SEÇÃO VIII - FERTILIZANTES E CORRETIVOS

CHEMICAL AND PHYSICAL PROPERTIES OF ORGANIC RESIDUES[1]

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SUMMARY

Due to human activity, large amounts of organic residue are generated daily. Therefore, an adequate use in agricultural activities requires the characterization of the main properties. The chemical and physical characterization is important when planning the use and management of organic residue. In this study, chemical and physical properties of charcoal, coffee husk, pine-bark, cattle manure, chicken manure, coconut fiber, sewage sludge, peat, and vermiculite were determined. The following properties were analyzed: $N\text{-}NH_4^+$, $N\text{-}N0_3^-$, and total concentrations of N, P, S, K, Ca, Mg, Mn, Zn, Cu, and B, as well as pH, Electrical Conductivity (EC) and bulk density. Coffee husk, sewage sludge, chicken manure and cattle manure were generally richer in nutrients. The EC values of these residues were also the highest (0.08 - 40.6 dS m^{-1}). Peat and sewage sludge had the highest bulky density. Sodium contents varied from 0 to 4.75 g kg^{-1}, with the highest levels in chicken manure, cattle manure and sewage sludge. Great care must be taken when establishing proportions of organic residues in the production of substrates with coffee husk, cattle or chicken manure or sewage sludge in the calculation of the applied fertilizer quantity in crop fertilization programs.

Index terms: substrate, organic residue, soil contamination, residue disposal.

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RESUMO: *CARACTERIZAÇÃO QUÍMICA E FÍSICA DE RESÍDUOS ORGÂNICOS*

Uma diversidade de resíduos orgânicos, oriundos das atividades humanas, é gerada diariamente e demanda pesquisas para avaliar a viabilidade técnica, econômica e ambiental do seu uso agrícola. A caracterização química e física auxiliam no planejamento de uso e no manejo dos resíduos orgânicos, pois permitem avaliar atributos que tornam o uso na agricultura atrativo ou limitante. Este trabalho teve como objetivos a caracterização química e física e a avaliação de teores de nutrientes e de Na em carvão vegetal, casca de café, casca de pínus, esterco bovino, esterco de galinha, fibra de coco, lodo de esgoto, turfa e vermiculita. Os seguintes atributos foram analisados: N-amônio e N-nitrato e os teores totais de N, P, S, K, Ca, Mg, Mn, Zn, Cu, B e Na, além do pH em água, da condutividade eletrolítica (CE) e da densidade aparente dos materiais. A casca de café, o lodo de esgoto e os estercos de galinha e de bovino foram os materiais que apresentaram as maiores concentrações totais de: N, N-amônio, N-nitrato, P, S, K, Ca, Zn, Cu e B; foram, também, os resíduos que apresentaram os maiores valores de CE (0,08 a 40,6 dS m^{-1}). A turfa e o lodo de esgoto mostraram os maiores valores de densidade aparente. Os teores de Na apresentados pelos materiais variaram de 0 a 4,75 g kg^{-1}, sendo os maiores valores verificados para os estercos de galinha e de bovino e o lodo de esgoto. O uso de casca de café, de estercos de bovino e de galinha e do lodo de esgoto demanda maiores cuidados para estabelecer as suas proporções para a produção de substratos ou no cálculo da quantidade a ser utilizada em programas de adubação das culturas.

Termos de indexação: substrato, resíduo orgânico, contaminação do solo, disposição de resíduos.

INTRODUCTION

The possibility of reducing the use of non-renewable sources in agriculture, along with the need for the suitable disposal of organic residue in the environment, makes nutrient and energy cycling by using organic materials attractive in economic, agricultural and environmental terms. Besides the possibility of nutrient cycling and cost reduction, organic residues have the potential to replace non-renewable materials used in the production of seedlings, such as peat and vermiculite. In view of the diversity, there is a need to characterize these organic materials to prepare mixtures and substrates suitable for plant growth. The characterization allows the separation of potential agronomic residues from materials that represent a risk of environmental contamination. Furthermore, wastes with a higher risk to plants can be diluted or amended to increase the agronomic efficiency (Sharma et al., 1997; Carrijo et al., 2002, Benito et al., 2005; Hernández-Apaolaza et al., 2005, Melo & Silva, 2008).

The origin of anthropogenic organic residues can be classified in animal, vegetable, urban, industrial and agro-industrial (Sharma et al.1997; Silva, 2008). The characteristic of the waste is related to the production process, handling of by-products, processing level, species and age of animals, management and feeding schemes, mixtures and use of manure beds, the plant species and management system of the biomass produced, and by the composting degree of the material, etc (Abad et al.2002; Abreu Junior et al. 2005; Silva, 2008). Among the options available, the use for agricultural purposes is certainly the most interesting from the economic, environmental, and social point of view, and waste recycling has an unquestionable benefit since it minimizes the environmental problem caused by inadequate disposal (Pires & Mattiazzo, 2008).

