



# Changes on soil structural stability after *in natura* and composted chicken manure application

Thadeu Rodrigues de Melo<sup>1</sup> · Alex Figueiredo<sup>1</sup> · Wesley Machado<sup>1</sup> · João Tavares Filho<sup>1</sup>

Received: 21 March 2018 / Accepted: 19 February 2019 / Published online: 27 February 2019  
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## Abstract

**Purpose** Many studies evaluate the effect of successive applications of chicken manure on soil attributes. In Brazil, the commercialization of this waste is common, implying on its sporadic use instead of many applications at the same area. The short-term effects of a single application of chicken manure and the role of its composting on soil structural stability are not fully understood. This study investigated application of *in natura* (uncomposted) and composted chicken manure on the structural stability of a Rhodic Ferralsol after a short period following single application.

**Methods** The experiment was performed in a Rhodic Ferralsol in Londrina, Paraná, Brazil. We applied *in natura* and composted chicken manure at doses of 4.5, 9.0, 13.5, and 18.0 Mg ha<sup>-1</sup> plus a control without application. Soil samples were collected after 185 days at the 0.0–20.0 cm layer for laboratorial analysis.

**Results** The composting of chicken manure did not affect soil structural stability. Chicken manure did not alter water-dispersible clay ( $\bar{x} = 21.7\%$ ), but increased the mean weight diameter of water-stable aggregates ( $MWD = 5.43 + 0.068 \times \text{dose}$ ) through the agglomeration of aggregates with 0.5–4 mm into 8–19 mm.

**Conclusion** Even after a short period of 185 days, the application of chicken manure increases the structural stability of Rhodic Ferralsols and its composting, in the way performed by many farmers, is not associated with the improvement of soil structural stability in short-term. However, other advantages arise from the composting of the manure and need to be considered prior its use.

**Keywords** Aggregates · Soil management · Soil physical quality · Organic wastes · Water-dispersible clay

## Introduction

Structural stability is essential for the maintenance of soil quality, productive capacity, and environmental services. It is known that stable macroaggregates are directly related to the quality and persistence of soil structure (Bronick and Lal 2005; Tavares Filho et al. 2014), which can be affected by its management, such as the application of animal manures (Barbosa et al. 2015; Costa et al. 2009).

Brazil is the biggest exporter and the second biggest producer of chicken meat in the world and Paraná is the major producer state, accounting for 33% of national slaughter (ABPA 2017). With increases in chicken meat production

in recent decades, the generation of chicken manure has intensified, as has the need to find an adequate destination for this waste.

The major use of chicken manure is as organic fertilizer that can reduce costs to the farmers. The composting of chicken manure is recommended due to the increment of nutrients availability and the elimination of pathogens (Orrico Júnior et al. 2010), although this process is rarely done in commercial contexts. When performed, the composting is carried out in windrows, kept exposed to environmental conditions, with few or no turning of the pile.

In Brazil, chicken manure trade is well structured, and so chicken meat producers does not apply it several times at the same area. Instead, it is more common that farmers eventually buy chicken manure to use as organic fertilizer. There are several studies in the literature evaluating the effect of successive manure applications on soil attributes (Barbosa et al. 2015; Zhang et al. 2016), but few of them consider short-term effects after a single application (Costa

✉ Thadeu Rodrigues de Melo  
thadeurodrigues@hotmail.com

<sup>1</sup> Department of Agronomy, State University of Londrina, Celso Garcia Cid Highway, s/n, Zip Code 10011, Londrina, PR CEP 86057-970, Brazil



et al. 2009). The role of chicken manure composting on soil structural stability after a single application is not fully understood.

Our hypothesis is that chicken manure can change soil structural stability even after a short period from its application and that the resulting changes depend on its composting. Here we tested if the application of *in natura* and composted chicken manure can improve the structural stability of a Rhodic Ferralsol after a short period from the application.

## Materials and methods

### Experimental area and design

The experiment was carried out at the State University of Londrina (latitude 23°23'S, longitude 51°11'W, altitude 566 m) in Londrina, Paraná, Brazil (Fig. 1). According to Köppen's classification, the climate is Cfa—humid subtropical. The soil of the experimental area is classified as a Rhodic Ferralsol (IUSS Working Group WRB 2015) and its chemical and physical attributes are shown in Table 1. It was originated from basalt weathering and has a predominance of kaolinite and considerable presence of iron and aluminum sesquioxides in the clay fraction (Costa et al. 2004; Fig. 2).

