Journal of Agricultural Science; Vol. 10, No. 6; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

# Characterization of Organic Wastes and Effects of Their Application on the Soil

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Received: March 13, 2018 Accepted: April 17, 2018 Online Published: May 15, 2018

doi:10.5539/jas.v10n6p291 URL: https://doi.org/10.5539/jas.v10n6p291

**Abstract**

The agricultural farming activities generate organic waste whose indiscriminate deposition can be prejudicial to the environment. However, careful application of these wastes as organic fertilizers it is a possibility to improve soil fertility. This study aimed to confirm the hypotheses that organic wastes produced in various production chains in the semi-arid region of Ceará have contents of nutrients that give them potential as organic fertilizers and, since they are used as organic fertilizers, these residues improve the chemical soil attributes. Nutrient contents were determined at the laboratory and then the wastes were placed in decomposition bags and applied in a Fluvic Neosol. Soil samples were collected in the 0-0.10 m layer 90 days after wastes were applied. The residues presented nutrient contents that allow their use as organic fertilizers, except the shrimp farming residue that presented sodium content above that allowed by legislation, resulting also in higher element contents in the soil. In addition, the shrimp farming showed the lowest organic carbon content in relation to others chemical elements. The residues of the poultry industry and the compound made with residues of small ruminants presented the highest of nitrogen and phosphorus levels. The carnauba residue was associated with phosphorus immobilization because it presented C/P ratio higher than 300.

**Keywords:** organic fertilization, reuse of wastes, soil chemistry

## 1. Introduction

Deforestation, combined with intensive land cultivation without adopting conservation practices, leads to reduction of soil fertility (Kassa et al., 2017). Utilization of organic fertilizers and adoption of practices to increase organic matter contents in the soil are fundamental to improve soil fertility (Barral et al., 2011; Villarino et al., 2017).

Organic fertilizers can be wastes from numerous agricultural and industrial activities because the population growth has contributed to increasing their production (Asquer et al., 2017; Ramachandra et al., 2018). Applying these materials in the soil emerges as a promising alternative because, besides the advantages related to improvements in soil physical, chemical and biological attributes, it represents low cost of acquisition and reduces the environmental impacts caused by inadequate disposal (Xiao et al., 2017).

With the increment in the cost of mineral fertilizers (Xun et al., 2016) and increasing levels of environmental pollution, adequate utilization of organic wastes is an alternative to supply nutrients such as nitrogen and phosphorus in smallholdings in the Brazilian semi-arid region (Rocha et al., 2013; Sanchéz et al., 2017). Recycling wastes from various production chains, whose inadequate disposal can cause negative impacts on the environment (Sharifi et al., 2016), presents itself as an important alternative to use them as organic fertilizers (Yang et al., 2017).

Organic wastes have nutrients necessary to plants, such as nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), among others (Vendrusculo et al., 2016; Sanchéz et al., 2017). Using organic wastes as organic fertilizers must be performed wisely because, if the amounts added are higher than those required by the crops, there will be accumulation of nutrients in the soil (Yang et al., 2017) and, probably, there will be nutrient losses to environment. To verify the potentialities of applying organic wastes in agriculture, the first step is their characterization (Wei et al., 2017). Thus, the mineral composition of the waste can indicate its potential to supply nutrients to plants, being able to complement or in some cases replace mineral fertilization (Xun et al., 2016).

The Brazilian Northeast region generates wastes such as sludge from shrimp farming tanks, carnauba palm *bagana* (leaf fibers, byproduct of wax production), poultry agro-industry waste, organic waste from the production/slaughter of small ruminants and waste from the guava processing agro-industry.

Studies on the influence of the application of these wastes in the soil and their effects on its chemical attributes are important. The present study aimed to confirm the hypotheses that the previously mentioned wastes have contents of nutrients that give them potential to be used as organic fertilizers and, since they are used as organic fertilizers, these residues improve the chemical soil attributes.

