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PHYSICAL FRACTIONATION AND CARBON AND NITROGEN STOCKS IN SOIL AFTER POULTRY WASTE APPLICATIONS[1]

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ABSTRACT - Residues from turkey production are often used as fertilizers in pastures near producing regions. These residues can contribute to the increase of carbon and nitrogen stocks in the soil. This study aimed to evaluate the cumulative effects of nine applications of turkey litter rates on C and N fractions and stocks in a *Latossolo Vermelho distroférrico* (Oxisol) cultivated under rotational grazing. The experimental area was divided into 16 pickets of 0.5 ha each and cultivated with *Urochloa decumbens* in a rotational grazing system. The treatments consisted of accumulated doses of turkey litter (38.3; 54.8 and 69.2 Mg ha^{-1}), with applications carried out between 2008 and 2017, in addition to a control treatment, without application of this material. After nine years of application, total organic carbon (TOC) and total nitrogen (TN) stocks in the soil increased as turkey litter rates increased, reaching increments in the 0-0.2 m layer of 11.2 Mg ha^{-1} and 1.03 Mg ha^{-1}, respectively, when compared to the control treatment. In the same 0-0.2 m layer, the maximum increments in carbon stock in particulate organic matter (POC) and nitrogen stock in particulate organic matter (N-POM) were obtained with the estimated total doses of 62 and 66 Mg ha^{-1}, respectively. In addition to increasing the amount, the use of turkey litter improved the quality of the carbon present in the soil, since the carbon management index, in the 0-0.2 m layer, was increased by 124% when using the highest accumulated dose.

Keywords: Turkey litter. Labile fraction. Oxisol.

FRACIONAMENTO FÍSICO E ESTOQUES DE CARBONO E NITROGÊNIO NO SOLO APÓS APLICAÇÕES S DE RESÍDUO AVIÁRIO

RESUMO - Resíduos da produção de peru frequentemente são utilizados como fertilizantes em pastagens próximas a regiões produtoras. Esses resíduos podem contribuir para a elevação dos estoques de carbono e nitrogênio no solo. Neste estudo objetivou-se avaliar os efeitos acumulados de nove aplicações de doses de cama de peru nas frações e estoques de C e N em um Latossolo Vermelho distroférrico, sob pastejo rotacionado. A área experimental foi dividida em 16 piquetes de 0.5 ha cada, e cultivada com *Urochloa decumbens* em sistema de pastejo rotativo. Os tratamentos consistiram em doses acumuladas de cama de peru (38.3; 54.8 e 69.2 Mg ha^{-1}), com aplicações realizadas entre 2008 e 2017, além de um tratamento controle, sem aplicação desse material. Os estoques de carbono orgânico total (TOC), nitrogênio total (TN) no solo aumentaram à medida que se aumentou as doses de cama de peru, chegando a incrementos, na camada de 0-0.2 m, de 11.2 Mg ha^{-1} e 1.03 Mg ha^{-1}, respectivamente, quando comparados ao tratamento controle. Na mesma camada de 0-0.2 m, os máximos incrementos nos estoques de carbono na matéria orgânica particulada (POC) e nitrogênio na matéria orgânica particulada (N-POM) foram obtidos com as doses totais estimadas de 62 e 66 Mg ha^{-1}, respectivamente. Além de aumentar a quantidade, o uso da cama de peru resultou em melhoria da qualidade do carbono presente no solo, uma vez que o índice de manejo de carbono, na camada de 0-0.2 m, foi aumentado em 124 %, quando do uso da maior dose acumulada.

Palavras-chave: Cama de peru. Fração lábil. Latossolo Vermelho.

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INTRODUCTION

The state of Goiás stands out in the Brazilian scenario as an agribusiness powerhouse due to its production of milk, beef and poultry, particularly in the southwest of the state. The production of these confined birds generates large amounts of waste, which can be used as a source of fertilizers in various crops, including pastures (PINTO et al., 2012; SILVA et al., 2018; RIBEIRO et al., 2019a), which represent 54% of the 26 million hectares of agricultural establishments in the state of Goiás (IBGE, 2017).