Just as important as emphasizing the agricultural advantages, it should be remembered that, in general, the nutrient proportions in the waste are neither adequately balanced for plant nutrition, nor is the efficiency known (Pires & Mattiazzo, 2008). Organic residue must be in accordance with current legislation in terms of composition and use, to avoid environmental pollution risks by inadequate disposal, particularly with regard to soil pollution and water eutrophication (Dias et al., 2010).

Due to the heterogeneity of organic residues, nutrient and physical and chemical properties vary widely, even among materials from the same origin. The nutrient content of plant residues reported by Silva (2008) ranged, for N, P_2O_5, K_2O, Ca, Mg, Cu, Mn, and Zn, respectively: 11–73 g kg^{-1}, 1–29 g kg^{-1}, 5–38 g kg^{-1}, 4–54 g kg^{-1}, 1–6 g kg^{-1}, 23–18 mg kg^{-1}, 23–29 mg kg^{-1}, and 70–298 mg kg^{-1}. The castor bean cake studied by Severino et al. (2006) contained 128 g kg^{-1} of total N. The nutrient content of animal origin materials presented by Melo and Silva (2008) and Silva (2008) are, respectively, for N, P, K, Ca, Mg, S, Zn, Mn and Cu: 11–54 g kg^{-1}, 1–42 g kg^{-1}, 3–49 g kg^{-1}, 5–153 g kg^{-1}, 2.6 to 14 g kg^{-1}, 0.9–8 g kg^{-1}, 48–1189 mg kg^{-1}, 340–2055 mg kg^{-1}, and 15–1388 mg kg^{-1}. According to Sharma et al. (1997), the ranges of pH and EC for organic residue use in agriculture are, respectively, 6–8.5 and 0.64–6.85 dS m^{-1}. For substrate, the tolerable ranges of pH and Electrical Condutivity (EC) are, respectively, 5.3–6.5 and 0.75–3.49 dS m^{-1} (Abad et al., 2001, Garcia-Gomez et al., 2002).

The characteristics of plant residues vary depending on the plant species, plant tissues, and soil chemical and physical properties, but are generally nutrient-poor and have lower EC than animal or municipal wastes (Abad et al., 2002; Garcia-Gomez et al., 2002; Benito et al., 2003; Benito et al., 2005; Benito et al., 2006; Domeño et al., 2009; Bernal et al. 1998; Ingelmo et al., 1998; Hernández-Apaolaza et al., 2005; Bardhan et al., 2008; Ostos et al., 2008). Benito et al. (2006) concluded that composts obtained from pruning must be mixed with other ingredients rich in nutrients, to compensate the low-nutrient level. Aside from the low nutrient levels commonly found in plant residues, another factor that does not allow the use of these materials as single or dominant components in composts is that forest residues, such as bark, sawdust and wood chips, may contain phytotoxic phenolic components. Depending on the concentration, these residues can affect the plant growth and development (Ortega et al., 1996). On the other hand, the exclusive use of animal or municipal solid waste as major components of composts is not justified either. Cattle manure have high salinity levels (Bardhan et al. 2008), and, depending on its proportion in the substrate, can affect EC in the mixture with other materials and therefore restrict their amount. Sewage sludge, depending on the chemical composition, can not be the exclusive or dominant component in residue mixtures, since it can increase the content of heavy metals and electrical conductivity (Ingelmo et al., 1998; Bardhan et al., 2008; Ostos et al., 2008). The imbalance of nutrients in view of the plant demand and the variability in nutrient contents (Westerman & Bicudo, 2005), as well as other properties, of chemical and physical nature, may limit the agricultural use of organic residues. However, to correct these factors, the residues must be analyzed, with a view to the exploitation of the agricultural potential and reduction of pollutant load in the environment, caused by improper disposal. Knowledge about the properties of organic residues may help determine the proportions of these materials to produce substrate and container media for adequate plant growth.

The objectives of this study were to characterize the chemical and physical properties of organic wastes, to evaluate the agronomic potential of these materials to produce substrates and container media and to determine the quantities required in crop fertilization programs.

MATERIAL AND METHODS

Experimental site and tested materials

The following organic residues were analyzed: sewage sludge (from a Wastewater Treatment Plant, in Jundiaí, São Paulo, where residential and industrial sewage is treated), chicken manure (Nepomuceno, MG), cattle manure, eucalyptus sawdust, charcoal (obtained from pyrolysis of eucalyptus) and coffee husk (Lavras, MG), coconut fiber and pine-bark (Holambra, SP). The fresh cattle manure and chicken manure were collected on dairy and egg production farms and air-dried. The sewage sludge was physically and chemically stabilized. The sawdust was collected from the sawmill of the Federal University of Lavras, immediately after cutting eucalyptus logs, and coffee husk was provided by the coffee bean processing center UFLA/CEPE-Café. Coconut fiber and pine-bark were purchased on the market. Peat and vermiculite samples were also analyzed and the particle size was characterized as medium.