The experiment was installed using a randomized block design with a factorial scheme plus an additional factor (2×4+1) and four replications. Chicken manure, *in natura* and composted, was applied at four doses (4.5, 9.0, 13.5, and

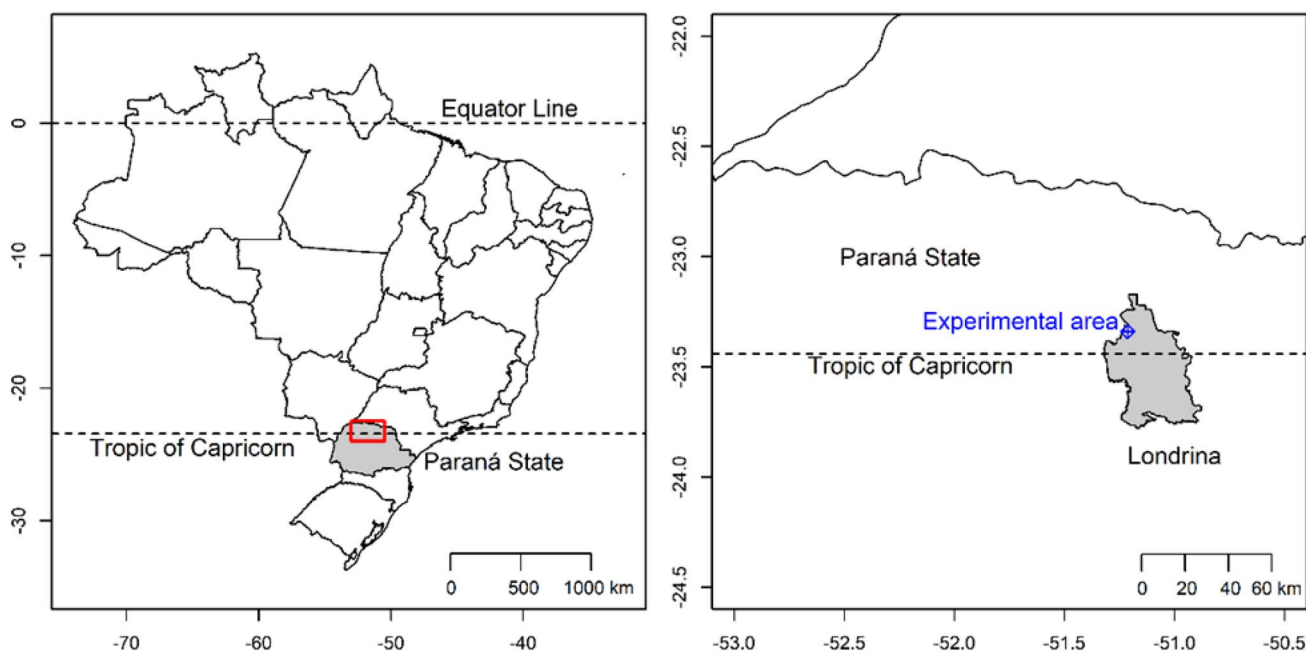
**Table 1** Physico-chemical characterization of the Ferralsol evaluated in the experiment

Attribute	Unit	Value
Clay	g kg <sup>-1</sup>	619
Silt	g kg <sup>-1</sup>	180
Sand	g kg <sup>-1</sup>	201
C	g kg <sup>-1</sup>	16.13
Ca <sup>2+</sup>	cmol <sub>c</sub> kg <sup>-1</sup>	9.20
Mg <sup>2+</sup>	cmol <sub>c</sub> kg <sup>-1</sup>	2.35
K <sup>+</sup>	cmol <sub>c</sub> kg <sup>-1</sup>	0.20
Na <sup>+</sup>	cmol <sub>c</sub> kg <sup>-1</sup>	0.00
Al <sup>3+</sup>	cmol <sub>c</sub> kg <sup>-1</sup>	0.00
pH <sub>H<sub>2</sub>O</sub>	-log[mol l <sup>-1</sup> ]	6.17
ΔpH	-	-0.67