When well managed and fertilized, pastures have great production potential (SILVA et al., 2018). Pasture fertilization can be performed using both conventional synthetic fertilizers and synthetic fertilizers associated with organic fertilizers (WANG et al., 2016; SILVA et al., 2018), or even using only organic fertilizers, such as poultry waste (RIBEIRO et al., 2019a). The use of these residues can increase fertility, contributing to increasing the carbon (C) and nitrogen (N) stocks in the soil (PINTO et al., 2012; RIBEIRO et al., 2019b), thus reducing the impacts of the conversion of native areas to the various agricultural activities.

The conversion of the native Cerrado areas to agricultural activities can initially reduce the C stored in the soil (SILVA et al., 2016). However, conservation systems can minimize the impacts of agricultural activities and recover the amount of C lost in the initial soil tillage operations (SOUZA et al., 2016). The increase in C stocks in the soil can occur when grass crops are cultivated under proper management and fertilization, either in crop succession system or even in isolated monocultures (PINTO et al., 2012; ASSMANN et al., 2014; CECAGNO et al., 2018). These increments in C stocks through agricultural activities can compensate for emissions of greenhouse gases, ranging from 34 to 98%, contributing to mitigating their effects (RIBEIRO et al., 2019b).

In integrated production systems, the increase in C stocks depends on the combination of soil-plant-atmosphere-animal relationship, climate, soil type, and quantity and quality of organic residues (ASSMANN et al., 2014). Although C and N stocks are often used in studies that assess soil quality, they may not always indicate management variations in the short term. For this, other attributes have been used, such as the C and N stocks in particulate organic matter (POC and N-POM) and the C management index (CMI) (ASSMANN et al., 2014; SOUZA et al., 2016). CMI is considered a sensitive attribute because it is correlated with other physical, chemical and biological indicators of soil quality (ZANATTA et al., 2019).

The use of poultry waste as organic fertilizers can contribute to increasing organic matter content (WANG et al., 2016; RIBEIRO et al., 2019a), as well as C and N stocks in soil (PINTO et al., 2012). However, studies evaluating the cumulative effect of successive applications of poultry waste are still essential, especially for residues from turkey rearing, since almost all of the studies evaluate chicken litter. Thus, the objective of this study was to evaluate the accumulated effects of nine applications of turkey litter doses on C and N fractions and stocks in a *Latossolo Vermelho distroférrico* (Oxisol) under rotational grazing.

MATERIAL AND METHODS

The experiment was carried out at Alvorada Farm, located in Portelândia - GO (17°17’36.40” S, 52°38’59.66” W). The region has an average annual temperature of approximately 24.2 ºC and an average rainfall of 1,400 mm (Figure 1). The predominant climate is warm, semi-humid and remarkably seasonal, with rainy summer and dry winter, being classified as “Aw”, according to Köppen’s classification.

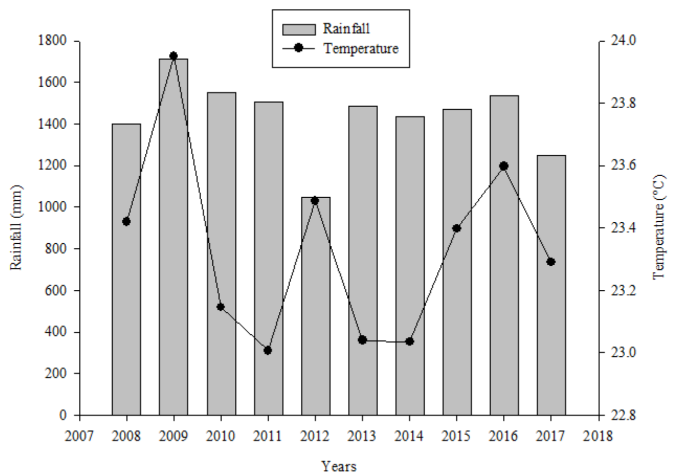

Figure 1. Distribution of accumulated annual rainfall (mm) and average temperature during the experimental period, in the municipality of Mineiros, GO, Brazil.

The soil of the experimental area was classified as *Latossolo Vermelho distroférrico* (Oxisol) (SANTOS et al., 2018) and has, in the 0-0.20 m layer, 739 g kg^{-1} of clay, 125 g kg^{-1} of silt and 136 g kg^{-1} of sand. The experimental area is composed of 16 pickets of approximately 0.5 ha each (experimental unit), which have been cultivated since 1995 with *Urochloa decumbens*, for dairy cattle, in a rotational grazing system (Figure 2).