Laboratory tests

Multielement analyses of waste, peat and vermiculite were performed by nitric-perchloric digestion, using a method described in Tedesco et al. (1995), with some modifications. A 40-tube block digester was used, with aluminum body and thermostat to digest a sample mass of 200 mg, in triplicate. The night before digestion, 6 mL of HNO_3 p.a. was blended with the sample and digestion was performed the day after, with a gradual temperature elevation up to 150 ºC. Samples were digested until about 1 mL of acid remained in the digestion flask. When necessary, an additional 3 mL of HNO_3 p.a. was added for sample clearing and the digestion process was continued until the extract volume was reduced to ± 1 mL. The extracts were cooled to room temperature, 2 mL of $HClO_4$ p.a. were added to the samples and the block temperature elevated to 200 ºC, until approximately 2 mL of extract was left. After cooling, the volume was completed to 15 mL with double distilled water, filtered through a cellulose membrane and transferred to a 55 mL Falcon flask. After digestion, the extracts were analyzed, determining the S levels by turbidimetry and P by colorimetry; other chemical elements, except for N, Na, K and B, were quantified in atomic absorption equipment. Since K recovery by nitric-perchloric digestion was low, an aqua regia digestion method was used for K quantification (Melo & Silva, 2008), with some modifications. As described above, 200 mg sample was used, plus 6 mL of HCl and 2 mL of HNO_3, respectively, at a ratio of 3:1(v/v), in the night before the beginning of digestion. The sample had rested for 16 h, for pre-digestion. Then, block digestion was initiated with a gradual temperature rise to 120 ºC. The sample was digested until approximately 1 mL of acid was left, and then removed from the block, cooled to room temperature and the volume of the digested extract completed to 15 mL with double distilled water. Then the extract was filtered through a cellulose membrane and transferred to a 55 mL Falcon flask. The extract obtained by aqua regia digestion was used to determine the K and Na levels using a flame photometer.

Total N was determined by the *Kjeldahl* method. To quantify the total N, 0.1 g of material was weighed in a glass tube and 3 mL of concentrated H_2SO_4 was added in a mixture of K_2SO_4 + $CuSO_4$ p.a. to each tube. The samples were digested in a digester block, with gradual elevation of the temperature to 350 ºC, until the extracts of the mixtures had a greenish color. The levels of inorganic N (ammonium and nitrate) were determined by extraction with KCl 2 mol L^{-1}, 10 g of sample and addition 100 mL of extractant, shaking for 1 h and resting for half an hour. Then, an aliquot of the supernatant (30 mL) was taken and distilled with MgO for the quantification of N-NH_4^+, and then with Devarda alloy powder, to quantify N-NO_3^-. Thereafter, N-ammonium and N-nitrate were quantified by titration, using HCl 0.07143 mol L^{-1} solution as titrant (Embrapa, 1999). To determine the B content in the material, a method proposed by Malavolta et al. (1997) was applied, based on the color development in the substrate by addition of curcumin and quantification of B by colorimetry. Of each sample 0.25 g was transferred to crucibles, which was taken to the furnace for incineration to white ash at 550 °C (within about 3 h). After cooling, 10 mL of 0.1 mol L^{-1} HCl were added to dissolve all the ash. An aliquot of 1 mL was taken from the extract obtained above, to be mixed in glass vials with 4.0 mL of curcumin dissolved in oxalic acid. These bottles were kept in a water bath at 55–58 °C until complete evaporation of the whole extract. After cooling, 25 mL of 95 % ethyl alcohol was added and stirred into the vials to dissolve any residue. These extracts were analyzed with a colorimeter, and the readings were taken at a wavelength of 540 nm to determine total B. The electrical conductivity and pH were determined at the ratio residue:water of 1:2 and the samples were centrifuged for 20 min at 220 rpm (Abreu et al., 2006).

The method of self-compacting (Brazil, 2007) was used to determine bulk density. A 500 mL plastic beaker was filled to the 300 mL mark with substrate. Then, this cylinder was lifted and dropped 10 times, falling under the action of its own weight from a height of 10 cm. With a spatula, the surface was slightly leveled and the volume (mL) read. Then, the material was weighed (g) by subtracting the mass of the beaker. The moisture of each material used in the self-compression was determined, to calculate the density based on dry weight. The procedure was repeated three times using different subsamples.

Statistical analysis

A fully randomized design with three replications of each organic residue was used to determine physical and chemical properties. All data were analyzed for significant differences using analyses of variance and Scott-Knott´s test (p = 0.05). Statistical analyses were conducted using the statistical program Sisvar (Ferreira, 2003).

