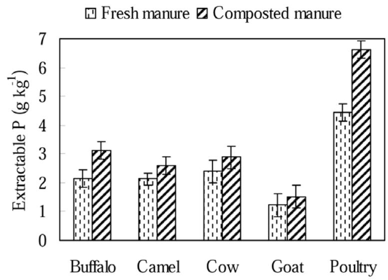

Figure 1. Changes in total C and total N in fresh and composted livestock manures

3. Results and Discussion

Extractability of elements differed significantly ($p<0.05$) between fresh and composted manure irrespective of the kind of animal manure. The differences in nutrient concentrations were highly related to the type of manure composted (Figure 1-3). For total C content, manures differed in the order cow > goat > buffalo > poultry > camel. There was an obvious reduction in total C in composted manures as compared to fresh manures. The reductions in total C was 15% for buffalo, 21% for camel, 17% for cow, 32% for goat and 29% for poultry manure. Generally, the source of raw material influences the humification process during composting (Chefetz *et al.*, 1996). This is not unexpected since composting is essentially a biochemical process in which C and N are mineralized and lost in gaseous forms as carbon dioxide, ammonia, N_2O and N_2. These declining trends were similar to those reported previously (Eneji *et al.*, 2003a). Eneji *et al.* (2003b) also reported a decrease in total C by 18% after 195 days of co-composting animal wastes. It has been reported elsewhere that chemical composition affected the decomposition rate of all organic matter including crop residues (Kumar and Goh, 2000; Martens, 2000), compost (Tiquia *et al.*, 2002), and manure (Gordillo and Cabrera, 1997).

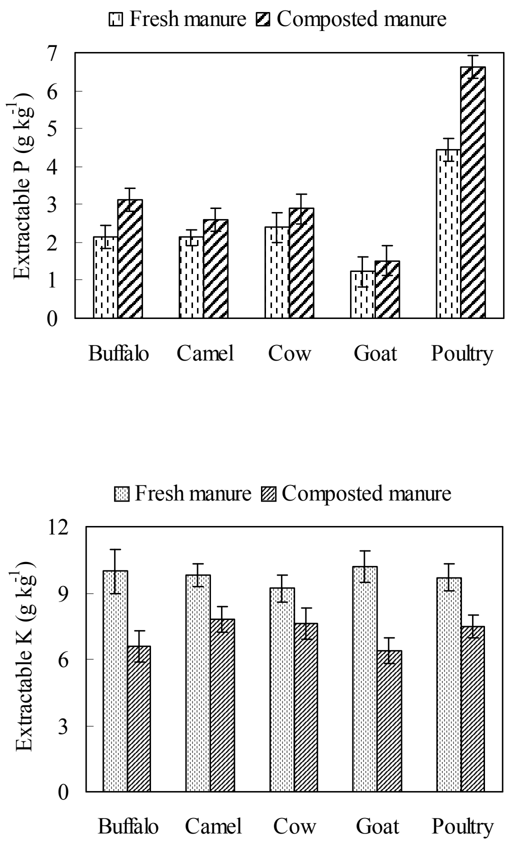

Figure 2. Changes in extractable P and K in fresh and composted livestock manures

Our fresh (non-composted) manures had much higher total N content than composted manures (Figure 1) and among sources, total N varied in the order buffalo > poultry > cow > camel > goat. Since the content of N declined significantly with composting, it would be necessary to supplement the manure with inorganic sources of N when applied as fertilizer. The lower total N in composted samples may also infer that the use of composted waste would be less polluting. Irshad *et al.* (2011) reported a marked decrease in extractable NH_4-N during composting. Fresh manure had 87 mg kg^{-1} of NH_4 compared with only 15 mg kg^{-1} after 100 days of composting.

Significant increases in extractable P were found in composted manure as compared to fresh manure (Figure 2). The content in fresh manures were in the order poultry > cow > buffalo > camel > goat, whereas in composted the pattern was poultry > camel > cow > buffalo > goat. The extractable P increased when composted by 44% in buffalo, 22% in camel, 21% in cow, 24% in goat and 49% in poultry manure (Figure 2). The fluctuation observed in the release of P nutrient could be due to the variation in the microbial activity, C/N ratio of manure samples and time of composting. Adler and Sikora (2005) observed an increased inorganic N and decreased water-extractable P as the organic matter decomposed. Others have also observed a decrease in water-extractable P over time with different types of composts (Traore *et al*., 1999). When P was fractionated, it was found that forms of inorganic P such as HCl-soluble P increased and water-extractable P decreased (Traore *et al*., 1999; Eneji *et al.*, 2003c) over time of composting. This trend suggests the possible transformation of water-extractable P to more stable forms, which would reduce the potential for runoff losses.

Statistically significant ($p<0.05$) changes were found for K content among livestock manures butthe content substantially decreased after composting (Figure 2). Fresh manure K levels (g kg^{-1}) were in the order of 10.1 for buffalo, 9.8 for camel, 9.2 for cow, 10.2 for goat and 9.7 for poultry manure. After composting the values (g kg^{-1}) were 6.6, 7.8, 7.6, 6.4 and 7.5 respectively. The decreased K in composted samples could be attributed to the formation of insoluble K complexes in the presence of inorganic elements or changed pH value. Viller *et al*. (1993) reported differences of 42 and 55% in the contents of available Ca and Mg extracted with acetic acid after composting of the manure. Eneji *et al*. (2003c) reported that manure was an ample source of macro- and micronutrients upon application to soils. Chemical composition of manure can influence the amount of nutrients released, and the rate at which they are released. Significant correlations have been reported between the initial chemical composition of organic residues and the mineralization rate (Palm and Sanchez, 1991; Mafongoya *et al*., 1997).