## 2. Material and Methods

Each one of the organic wastes used in the study was homogenized at collection to obtain a uniform and representative composite sample. Shrimp farming waste was obtained by scraping the bottom of the shrimp farming tanks; carnauba palm *bagana* was collected at the courtyard of the carnauba wax processing industry; wastes from poultry agro-industry and production/slaughter of small ruminants were obtained from composting piles; and the wastes from the guava processing agro-industry were obtained in piles of material located at the end of the processing line. Subsequently, the organic wastes were dried in forced-air oven at 65 ºC for 48 hours and then analyzed to determine the contents of nutrients (MAPA, 2014).

To study the effects of applying organic wastes on soil chemical attributes, an experiment was carried out at the Vale do Curu Experimental Farm, belonging to the Center of Agricultural Sciences of the Federal University of Ceará (UFC), located in the municipality of Pentecoste, CE. This municipality is situated in the semi-arid region at the geographic coordinates 39º15′ and 39º30′ S latitude and 39º15′ and 3º20′ W longitude, at altitude of 47 m.

According to Köppen's classification, the climate of the region is BShw', hot semi-arid, with mean annual rainfall of 806.5 mm, concentrated from January to April, and mean temperatures between 22 and 28 ºC (Pereira Filho et al., 2015). The soil of the area was classified as Fluvic Neosol (alluvial soils) (Santos et al., 2013) and its chemical and physical characteristics are presented in Table 1.

Table 1. Chemical characterization and granulometry of the soil collected in the 0-10.0 cm layer in the experimental area located in Pentecoste, CE, Brazil

| Depth (0.0-0.10 m) | |
|---|---|
| pH (1:2.5 $H_2O$) | 7.4 |
| Ca (cmol$_c$ kg$^{-1}$) | 6.5 |
| Mg (cmol$_c$ kg$^{-1}$) | 4.5 |
| K (cmol$_c$ kg$^{-1}$) | 0.01 |
| Na (cmol$_c$ kg$^{-1}$) | 0.01 |
| P (g kg$^{-1}$) | 10.0 |
| CO (g kg$^{-1}$) | 6.3 |
| SB (cmolc kg$^{-1}$) | 11.0 |
| H+Al (cmol$_c$ kg$^{-1}$) | 1.1 |
| Al (cmol$_c$ kg$^{-1}$) | 0.1 |
| CEC (cmol$_c$ kg$^{-1}$) | 23.2 |
| V (%) | 47.4 |
| m (%) | 0.8 |
| Sand (g kg$^{-1}$) | 790.0 |
| Silt (g kg$^{-1}$) | 190.0 |
| Clay (g kg$^{-1}$) | 20.0 |

*Note*. SB: sum of bases; CEC: cation exchange capacity; V (%): base saturation; m (%): aluminum saturation.

### *2.1 Analyzed Chemical Attributes*

The pH was measured in a 0.01 M $CaCl_2$ through potentiometry. The contents of $Ca^{2+}$, $Mg^{2+}$ were extracted with 1 mol L$^{-1}$ KCl and determined through absorption spectrometry (Donagema et al., 2011). The contents $K^+$, $Na^+$

were extracted with diluted HCl solution and determined by flame photometry (Donagema et al., 2011). The content P was extracted with Mehlich 1 and determined by colorimetry (Donagema et al., 2011).

The contents of total organic carbon (TOC) were determined by wet oxidation with potassium dichromate in sulfuric medium determined as described by Yeomans and Bremmer (1988).

Potential acidity (H+Al) was extracted with 0.5 mol $L^{-1}$ calcium acetate solution at pH 7.0 and determined by alkalimetric titration using 0.025 mol $L^{-1}$ NaOH (Donagema et al., 2011). Exchangeable aluminum, extracted with 1 mol $L^{-1}$ KCl solution and determined by titration with 0.025 mol $L^{-1}$ NaOH (Donagema et al., 2011).