RESULTS AND DISCUSSION

The total concentrations of macronutrients, except Ca and Mg, are shown in figure 1. Total N ranged from 2 to 47.4 g kg^{-1}, with the highest value determined for chicken manure. The N content of the chicken manure was in the range of 25–54 g kg^{-1} presented by Silva (2008), but higher than values found by Dias et al. (2010) and Walker and Bernal (2008). Total N in coffee husk, cattle manure and sewage sludge was above 18 g kg^{-1} and up to 12.2 g kg^{-1} in coconut fiber, pine-bark, sawdust, peat, charcoal and vermiculite. Of all plant residues, coffee husk had the highest N content, which was higher than reported by Dias et al. (2010). The total N in sewage sludge (22.3 g kg^{-1}) was lower than the range of 23–55 g kg^{-1} verified by Abreu Junior et al. (2005) in several sewage sludges in Brazil. This may be related to the process of sun drying and aeration of the sewage sludge before its disposal on agricultural soils.

Chicken manure and sewage sludge were the residues with the highest levels of N-NH_4^+. Average values of N-NH_4^+ differ considerably among the residues evaluated, ranging from 12.7 to 2426 mg kg^{-1}. This result differs from the range presented by Melo et al. (2008), who found 15–608 mg kg^{-1} of N-NH_4^+ in wastes of different origins. Although high, the amount of N-NH_4^+ in chicken manure was about eight times lower in this study than reported by Bernal et al. (1998) for compost. In chicken manure, N loss due to volatilization during organic matter decomposition is common. Ammonia losses can be reduced by adding gypsum or simple superphosphate (Prochnow et al., 1995), or by decreasing the pH in the compost pile.

The maturation degree of waste is relevant, since residues in an advanced stage of humification have higher levels of N-nitrate than N-ammonium (Sanchez-Monedero et al., 2001). The N-NO_3^- concentrations in coffee husk, cattle manure, chicken manure and sewage sludge were above 150 mg kg^{-1} (Figure 1) and below 60 mg kg^{-1} in the other residues. The higher N-NO_3^- concentration in the waste may be related to the highest concentration of total N in these materials (Melo and Silva, 2008). Residues in an advanced stage of humification have higher levels of N-NO_3^- than of N-NH_4^+ (Sanchez-Monedero et al., 2001).

The P content of 18.4 g kg^{-1} in chicken manure was almost four times as high as in cattle manure (5.5 g kg^{-1}) and sewage sludge (4 g kg^{-1}). The P levels in the other residues were up to 1.8 g kg^{-1}. Melo &