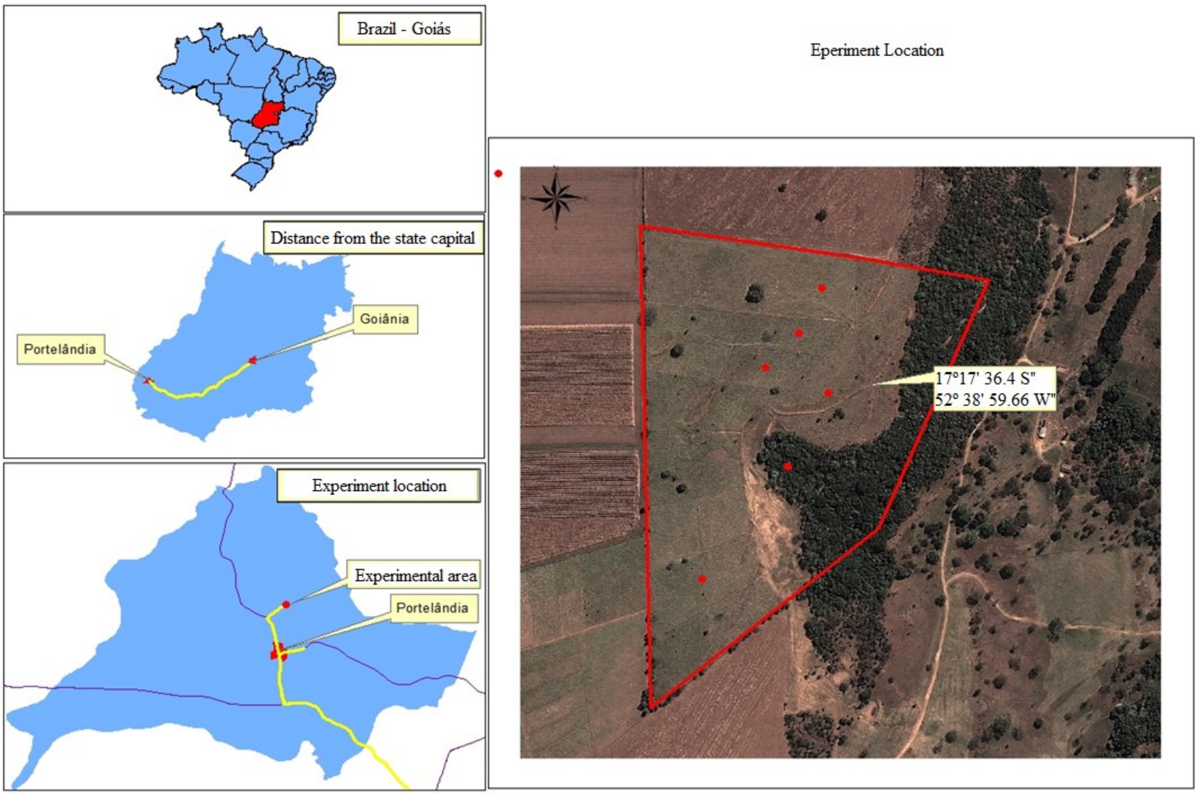

Figure 2. Photo of the experimental area in the municipality of Portelândia, GO, Brazil.

The experiment was implemented in 2008, adopting a randomized block design, with four replicates and treatments represented by accumulated doses of turkey litter: 0, 38.29, 54.79 and 69.24 Mg ha^{-1}, respectively corresponding to 0, 6, 8 and 9 years of use of turkey litter as fertilizer, given that the sampling for the evaluations of the present study was carried out in 2018. For chemical characterization of each treatment, samples were taken in the 0-0.05, 0.05-0.1 and 0.1-0.2 m layers, at four points per treatment, forming a composite sample (Table 1), and the chemical analyses were performed according to Teixeira et al. (2017).

Table 1. Basic chemical characterization of the experimental area, in the 0-0.05, 0.05-0.1 and 0.1-0.2 m layers.