Sum of bases, cation exchange capacity, base saturation and aluminum saturation were calculated based on the methods described in Donagema et al. (2011).

Granulometry determined by the pipette method, with physical dispersion by quick agitation (12,000 rpm, 10 min) (Gee; Bauder, 1986).

### *2.2 Field Experiment*

The field experiment was set in completely randomized design, comprising six treatments and four replicates. Treatments were: soil without application of wastes; shrimp farming waste (T1); carnauba palm *bagana* (T2); poultry agro-industry waste (T3); organic compost from the production/slaughter of small ruminants (T4); and waste from guava processing agro-industry (T5).

Soil samples were collected in the 0-0.10 m layer within the influence area of each one of the wastes evaluated, 90 days after application. These samples were subjected to the same analyses mentioned in the soil characterization.

### *2.3 Statistical Analysis*

The data were statistically analyzed by F test for analysis of variance and Tukey test for means comparison. The analyses were carried out using the statistical program Sisvar (Ferreira, 2014).

## 3. Results and Discussion

### *3.1 Chemical Composition Analysis of the Organic Wastes*

The analyzed materials showed variations in the attributes evaluated for characterization (Table 2), which is explained by their different origins (Sharma et al., 2017).

Table 2. Chemical composition of the organic wastes evaluated

| Components | Treatments | | | | |
|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 |
| pH ($CaCl_2$) | 7.5 | 4.2 | 6.1 | 6.4 | 6.8 |
| Umidade (%) | 3.0 | 8.4 | 6.6 | 6.4 | 9.8 |
| N (g $kg^{-1}$) | 13.8 | 20.6 | 29.8 | 14.8 | 26.7 |
| CO (g $kg^{-1}$) | 44.9 | 161.6 | 145.1 | 157.2 | 162.9 |
| P (g $kg^{-1}$) | 0.6 | 0.3 | 7.6 | 8.3 | 1.4 |
| K (g $kg^{-1}$) | 36.9 | 3.1 | 20.2 | 1.9 | 2.6 |
| Ca (g $kg^{-1}$) | 49.0 | 7.0 | 8.7 | 20.3 | 4.2 |
| Mg (g $kg^{-1}$) | 5.1 | 1.7 | 1.2 | 7.5 | 0.4 |
| Na (g $kg^{-1}$) | 51.4 | 0.4 | 2.5 | 3.5 | 0.2 |
| S (g $kg^{-1}$) | 1.1 | 3.3 | 1.2 | 1.3 | 2.2 |
| Cu (mg $kg^{-1}$) | 1.0 | 0.1 | 0.1 | 0.3 | 0.1 |
| Fe (mg $kg^{-1}$) | 6.1 | 20.2 | 7.3 | 53.4 | 7.6 |
| Mn (mg $kg^{-1}$) | 0.9 | 2.3 | 1.5 | 3.5 | 1.1 |
| Zn (mg $kg^{-1}$) | 0.6 | 0.4 | 0.6 | 2.0 | 0.6 |
| C/N | 3.2 | 7.8 | 4.8 | 10.6 | 6.1 |
| C/P | 74.8 | 538.6 | 19.0 | 18.9 | 116.3 |
| C/S | 40.8 | 48.9 | 120.9 | 120.9 | 74.0 |

*Note*. T1: shrimp farming waste; T2: carnauba palm *bagana*; T3: poultry agro-industry waste; T4: organic compost produced with wastes from small ruminants; and T5: waste from guava processing agro-industry. *Contents of chemical elements based on the dry matter of the analyzed materials.