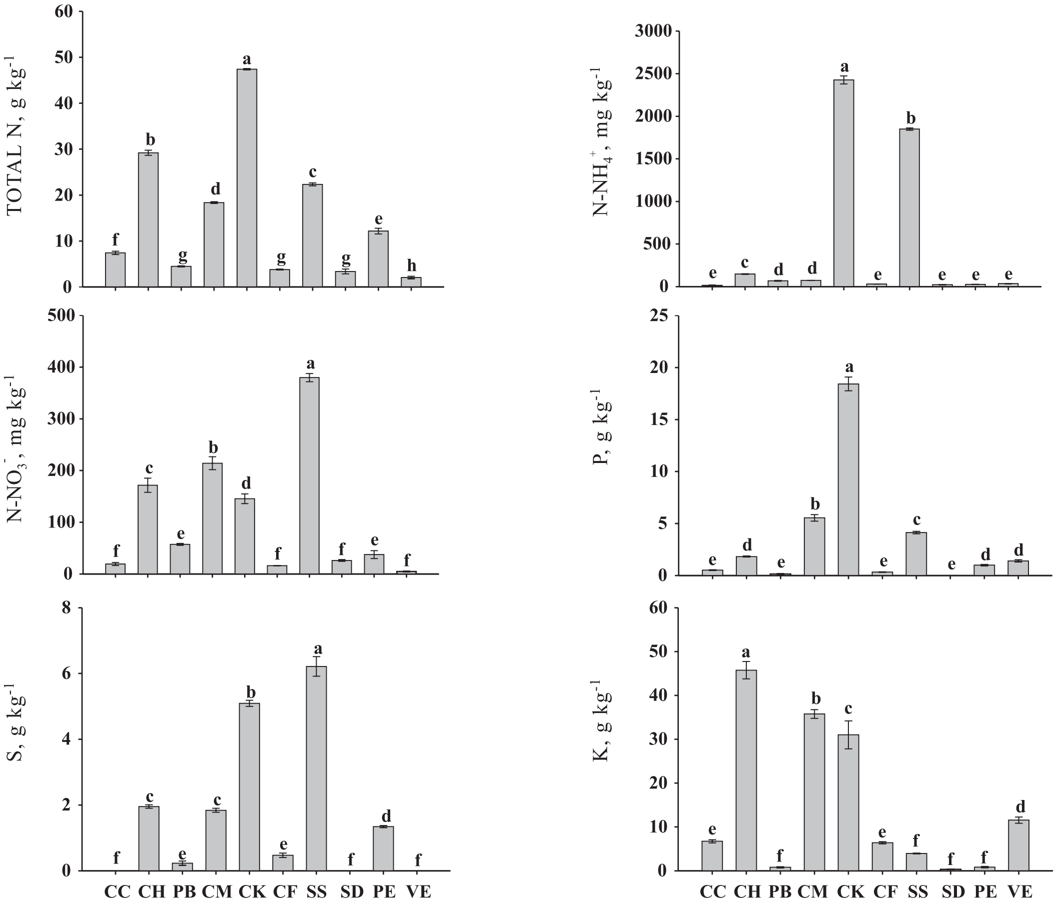

Figure 1. Total N, N-NH_4^+, N-NO_3^-, S, P and K in organic residues and vermiculite. CC: charcoal; CH: coffee husk; PB: pine-bark; CM: cattle manure; CK: chicken manure; CF: coconut fiber; SS: sewage sludge, SD: sawdust; PE: peat and VE: vermiculite. Means followed by the same letter do not differ significantly by the Scott-Knott test ($p < 0.05$).

Silva (2008) observed an average value of P for chicken manure and cattle manure of 39.1 and 2.1 g kg^{-1}, respectively. The P concentration in cattle manure was lower than the 8.7 g kg^{-1} observed by Severino et al. (2006). The P content of sewage sludge is within the range reported by Silva (2008) for sludges from several regions, from 0.5 to 40 g kg^{-1}. The S contents of sewage sludge (6.21 g kg^{-1}) and chicken manure (5 g kg^{-1}) were higher than those of coffee husk (2 g kg^{-1}) and cattle manure (1.8 g kg^{-1}). S concentrations in the other residues reached 1.3 g kg^{-1}. The S concentration in sewage sludge was similar to results of Abreu Junior et al. (2005). The S content of cattle and chicken manure was, respectively, above and below the values observed by Melo & Silva (2008), but within the range presented by Silva (2008).

Coffee husk had the highest K concentration of all wastes, while chicken manure had the highest N and P, and sewage sludge the highest S concentrations. Chicken and cattle manure had K concentrations above 30 g kg^{-1}, which is higher than contents observed in cattle manure by Severino et al. (2006) and Melo & Silva (2008). Low K concentration in sewage sludge is a common characteristic of this residue, with a K content for some samples lower than 1.0 g kg^{-1} (Abreu et al. 2005; Silva 2008). In sewage treatment plants, the sludge is obtained after fermenting the solid part of the sewer waste, which, in a previous step, is separated from the liquid fraction, resulting in K leaching into the wastewater and low nutrient levels in the sludge (Silva, 2008; Tedesco et al., 2008).

The Ca and Mg and micronutrient concentrations are shown in figure 2. The Ca concentration in chicken manure was 121.1 g kg^{-1}, but ranged from 0.59 to 23.4 g kg^{-1} in the other residues. This high calcium content in chicken manure is due to the application of phosphogypsum in manure on the farms of egg and meat production, aiming at a reduction of ammonia volatilization. Limestone is also commonly added to the chicken diet. The average Ca content in cattle manure was higher than verified by Severino et al. (2006) and Melo & Silva (2008), but within the range reported by Silva (2008). The Ca content in sludge was 23.4 g kg^{-1}, which is higher than observed by