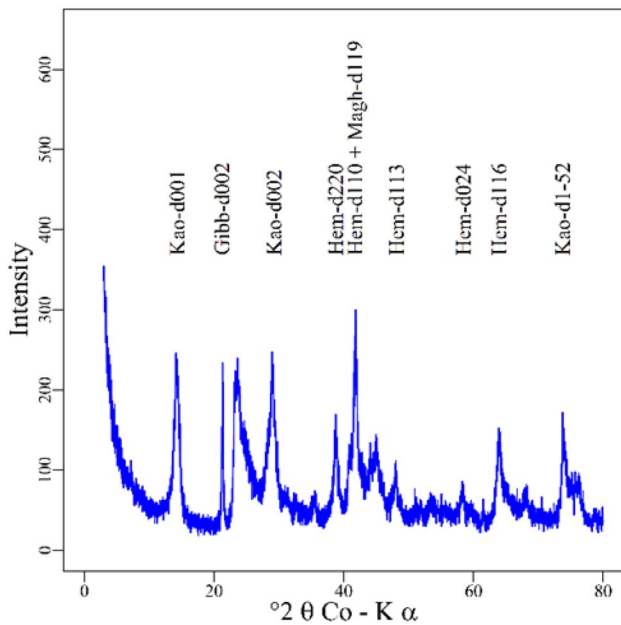
Analyses performed in samples sieved at 2 mm. Granulometry determined after dispersion with NaOH (0.1 mol L<sup>-1</sup>) during 16 h at 200 RPM; C: carbon determined after oxidation with K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>; exchangeable cations extracted with KCl 1 mol L<sup>-1</sup> (Ca<sup>2+</sup>, Mg<sup>2+</sup> and Al<sup>3+</sup>) and with Mehlich-1 (K<sup>+</sup> and Na<sup>+</sup>); pH<sub>H<sub>2</sub>O</sub> and pH<sub>KCl</sub> determined in a 1:2.5 soil/solution (*m:v*) ratio; ΔpH = pH<sub>KCl</sub> - pH<sub>H<sub>2</sub>O</sub>

18.0 Mg of dry matter ha<sup>-1</sup>); the control had neither waste nor mineral fertilizers applied.

The chicken manure was collected from a commercial aviary located in Londrina, Paraná, which houses 12 chickens m<sup>-2</sup>, 1 week after the removal of the fifth flock. Part of the collected chicken manure was air-dried and protected from rain and air moisture (*in natura* chicken manure), while the remaining was composted until thermal



**Fig. 1** Location of the experimental station in Londrina, Paraná, Brazil



**Fig. 2** X-ray diffractogram of the clay fraction from the Rhodic Ferralsol under study

**Table 2** Characterization of the chicken manures used in the experiment

Attribute	Unit	<i>In natura</i>	Composted
pH <sub>H<sub>2</sub>O</sub>	–	6.8	7.5
C	g kg <sup>-1</sup>	380	405
N	g kg <sup>-1</sup>	27.0	24.7
Ca	g kg <sup>-1</sup>	45.6	42.3
Mg	g kg <sup>-1</sup>	5.6	3.4
K	g kg <sup>-1</sup>	29.1	35.1
S	g kg <sup>-1</sup>	7.5	6.7
Zn	mg kg <sup>-1</sup>	280	190
Cu	mg kg <sup>-1</sup>	390	295
Fe	mg kg <sup>-1</sup>	2885	2689

pH<sub>H<sub>2</sub>O</sub> determined at 1:10 (*m:v*) proportion; C determined after oxidation with K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>; N determined after sulfuric digestion; Ca, Mg, K, Na, S, Zn Cu and Fe determined after nitroperchloric digestion

stabilization (composted chicken manure) (Table 2). The composting process consisted of visual and tactile monitoring of moisture every 3 days, with subsequent wetting and plowing of the pile.

After the black oat (*Avena strigosa* Schreb.), used as green manure in the winter, the chicken manure was manually applied on the soil surface. Soybean was cultivated and harvested in the area before soil sampling. Soil samples were collected at 0.0–20.0 cm for chemical and physical analyses. The period between chicken manure application and soil sampling was 185 days (Fig. 3).

## Laboratorial analyses

The stability of soil aggregates (<19 mm) in water was evaluated according to Castro Filho et al. (1998), using sieves with 8, 4, 2, 1, 0.5, and 0.25 mm mesh, in triplicate. The mean weighted diameter was calculated, after the correction of samples according to their dry mass (105 °C), as:

$$\text{MWD} = \sum D_i \times w_i$$

Where:  $D_i$ —arithmetic mean of superior and inferior sieve mesh in relation to each aggregate size class; and  $w_i$ —proportion of each class (mass) in relation to the sample.