The chemical composition analysis of the organic wastes revealed their capacity to contribute to plant nutrition and recover the fertility of degraded soils. According to the Normative Instruction DAS/MAPA 25/2009, carnauba palm *bagana* (T2), poultry agro-industry waste (T3), organic compost produced with wastes from small ruminants (T4) and waste from guava processing agro-industry (T5) have contents of nutrients that allow their use as organic fertilizers. On the other hand, shrimp farming waste (T1) showed high sodium content, above the maximum value allowed by the Normative Instruction DAS/MAPA 25/2009, which establishes that the material must have 5% of the element to be used as organic fertilizer.

Sodium contents in the studied wastes varied from 0.2 to 51.4 g $kg^{-1}$ (Table 2). Highest contents were found in shrimp farming waste; therefore, its use may lead to Na accumulation in the soil and cause negative effects on chemical and physical properties and on its biological processes (Sanchéz et al., 2017). In addition, excess salinity in the soil can compromise the availability of water and nutrients to plants, directly affect the osmotic potential of the soil solution and, additionally, high level of exchangeable Na may lead to degradation of soil structure, dispersion of clays and toxicity to plants (Pereira et al., 2017).

OC and N contents in the organic wastes ranged from 44.90 to 162.90 g $kg^{-1}$ and from 13.82 to 29.86 g $kg^{-1}$, respectively (Table 2). The treatment T1 (shrimp farming waste) showed the lowest C content, whereas T2, T3, T4 and T5 showed higher values, and the highest C content was found in T5 (waste from guava processing agro-industry).

N contents in the treatments T2, T3 and T5 were high, reaching values approximately 50% greater than those found in T1 and T4 (Table 2). The highest N contents differed from those found by other authors for the same types of wastes (Nascimento et al., 2015). This indicates that there are factors causing variations in the N contents of these materials, and it is necessary to carry out chemical analyses to determine the N contents in the wastes.

High contents of total N in organic wastes indicate that they may act as immediate source of N to plants (Barral et al., 2011). The treatment T3 (poultry agro-industry waste) showed the highest N content, which is important information because poultry production has increased and expanded in the national territory, along with the generation of wastes associated with this activity (Nascimento et al., 2015).

Regarding P contents, the treatments T3 and T4 showed the highest values (Table 2). Thus, poultry agro-industry wastes and organic compost produced with wastes from small ruminants can be used as alternative complementary sources of P to the soil, especially soils of the semi-arid region, which mostly have low P contents (Souto et al., 2013). One alternative to eliminate animal waste is composting, forming organic compounds and humus (Sanchéz et al., 2017). Composting of animal waste also allows for nutrient cycling because it transforms wastes into adequate products for agricultural use (Souza et al., 2012).

The results relative to the waste from the production/slaughter of small ruminants (T4) are fundamental in the search for alternatives of use for this material in the Brazilian semi-arid region, because it is known that, in regional terms, 91.4% of the total herd of goats (IBGE, 2013) and 56.5% of sheep are concentrated in the Northeast region (IBGE, 2014).

C/N ratios oscillated among the treatments evaluated, with highest value (10.6) found in T4 (organic compost produced with wastes from small ruminants) and lowest value (3.2) found in T1 (shrimp farming waste). When the C/N ratio in the organic waste is higher than 30, there is a predominance of nutrient immobilization; however, when it is below 20, mineralization prevails (Souto et al., 2013; Santonja et al., 2015). On the other hand, wastes with high N contents and C/N ratio below 10/1 may release nutrients more rapidly than materials with C/N ratio above 20 (Al-Bataina et al., 2016).

For the C/P ratio, the highest value (538.6) occurred in T2 (carnauba palm *bagana*), whereas the lowest value (18.9) was found in T4 (organic compost produced with wastes from small ruminants). According to Maluf et al. (2015), P mineralization is regulated by the C/P ratio, so that values higher than or equal to 300 lead to immobilization, while values lower than 200 favor mineralization. Only the treatment T2 (carnauba palm *bagana*) showed values above 300, which indicates that this waste tends to immobilize P.