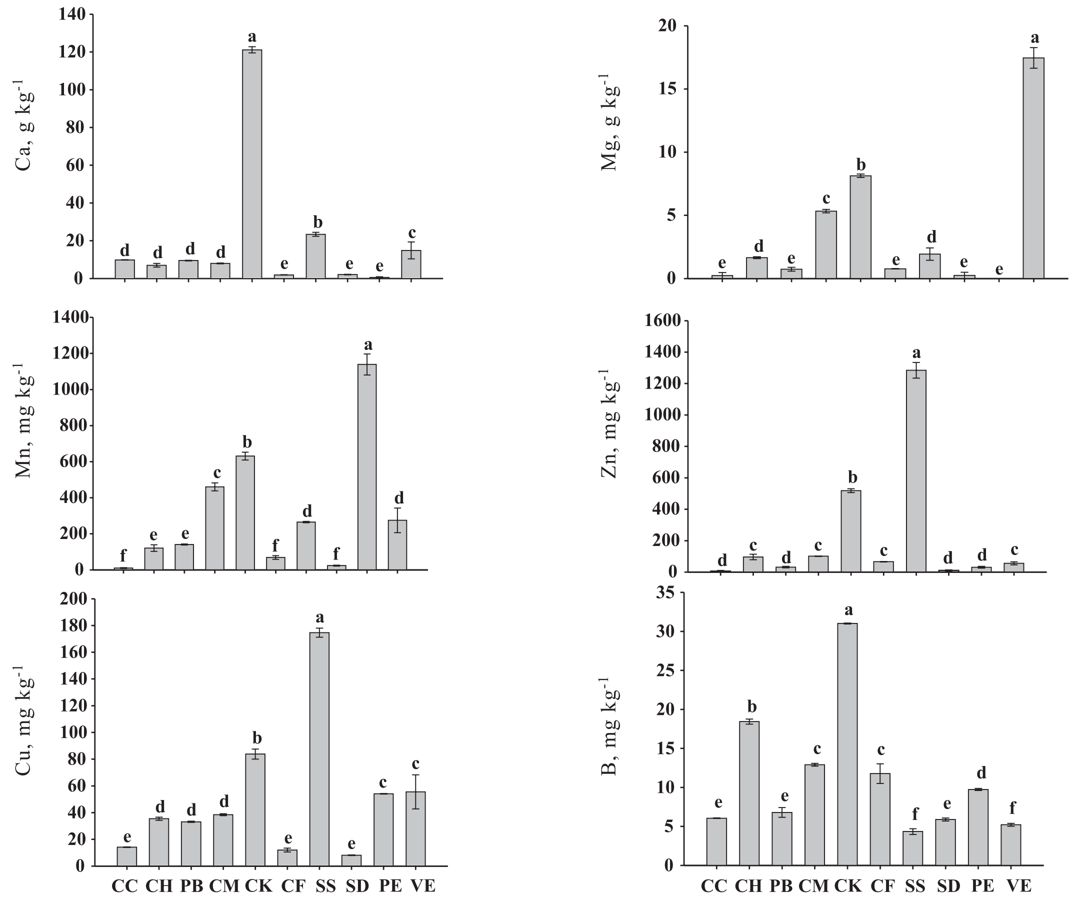

Figure 2. Total concentrations of Ca, Mg, Mn, Zn, Cu, and B in organic residues and vermiculite. CC: charcoal; CH: coffee husk; PB: pine bark; CM: cattle manure; CK: chicken manure; CF: coconut fiber; SS: sewage sludge, SD: sawdust; PE: peat and VE: vermiculite. Means followed by the same letter do not differ significantly by the Scott-Knott test ($p < 0.05$).

Guerrini and Trigueiro (2004). However, Ca concentrations above 100 g kg^{-1} in sewage sludge are common (Abreu Junior et al., 2005). Cattle manure had an average Mg content of 5.3 g kg^{-1}. In other wastes, Mg contents ranged from 0 (peat) to 1.9 (sewage sludge) g kg^{-1}. Lima et al. (2006) found an average of 1.8 g kg^{-1} Mg in cattle manure, which is lower than observed in our study. The average content of Mg in sewage sludge was similar to that found by Guerrini and Trigueiro (2004). The Mg concentration in the vermiculite was twice as high as in chicken manure.

Peat had the highest Mn content, followed by cattle manure, chicken manure, sewage sludge, and vermiculite. In the other materials, Mn values ranged from 10.5 (charcoal) to 140.8 (pine-bark) mg kg^{-1}. The average contents of Mn observed for cattle manure (460.2 mg kg^{-1}) and chicken manure (630.8 mg kg^{-1}) were higher and lower than those reported by Melo & Silva (2008), respectively. The average Mn content of 246.8 mg kg^{-1} in sewage sludge was higher than that reported by Guerrini & Trigueiro (2004). However, the average values in sludges observed elsewhere can exceed 800 mg kg^{-1} (Abreu Junior et al., 2005; Silva, 2008). Sewage sludge contained on average 1284.7 mg kg^{-1} Zn, which is the highest level of the element in the residues studied. With half the concentration, the chicken manure is the second in average Zn content, and the values of the other materials were in a range of 6.1 (charcoal) to 101.5 (cattle manure) mg kg^{-1}. The average Zn concentration in sewage sludge in this study was higher than observed by Guerrini & Trigueiro (2004), but below the maximum (2800 mg kg^{-1}) permitted by the Brazilian law, in the case of agricultural use of sludge (Brazil, 2006). The average Zn contents of 101.5 and 518.5 mg kg^{-1} for cattle manure and chicken manure, respectively, were lower than observed by Melo & Silva (2008), but within the range of concentrations measured by Silva (2008). Sewage sludge also had the highest Cu concentration (174.7 mg kg^{-1}), which is twice as high as in chicken manure. In chicken manure, a likely source of slurry enrichment with Cu and Zn are the routinely used mineral supplements in feeds on farms. Charcoal, coconut fiber and sawdust contained lowest Cu levels. The average Cu content in the sewage sludge was below that observed by Guerrini & Trigueiro (2004) and also below the concentration (1500 mg kg^{-1}) permitted by Brazilian law (Brazil, 2006) regulating the agricultural use of sludge. The average levels of B ranged from 4.3 (sewage sludge) to 31.0 mg kg^{-1} (chicken manure). The residues with intermediate B values were coffee husk, cattle manure, coconut fiber and peat, and the others contained values of less than 10 mg kg^{-1}. The average B concentration found for chicken manure was similar to Walker & Bernal (2008). B is very susceptible to leaching losses (Furtini Neto et al., 2001), which may have been the reason for the low B content in sewage sludge. The average B concentration in sewage sludge determined in this study was lower than found elsewhere (Abreu Junior et al., 2005; Silva, 2008).