Accumulated Doses	pH $CaCl_2$	TOC	P	K		Mg	Al	H +Al	SB	T	V%
Mg ha^{-1}		g kg^{-1}	mg dm^{-3}	------------------------------cmol$_c$ dm^{-3}--------------------------							%
----------0-0.05 m----------											
0	4.5	22	2	0.18	1.5	0.7	0.4	5.2	2.38	7.58	31.44
38.29	5.1	21	2	0.14	3.6	0.9	0.1	4.7	4.64	9.34	49.67
54.79	5.2	23	4	0.16	4.5	0.5	0.1	3.4	5.16	8.56	60.30
69.24	5.0	26	4	0.18	3.7	0.6	0.1	4.2	4.48	8.68	51.64
----------0.05-0.1 m----------											
0	4.7	21	1	0.14	1.1	0.5	0.3	5.2	1.74	6.94	25.06
38.29	4.9	20	2.2	0.22	2.5	1	0.1	5.2	3.72	8.92	41.74
54.79	5.3	20	3	0.16	3.7	0.6	0.1	3.8	4.46	8.26	54.02
69.24	4.8	21	2	0.18	2.5	1	0.1	4.2	3.68	7.88	46.76
----------0.1-0.2 m----------											
0	4.4	18	1	0.12	1.2	0.6	0.3	4.7	1.92	6.62	29.05
38.29	4.8	20	1	0.14	2.2	0.7	0.1	5.8	3.04	8.84	34.38
54.79	5.0	19	1	0.16	2.0	0.7	0.1	4.2	2.86	7.06	40.55
69.24	4.9	20	1	0.14	2.7	0.8	0.1	5.2	3.64	8.84	41.17

The application of the turkey litter was always performed at the beginning of the rainy season, between September and October (Table 2), and the analyses were performed according to Teixeira et al. (2017).

The residue used as organic fertilizer was obtained in a turkey farm, with litter based on wood shavings, and its chemical composition, determined according to Tedesco et al. (1995), is shown in Table 3.

Table 2. History of turkey litter application in the experimental area and total quantity supplied (accumulated) of N and C.

Accumulated Dose	2008	2009	2010	2011	2012	2013	2014	2015	2017	Organic C	N
Mg ha^{-1}	------------- Quantity applied (Mg ha^{-1}) in each year -------------									-------- kg ha^{-1} ---------	
0	0	0	0	0	0	0	0	0	0	0	0
38.29	0	0	0	7.89	7.34	5.71	5.71	8.64	3	8.645	1.123
54.79	0	7.81	8.69	7.89	7.34	5.71	5.71	8.64	3	12.369	1.606
69.24	14.45	7.81	8.69	7.89	7.34	5.71	5.71	8.64	3	15.630	2.030

Table 3. Average chemical composition of turkey litter used in the fertilization of the experimental area.

N	P_2O_5	K_2O	Ca	Mg	Organic C	Dry Matter	pH Water	C:N
	--------------------------------------- g kg^{-1} ---------------------------------------							
40	50	35	40	9	300.8	733	7.7	10:1

Each year, after the application of turkey litter, the experimental area remained at rest for 45 days, an important period for grass (*U. ruziziensis*) growth. For the annual grazing, started in 2008, the stocking rate, which was the same for each picket (experimental unit), was fixed at 20-25 Girolando animals, with live weight between 550 and 600 kg (3.1 to 4 AU ha^{-1}, considering the AU with 450 kg live weight). Grazing occurred continuously in the rainy season (October-May) and only in the night time during the dry season (June-September), with animals fed corn silage during the day in this period.

Disturbed soil samples were collected at the end of the rainy season of the 10th year of the trial, in April 2018. The sampling was performed with Dutch-type auger, in the 0-0.05, 0.05-0.1 and 0.1-0.2 m layers, at eight points of each experimental unit (forming one composite sample by plot). The samples were air dried and sifted through a 2-mm mesh.

The particle-size physical fractionation of soil organic matter was performed according to the methodology of Cambardella & Elliott (1992). The contents of total organic carbon (TOC), total nitrogen (TN), in addition to carbon and organic nitrogen in particulate organic matter (MOP) were determined via elemental analyzer (Shimadzu TOC-V CSH).