A marked decrease in the extractable Na was observed after composting. Fresh buffalo manure exhibited the highest concentration of Na followed by poultry and camel manures whereas goat and cow showed relatively lower concentration. The low extractability of Na in composted samples may suggest that the use of composted animal waste would be beneficial to sodic soils. All manure samples showed a similar pattern of nutrient release in the order of K > Na > P > B. Unlike Na, B concentrations were greater in composted than fresh manures by 64% higher in buffalo, 6% in camel, 7% in cow, 13% in goat and 6% in poultry manure. Boron levels in manures were in the order cow > goat > camel > poultry > buffalo. Bolan *et al*. (2004) reported that the concentration of trace elements can vary considerably among animal manures. Additional variation is associated with the age of the animal, type of ration, housing type, and waste management practice. Eneji *et al*. (2003a) reported marked increases in total Fe, Zn, Cu and Mn, especially under anaerobic conditions during composting and decreases in the available heavy metal contents. Increased use of trace elements in animal feed have often concentrated their levels in manure by-products. The type of bedding material in animal wastes may also influence the litter dry

The electrical conductivity (EC) of manures increased substantially with composting, especially for buffalo, cow and poultry manure (Figure 4). This may be related to the transformation of organic material into inorganic forms. The EC level increased after composting from 8.6 to 9.5 in buffalo manure, 8.7 to 9 in camel manure, 9.6 to 10.7 in cow manure, 10.3 to 10.6 in goat manure and 8.3 to 9.2 in poultry manure. The higher EC values in composted manures could be attributed to the release of salts from the manure with the passage of time. Chang *et al*. (1990) found that manure application increased the total soluble salts and Na adsorption ratio in the soil. Changes in EC of certain composts could also be used as an index of compost maturity. Whenever the EC (together with nitrate and soluble organic matter) of cattle manure compost exhibited a constant value, the material was judged to be mature enough to be used as organic compost in container media (Inbar *et al*., 1991). Electrical conductivity is a measure of total cations and anions in solution and was usually determined largely by Mg and Ca ions (Clark *et al*., 1998).

Manure pH (except for poultry manure) reduced significantly with composting (Figure 4). The pH of buffalo manure was 8.7 in fresh and reduced to 7.7 in composted sample. For camel manure, the pH was 8.6 in fresh and 8.5 in compost, for cow manure pH was 8.5 in fresh and 7.4 in manure compost. Goat fresh manure showed pH of 8.9 and 7.8 in composted manure. Poultry manure had a pH of 8 in fresh and 8.4 in compost. This decrease in pH could be attributed to the modified chemical composition of manure through microbial action, notably the production of organic acids.

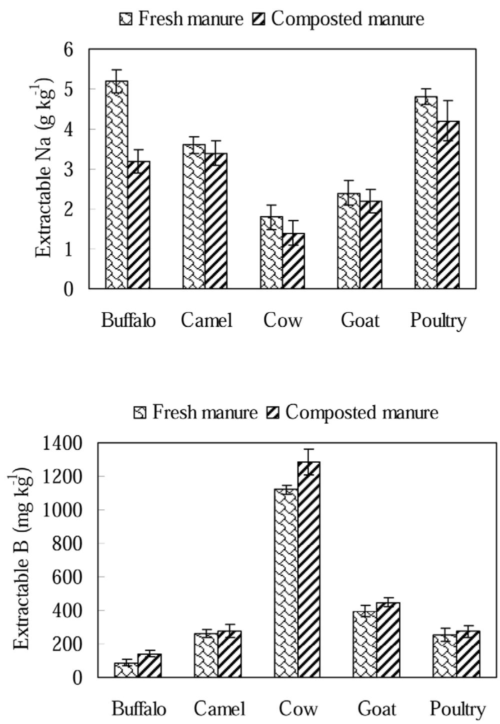

Figure 3. Changes in extractable Na and B in fresh and composted livestock manures

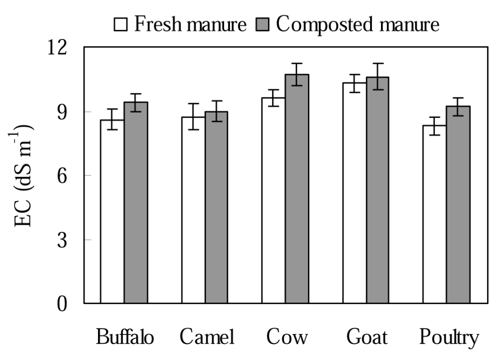

Figure 4. Changes in pH and EC in fresh and composted livestock manures

4. Conclusions

There were considerable differences in elemental composition among manures from different animal sources and composting reduced the contents of total C and N, exchangeable K and Na and pH but increased the EC, extractable P and B. These changes reflect a stabilization of the manure. Thus for use as soil amendments, the composted manure may need supplementation with inorganic N and K, depending on soil test results and crop requirements.

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