Samples were sieved (2 mm) for chemical, granulometric, and water-dispersible clay (WDC) analysis. The total organic carbon (C) was quantified by titration with FeSO<sub>4</sub> after oxidation with K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> in sulfuric medium. The pH<sub>H<sub>2</sub>O</sub> was measured in a 1:2.5 soil/water ratio (*m:v*). Ca<sup>2+</sup>, Mg<sup>2+</sup>, and Al<sup>3+</sup> were extracted with KCl (1 mol L<sup>-1</sup>) and determined by titration with EDTA-Na<sub>2</sub> (Ca<sup>2+</sup> and Mg<sup>2+</sup>) and NaOH (Al<sup>3+</sup>). K<sup>+</sup> and Na<sup>+</sup> were extracted with MEHLICH-1 and quantified by flame photometry.

For granulometric analysis, 100 mL of NaOH (0.1 mol L<sup>-1</sup>) was added in plastic bottles containing 20 g of soil. The suspension was shaken for 16 h at 200 RPM. The WDC was determined after shaking 20 g of soil and 100 mL of distilled water for 1 h at 200 RPM. Stoke's law was used to calculate the sedimentation time of the clay fraction ( $\emptyset < 2 \times 10^{-6}$  m).

## Statistical methods

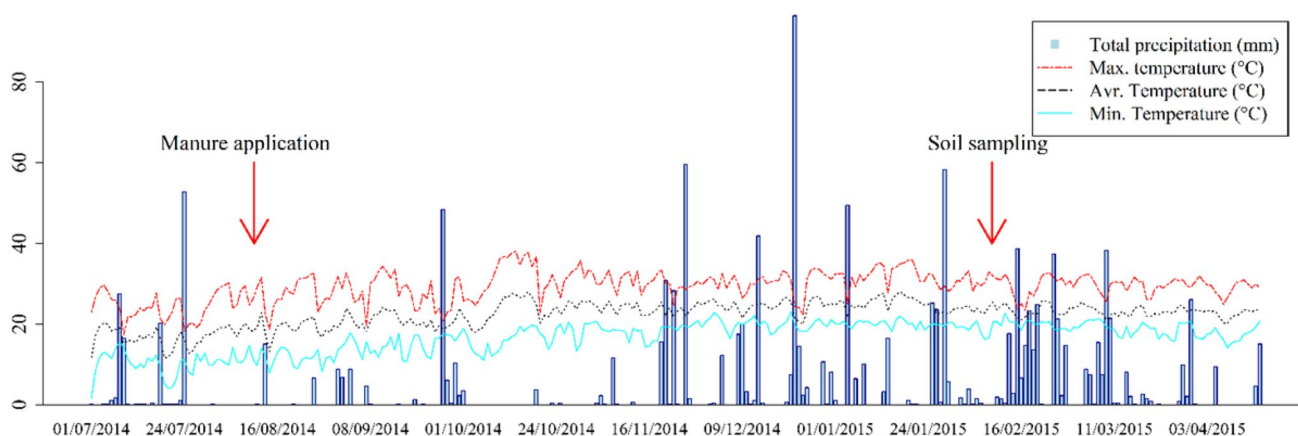
ANOVA was performed using Box–Cox transformation when the assumptions of homoscedasticity or normality, evaluated by Bartlett's and Shapiro–Wilk's tests, respectively, were not obeyed. Regression models were used to express the relationship between the chicken manure doses and the response variables.

## Results and discussion

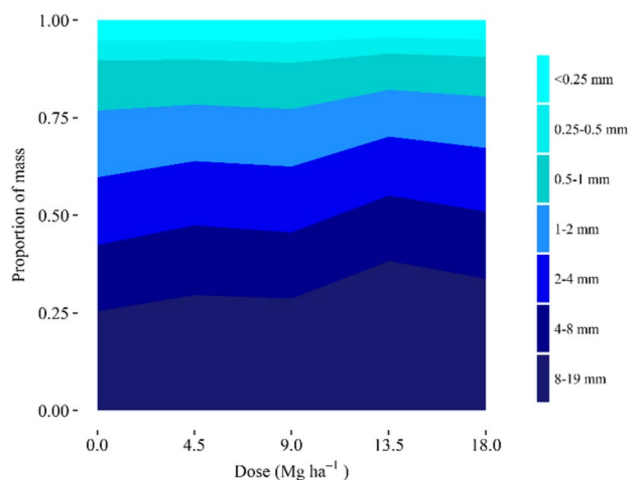
Chicken manure increased the structural stability of the studied Ferralsol regardless its composting. The composting process did not substantially alter the chemical attributes of the manure (Table 2), corroborating Orrico Júnior et al. (2010), which used the same composting method of the present study. However, due to the visual changes of the manure, we believe that the changes in the organic compounds were more qualitative than quantitative, which can be associated with the transformation of aliphatic molecules into aromatic (Merlin et al. 2014).