The stocks of TOC, TN, POC and N-POM were calculated by the equivalent soil mass method. For the calculation of C and N stocks, the sample with the lowest apparent density was used as a reference among the treatments and for each layer. Thus, density values of 1.00, 1.02 and 0.98 kg dm^{-3} were used for the layers of 0-0.05, 0.05-0.1 and 0.1-0.20 m, respectively. Total stocks (0-0.20 m layer) of C and N and its fractions were calculated by summing the stocks in each sampled layer.

Carbon management index (CMI) and its components were calculated according to Blair et al. (1995), with the adaptations of Diekow et al. (2005), in which POC corresponds to the labile fraction of SOM and the mineral-associated organic carbon (MAOC) corresponds to the non-labile fraction, according to the expression:

$$CMI = CPI \times CLI \times 100$$

Where: CPI is the TOC stock of the treatment/TOC stock of the reference; CLI is the C lability in the treatment/C lability in the reference; lability is the labile organic C stock/non-labile organic C stock. In this study, the reference area was based on the control treatment.

For the comparison of turkey litter doses, the data were subjected to analysis of variance and, when significant, polynomial regression analysis was applied. The analyses were carried out using the Rbio program with the R program interface (BHERING, 2017).

RESULTS AND DISCUSSION

The total organic carbon (TOC) and organic carbon contents in particulate organic matter (POC) were influenced by turkey litter applications in the three layers analyzed (Figure 3A, 3B), so that there were increments in TOC and POC contents with the increase of accumulated doses of turkey litter. The highest accumulated dose of turkey litter (69.24 Mg ha^{-1}), when compared to the control treatment, increased the TOC contents by 21, 26 and 22% in the 0.0-0.05, 0.05-0.1, and 0.1-0.2 m layers, respectively.