The contents of Na, and values of pH and EC are shown in figure 3. The average Na concentrations range from 0 (charcoal and coffee husk) to 4.75 g kg^{-1} (chicken manure). The highest average levels were observed in cattle manure, chicken manure and sewage sludge. The concentrations of Na in cattle and chicken manure are a result of the salt-enriched animal diet. Soil fertilization with, e.g., chicken manure, is recommended in view of the high nutrient concentration, mainly of N. However, the dose of an agricultural use of organic residues should also be limited for the saline load. The continued application of waste may cause soil salinization and nutritional and physiological damage to plants (Abreu Junior et al., 2005). The Na concentration in sewage sludge is high compared to the value reported by Guerrini & Trigueiro (2004), who found an average value of 0.117 mg kg^{-1}. The concentration of Na in sewage sludge can reach 31 g kg^{-1}, depending on the origin (Abreu Junior et al., 2005).

Concerning the acidity degree, the wastes can be categorized into two groups: residues with a pH above 7 (charcoal, cattle manure, chicken manure, and vermiculite), and pH below 7 (coffee husk, pine-bark, coconut fiber, sewage sludge, sawdust, and peat). According to Sharma et al. (1997), the pH range permitted for residues for agricultural use is 6–8.5. Thus, cattle manure with a pH of 9.26 is above the recommended value for agricultural use. Coffee husk (pH = 4.8), pine-bark (4.26), coconut fiber (5.41), sewage sludge (4.36), sawdust (4.16) and peat (4.7) are characterized as highly acidic, with lower pH values than recommended for agricultural residue use. According to Abad et al. (2001), the pH range considered ideal for components of substrates used for seedling production in containers would be 5.3–6.5. Considering this range for the appropriateness of the use of the materials studied, only coconut fiber would meet the requirement. However, all materials could be used for substrate production, bearing in mind that the acidity of the final substrate must be adjusted.

The EC values of coffee husk (19.0 dS m^{-1}), cattle manure (19.0 dS m^{-1}), chicken manure (40.6 dS m^{-1}),

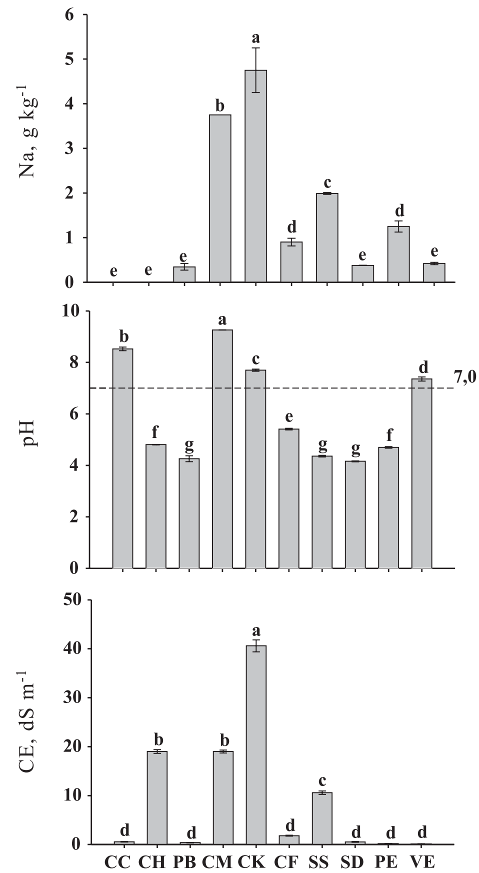

Figure 3. Total Na concentrations, pH and electrical conductivity (EC) in organic material and vermiculite. CC: charcoal; CH: coffee husk; PB: pine-bark; CM: cattle manure; CK: chicken manure; CF: coconut fiber; SS: sewage sludge, SD: sawdust; PE: peat and VE: vermiculite. Means followed by the same letter do not differ significantly by the Scott-Knott test ($p < 0.05$).

and sewage sludge (10.6 dS m^{-1}) were higher than adequate for agricultural use of organic residue (Sharma et al., 1997). Charcoal (0.54 dS m^{-1}), pine-bark (0.39 dS m^{-1}), coconut fiber (1.81 dS m^{-1}), sawdust (0.51 dS m^{-1}), peat (0.15 dS m^{-1}), and vermiculite (0.08 dS m^{-1}) had lower EC values, which indicates a facilitated use of these wastes in agricultural soils and substrates. The highest EC value found in coffee husk is probably due to its K content. The presence of salts and other ions in coffee husk cannot be ruled out either. The large amplitude of EC values ranged from 0.08 dS m^{-1} (vermiculite) to 40.6 dS m^{-1} (chicken manure). The EC value of composted cattle manure studied by Bardhan et al. (2008) was 15.9 dS m^{-1}, a value close to that of the cattle manure in this study. Considering the range of EC from 0.64 to 6.85 dS m^{-1} as suitable for agricultural residue use (Sharma et al., (1997), only coconut fiber with 1.81 dS m^{-1} would meet this requirement. Likewise, if a range from 0.75 to