During the period of the experiment, moderate temperatures and high pluviosity were observed (Fig. 3) and must





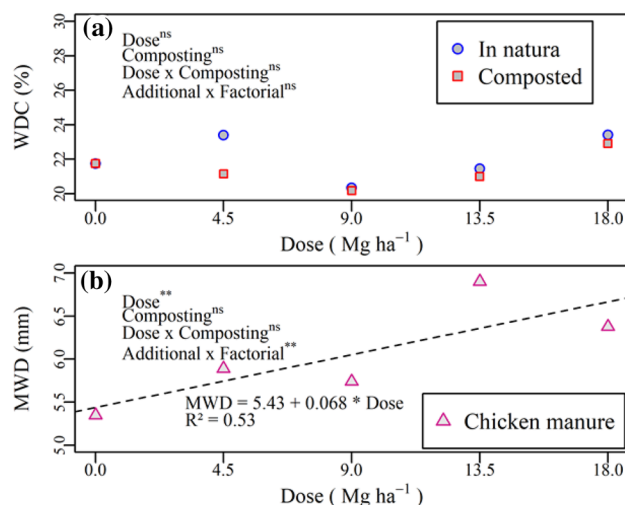
**Fig. 3** Daily total precipitation and average, maximum and minimum temperature during the period of the experiment



**Fig. 4** Proportion of water-stable aggregate size classes as a function of chicken manure doses

have allowed the decomposition of most of the manure. Studies under comparable conditions and time suggest 60% of decomposition (Pitta et al. 2012). Considering that the chicken manure is mainly composed of chicken feces and wood dust (Rogeri et al. 2016), most of this decomposition must be associated with fecal degradation once it has low C:N ratio and is easily degradable.

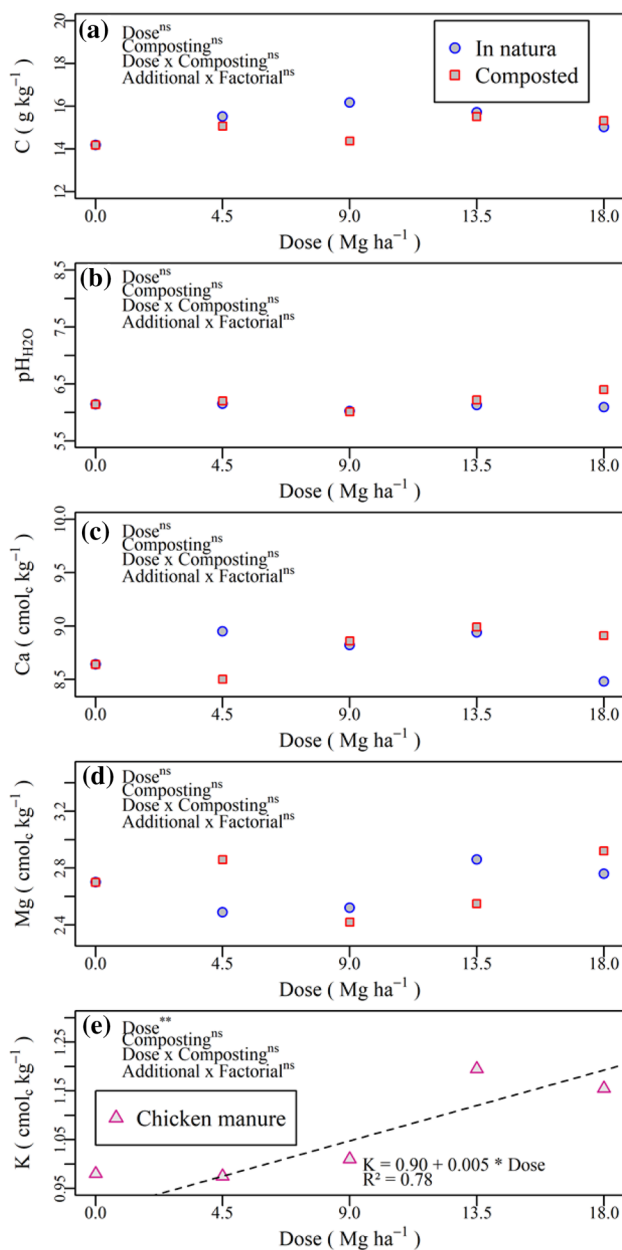
The statistically significant increment caused by chicken manure application occurred regardless of its composting and mainly through the agglomeration of 0.5–4 mm into 8–19 mm aggregates (Figs. 4, 5). The MWD values of our study are within the expected range, as observed by other authors studying soils weathered from basalt in Paraná (Barbosa et al. 2015; Gonçalves et al. 2013). These soils have a good resistance to hydric erosion (Reichert et al. 2009) and the increment in MWD caused by chicken manure can intensify this characteristic, once some studies suggest that