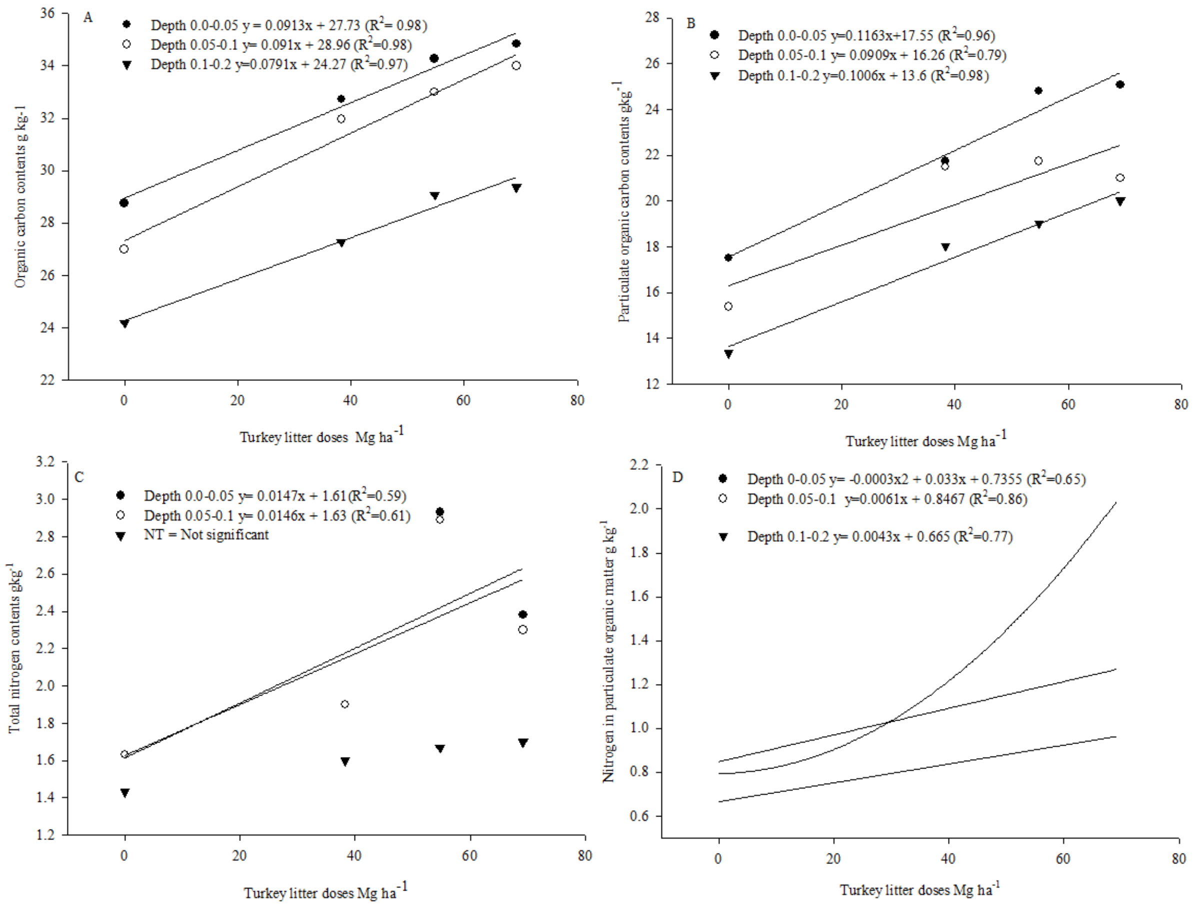

Figure 3. Total organic carbon (A), particulate organic carbon (B), total nitrogen (C) and nitrogen in particulate organic matter (D) in a *Latossolo Vermelho distroférrico* (Oxisol) managed under rotational grazing system as a function of accumulated doses of turkey litter, applied from 2008 to 2017.

Elevation of organic matter contents with the use of doses of 22.5 Mg ha^{-1} associated with mineral fertilization in corn crop was reported by Wang et al. (2016), corroborating the results found in the present study, where there were increases in TOC contents, but using only the turkey litter. Also in a pasture area fertilized with turkey litter, Ribeiro et al. (2019a) verified an increase in organic matter content after 8 years of successive applications of this organic residue in the soil surface layer.

The behavior of POC contents was similar to that of TOC contents. The highest dose of turkey litter (69.24 Mg ha^{-1}), when compared to the control treatment, increased TOC contents by 43, 41 and 50% in the 0.0-0.05, 0.05-0.1, and 0.1-0.2 m layers, respectively. The conversion of Cerrado areas to areas of agricultural activities can lead to reduction of TOC contents in the initial years of its implementation. On the other hand, POC contents can be recovered with integrated production systems after 3 years of adoption (SILVA et al., 2016). These authors also point out that the recovery of POC contents is mainly related to the role played by the roots of *Urochloa ruziziensis*, used after the soybean cycle. In this study, it is evident that the use of fertilization with turkey litter may have enhanced the role of *Urochloa decumbens* in increasing POC contents, reaching 50% increments in POC contents, 9 years after the adoption of turkey litter as a source of fertilizer.

The total nitrogen (TN) contents were influenced by the turkey litter applications, and this effect was limited to the 0-0.05 and 0.05-0.1 m layers (Figure 3C). In the layers of 0-0.05 and 0.05-0.1 m, the accumulated dose of 54.79 Mg ha^{-1} promoted increments of 80 and 77% when compared to the control treatment. TN contents can be reduced with the conversion of native Cerrado areas to agricultural activities, as reported by Souza et al. (2016) in murundu fields in the Cerrado of Goiás. This was also observed by Silva et al. (2016), who found reduction in TN contents after the conversion of native Cerrado area to various agricultural activities. However, in this study it can be observed that the use of turkey litter can increase TN contents, being an important tool to mitigate possible negative effects of some agricultural activities on the contents of this element in the soil.

The N contents of particulate organic matter (N-POM) were influenced in the 0-0.05, 0.05-0.1 and 0.10-0.20 m layers (Figure 3D). In the 0-0.05 m layer, it was estimated that the application of

55 Mg ha^{-1} of turkey litter increased the TN contents, reaching the maximum value at 1.55 g kg^{-1}, an increase of almost 100% compared to the control treatment. In the 0.05-0.1 and 0.10-0.20 m layers, N-POM contents responded positively to the use of turkey litter as a source of fertilizer. Compared to the control treatment, the dose of 69.24 Mg ha^{-1} was able to increase N-POM contents by 50 and 40% in the 0.05-0.1 and 0.10-0.20 m layers, respectively.

The N-POM fraction showed higher increments when compared to TN contents, which reinforces the important role of this fraction as an indicator of soil quality (SOUZA et al., 2016). Silva et al. (2016) reported that the increase in N-POM contents is related to the increase in POC, as both are dependent on the quality of plant residues and can indicate the effects of different land use and management systems (SILVA et al., 2016).