C/S ratios ranged from 40.8 to 120.9, and the highest value (120.9) was found in the treatments T3 and T4 (poultry agro-industry waste and organic compost produced with wastes from small ruminants), whereas the lowest value (40.8) was found in T1 (shrimp farming waste). C/S ratios above 400 may favor immobilization, while values lower than 200 lead to higher mineralization rates (Maluf et al., 2015).

For the metals Cu, Fe, Zn and Mn, the contents obtained in the chemical characterization demonstrate that these organic wastes do not cause concern regarding environmental contamination (Yang et al., 2017). Nonetheless, even in quantities allowed by the legislation, the application of organic wastes must be monitored because at low concentrations, milligrams or micrograms, these metals in some cases may cause harmful effects on the environment (Sharifi et al., 2016).

### *3.2 Soil Chemical Attributes After Application of Organic Wastes*

The following soil chemical attributes were influenced by the addition of organic wastes: pH, Ca, K and Na (Figure 2). Ca, K and Na contents were higher in the soil in response to the application of shrimp farming waste (T1). Application of organic wastes can cause, especially in superficial soil layers, increment in the contents of nutrients such as P, K, Ca and Mg (Lourenzi et al., 2016). In addition, the application of these wastes represents addition of carbon, which can cause quantitative and qualitative changes in soil organic matter (Barral et al., 2011; Xiao et al., 2017).