3.49 dS m^{-1} (Garcia-Gomez et al., 2002) is considered suitable for substrate components, only coconut fiber would satisfy the requirement. Domeño et al. (2009) found a three times higher EC value than observed in this study (5.64 dS m^{-1}) for coconut fiber, which illustrates the heterogeneous composition of organic residues. It was observed that the composition of most of the residues needed adjustments for pH and EC to become suitable for the varied agricultural uses. An alternative would be the mixture of materials with different physico-chemical levels and characteristics, targeting a balanced nutrient supply at optimum levels for crops, and the optimization of EC, density and pH for full plant growth and development.

Figure 4 presents the apparent density values for materials, which reached values ranging from 50.9 to 859 kg m^{-3}. According to Abad et al. (2001), the ideal density for substrates is less than 400 kg m^{-3}. Thus, the bulk densities of sewage sludge and peat only (697.3 and 859.0 kg m^{-3}, respectively) were greater than the maximum considered ideal. If only this property were taken into consideration, these residues could not be used as single components of substrates.

The physic-chemical characterization of materials shows that, in general, residues of plant origin have lower nutrient concentrations than waste from animal production and urban activities. Among the materials of animal origin, differences were noted in physical and chemical characteristics, since nutrients are more concentrated in chicken than in cattle manure, which can be explained by several reasons: lower water content in feces; the liquid and solid dejects are mixed, chicken manure is produced by birds raised, most of the time, on concentrated diets (Tedesco et al., 2008). Among the characterized materials, peat and vermiculite are inputs used in agricultural activities but have compositions that differ from the wastes.

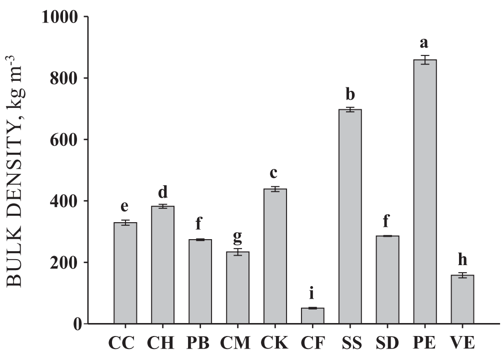

Figure 4. Bulk density of organic residues and vermiculite. CC: charcoal; CH: coffee husk; PB: pine-bark; CM: cattle manure; CK: chicken manure; CF: coconut fiber; SS: sewage sludge, SD: sawdust; PE: peat and VE: vermiculite. Means followed by the same letter do not differ significantly by the Scott-Knott test ($p < 0.05$).

Knowledge on their characteristics is therefore important to find possible renewable substitutes for their use in the substrate production. Vermiculite is a mineral component, so that with the use of nitric-perchloric digestion, this matrix was possibly not opened completely, since the recommended digestion would be the tri-acid with the use of HF and other acids. Therefore, it is possible that the nutrient levels were underestimated in relation to the concentrations present in this 2:1 clay mineral. However, although vermiculite is widely used as raw material in the composition of substrates, it is a non-renewable resource, requiring the search for substitute materials; the same is true for peat. Charcoal, pine-bark and sawdust had lower nutrient levels than the other materials, and are therefore indicated as conditioning or soil cover materials. However, these materials could be used together with other materials for composting to reduce the levels of electrical conductivity and provide a dilution effect of Na in materials with high saline load. Charcoal can be used as a structuring agent for chicken manure composting for reducing odor emissions and N loss, as well as allowing the production of stabilized composts with balanced nutrient compositions (Dias et al., 2010).

The use of organic residues in agriculture requires a physico-chemical characterization prior to use due to the great variation in the composition of these materials. The characterization is only one step in the process of using these materials, since it is also necessary to consider the current legislation, the continued monitoring of residue application and the effects of the use of these wastes on the environment, crops and harvested products.

CONCLUSIONS

1. Chicken manure is the waste with the highest nutrient concentrations, especially total N, N-NH_4^+, Ca, P, S and B. The levels of N-NO_3^-, Cu, Mn, S and Zn were the highest in sewage sludge, and of Mg in vermiculite. The levels of K, total N and N-NO_3^- in coffee husk were similar to those found in manure samples.

2. Acidity is high in some residues, indicating the need for blending them with materials of pH above 7.0, to get substrates with pH levels suitable for the growth of most crop species.

3. Electrical conductivity was low in most materials tested, but in coffee husk, chicken manure, cattle manure, and sewage sludge the EC values were above the values recommended for the growth of most crops.

4. Nutrient and Na levels were higher in organic residues with higher electrical conductivity.

5. Cattle manure, chicken manure, and sewage sludge contained high Na levels.

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