It is worth noting that, in the various layers, the use of turkey litter as a source of fertilizer, when applied alone in pasture, leads in general to the highest contents of POC,TOC, TN, and N-POM, except for N-POM in the 0-0.05 m layer. Therefore, it is evident that changes in these variables are observed since the first years with the adoption of the use of turkey litter (6 years), with the positive effect remaining in the long term, even after 9 years with its use.

It was verified in the present study that the highest contents of TOC, POC, TN and N-POM were found in the 0-0.05 and 0.05-0.1 m layers, with the maximum increments in the N-POM contents reached in the surface layer (Figure 3A, 3B, 3C, 3D). This behavior may be related to the supply of organic material (phytomass and poultry residue) and maintenance of soil structure (SOUZA et al., 2016). This deposition of residues on the soil and the increase of the organic matter contents in surface result in positive effects on nutrient cycling, aggregation, microbial activity, water storage and gas exchange with the atmosphere, which may favor soil sustainability and consequently higher yield of crops (BAYER et al., 2004).

The use of turkey litter had a positive effect on TOC and POC stocks, increasing them in all layers analyzed, except for POC stocks in the 0-0.2 m layer (Figure 4A, 4B). Even after 9 years with the addition of 69.24 Mg ha^{-1} of turkey litter, there were increases in TOC stocks in all evaluated layers. The increase in TOC stocks at the turkey litter dose of 69.24 Mg ha^{-1} compared to the control treatment was 21% in the 0-0.05 and 0.05-0.1m layers and 21% in the 0.1-0.2 and 0-0.2 m layers. The conversion of Cerrado areas to agricultural activity results in a reduction of C stocks in the soil in the initial years of its implantation, which can remain below that found in the area of natural vegetation even after 16 years, in the case of areas considered more fragile (SOUZA et al., 2016; SILVA et al., 2016). These same authors report that, for clay soils in no-tillage system, which have high carbon storage capacity, it takes 34 years to recover the organic matter stocks of the original conditions. In clay *Latossolo* (Oxisol), managed with integrated production systems, after 13 years under no-tillage and different grazing heights, Cecagno et al. (2018) verified that there is still potential for carbon accumulation, corroborating the results found in this study. One of the factors that may be related to increasing increments of carbon, even after 9 years with turkey litter additions, are organomineral interactions formed in soils with high specific surface and with the presence of oxides (VEZZANI; MIELNICZUK, 2011). Clay soils of oxidic nature may show a high correlation between carbon stocks and mean weight diameter of aggregates (SOUZA et al., 2016), contributing to the physical protection of carbon and consequently to greater accumulation. However, Siqueira Neto et al. (2010) observed that, after 12 years of implementation, conservation systems were efficient in recovering the C lost during the incorporation of native Cerrado areas. In the present study, although it is an area under pasture, which is efficient in adding C to the soil, fertilization with turkey litter was able to raise the C stocks in the soil.

As the turkey litter doses increased, POC stocks increased in the 0-0.05, 0.05-0.1 and 0.10-0.20 m layers (Figure 4B). When compared to the control, the dose of 69.24 Mg ha^{-1} increased POC stocks by 68, 86 and 109% in the 0-0.05, 0.05-0.1 and 0.10-0.20 m layers, respectively. In the 0-0.20 m layer, the estimated turkey litter dose of 62.5 Mg ha^{-1} caused a 90% increase compared to the control treatment, leading to POC stock accumulation of 19.8 Mg ha^{-1} in this layer. This fraction of organic matter is considered as the most sensitive to management and is related to the input of more easily decomposable compounds, present in plant residues (SOUZA et al., 2016; SILVA et al., 2016).

TOC and POC stocks result from the balance between the inputs and outputs of C in the soil (SILVA et al., 2016). Therefore, managements that promote greater inputs of plant and animal residues to the soil can contribute to increasing TOC and POC stocks. The higher contents of TOC and POC may be related to C inputs from the direct application of C to the soil, present in the turkey litter, whose C quantities varied approximately from 8.65 to 16.63 Mg ha^{-1}, between the lowest and highest accumulated dose of turkey litter (Figure 4A, 4B). Another factor that may have contributed to the increases in TOC and POC stocks is the improvement of fertility itself in treatments with the use of turkey litter (PINTO et al., 2012), increasing the root production of *Urochloa decumbens*.