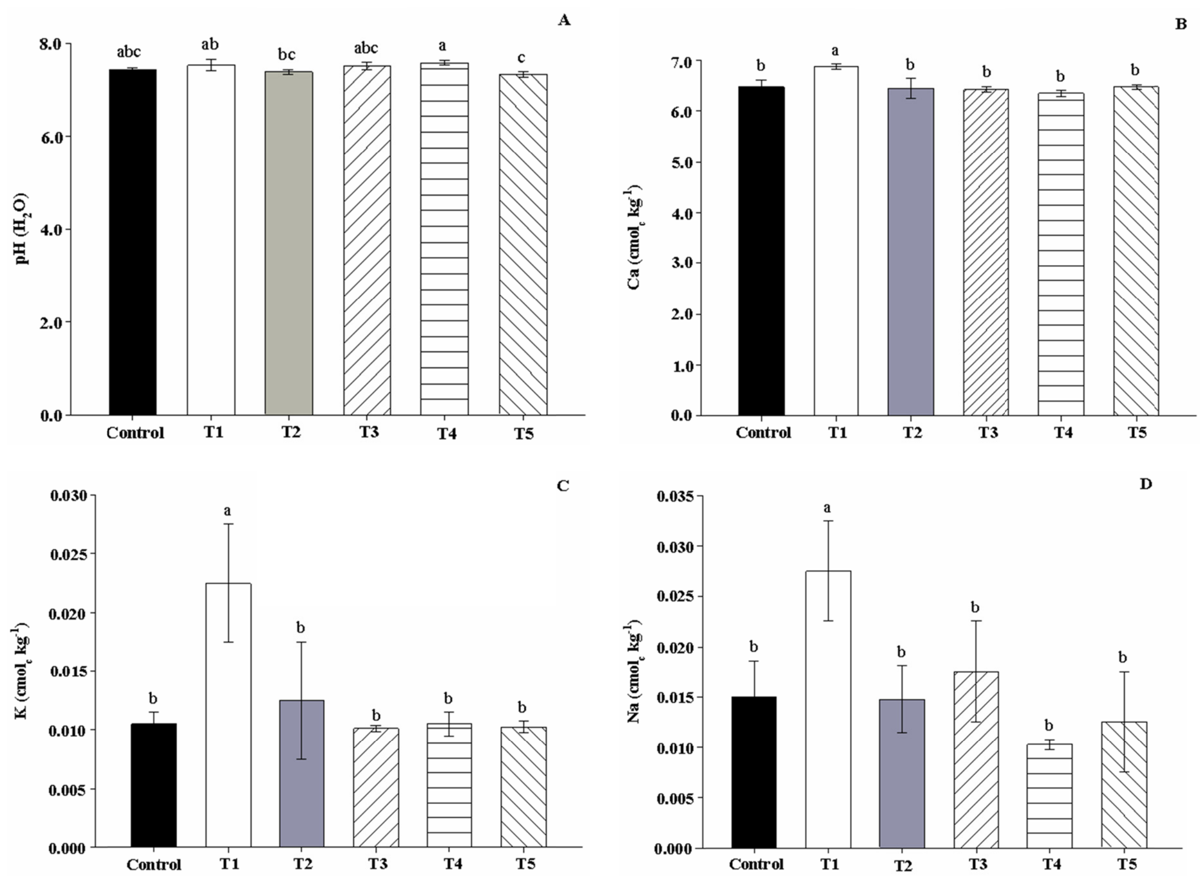


Figure 2. Soil chemical attributes (pH, Ca, K and Na) 90 days after applying the organic wastes. T1: soil within the influence area of shrimp farming waste; T2: soil within the influence area of carnauba palm *bagana*; T3: soil within the influence area of poultry agro-industry waste; T4: soil within the influence area of the organic compost from the production/slaughter of small ruminants and T5: soil within the influence area of waste from guava processing agro-industry. Means followed by the same lowercase letter not differ by Tukey test at 0.05 probability level

There was a significant increase of $Ca^{2+}$, $K^{+}$ and $Na^{+}$ in the soil by applying the shrimp farming residue (T1). This effect was expected, since this residue presented the highest levels of mentioned elements. However, the effect was below the capacity of the residue to provide these elements, since the amount of residue applied was equivalent to 1.8, 0.7 and 1.7 $cmol_c$ $kg^{-1}$ of calcium, potassium and sodium, respectively. The changes in the soil contents were less than 0.02 $cmol_c$ $kg^{-1}$, which corresponds about 35 times lower than amount applied.

Considering the pluvial precipitation events during the evaluation period, the permanence, mainly of $K^{+}$ and $Na^{+}$ in the residue applied in soil surface is unlikely. The lower levels of these elements in soil surface layer can be attributed to the leaching of these elements to the lower layers, which is potentiated by the low soil cation exchange capacity (Neossolo Flúvico), which presents only 2% of clay.

For Na contents, the behavior was similar to that of K in the soil within the influence area of shrimp farming waste (Figures 2C and 2D). The Na present in the organic wastes is soluble and, therefore, rapidly released to the soil in the first days if there is effect of rainfall or use of irrigation (Esse et al., 2001). This result is important because shrimp farming waste leads to higher Na content in the soil solution and its excess may hamper the availability of water and nutrients to plants and also compromise soil structure (Feng et al., 2017; Nassah et al., 2018).

Soil pH increased with the application of organic fertilization based on swine manure complemented with NPK, indicating that these materials, besides supplying nutrients, have potential to mitigate the effect of acidity shortly after application in the soil (Xun et al., 2016). Souza et al. (2012) applied doses of compost produced with wastes from small ruminants and also found increment in pH and reduction in H+Al, as the organic compost doses increased.

Despite the high N levels in treatments T2, T3 and T5 and high P levels in treatments T3 and T4 (Table 2), no were observed treatment effects on soil nitrogen and phosphorus contents. These results can be attributed to losses by leaching and/or immobilization of the elements in evaluated residues.

## 4. Conclusions

The residues evaluated in this study contents nutrients that allow their use as organic fertilizers, except the shrimp farming residue that presents high levels of sodium. The sodium present in the shrimp farming residue is transferred to soil and is subject to leaching, which can cause sodicity problems not only in soil in which it was applied, but also in groundwater. Long-term studies and about doses are necessary to determine if application of the evaluated residues improves the fertility of the soil on time, and also to define the best application doses of organic residues.

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