**Fig. 5** Water-dispersible clay (WDC) and mean weight diameter (MWD) as a function of chicken manure doses

aggregates bigger than 2 mm are less susceptible to be transported by water (Calegari et al. 2006; Xiao et al. 2017).

These changes corroborate those found by Veiga et al. (2009), who reported an increase in the stability of the aggregates of a Hapludox in southern Brazil after the application of chicken manure for 9 years. In our study, the supply of organic molecules from the manure favored the stabilization of larger aggregates, despite no statistical change could be observed on C (Fig. 6a). This could have happened because of the reduction of the wettability of the minerals (Chenu et al. 2000) and the formation of bonds between particles (Abiven et al. 2007). Additionally, the stimulus to soil biota activity, through the application of the chicken manure, can favor the stabilization of larger aggregates by the cementation of the smaller ones because



**Fig. 6** Chemical attributes of the Rhodic Ferralsol as a function of chicken manure doses

of the production of microbial exudates and fungal hyphae (Cardoso et al. 2013).

The absence of difference between the manures in the present study is probably associated with the single application on the area and the composting method adopted. Studying the effects of *in natura* and composted chicken manure on the physical attributes of a sandy loam Oxisol, Valadao et al. (2011) observed that composted chicken manure increased the MWD in comparison to the area under *in natura* chicken manure after 8 years of continuous application. However, these authors used an automatic agitator that allowed the

stabilization of the composting process in just 18 days. The rapid stabilization of the manure indicates a higher proportion of stable molecules after composting and explains the observed difference between the manures.

MWD was more responsive to chicken manure application than WDC (Fig. 5). Melo et al. (2015) also did not find differences in WDC after 90 days from the chicken manure application in an experiment in pots using the same soil as in the present study. Costa et al. (2009), however, showed a reduction in WDC after 60 days of the chicken manure application in a coarser Ferralsol from Minas Gerais, Brazil, revealing the variability of response due to the characteristics of each soil.

The Rhodic Ferralsols have a high content of kaolinite and metallic sesquioxides, mainly of iron in the clay fraction (Costa et al. 2004, Fig. 2). These minerals have sites of positive charges in the common soil conditions, which favors the electrostatic attraction and the formation of organic bonds between clays (Igwe et al. 2009; Tombácz and Szekeres 2006). The colloidal protection of organic matter is intense in these soils, coating the clay particles with organic molecules, which reduces their isoelectric point and make their dispersion less responsive to the addition of organic wastes.

The pH increment can intensify the charges unbalance at the surface of the particles, increasing their dispersion (Lee et al. 2012; Nguyen et al. 2013). In addition, changing the proportion of the exchangeable cations can expand the electric double layer and so the dispersion of the clay fraction (Mahanta et al. 2014). However, the treatments did not cause changes on these variables, except for K, (Fig. 6), explaining why the chicken manure addition did not influence WDC. Despite the changes on K<sup>+</sup> content, it probably was not enough to increase the dispersion of the clay fraction. This affirmation corroborates Melo et al. (2018), testing doses of sugarcane vinasse in a Cambisol from Brazil, who observed that the increment of K<sup>+</sup> up to almost 5% of the cation exchange capacity was not enough to increase the water-dispersible clay content.

## Conclusion

Even after a short period of 185 days, the application of chicken manure increases the structural stability of Rhodic Ferralsols and its composting, in the way performed by many farmers, is not associated with the improvement of soil structural stability in short-term. However, other advantages arise from the composting of the manure and need to be considered prior its use.

**Acknowledgements** We acknowledge the National Council for the Improvement of Higher Education—CAPES (Grant no. Finance Code 001) and the National Council for Scientific and Technological Development—CNPq (Grant no. 140987/2016-9 - PhD scholarship) for granting the productivity and the PhD scholarships to the authors.





## Compliance with ethical standards

**Conflict of interest** The authors declare that there are no conflicts of interest associated with this study.

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