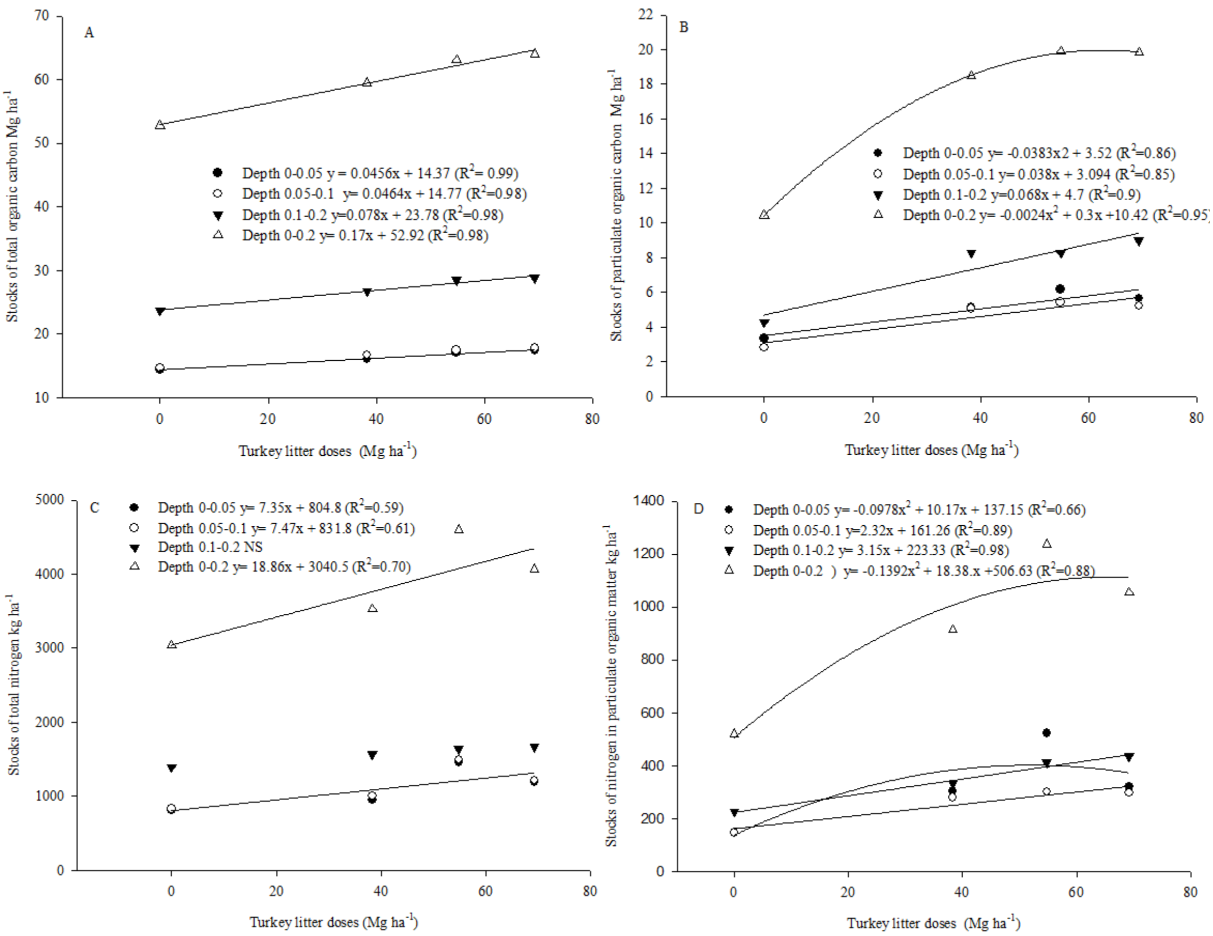

Figure 4. Stocks of total organic carbon (A), particulate organic carbon (B), total nitrogen (C) and nitrogen in particulate organic matter (D), in a *Latossolo Vermelho distroférrico* (Oxisol) managed under rotational grazing system as a function of accumulated doses of turkey litter, applied from 2008 to 2017.

In this study, when compared to the control treatment, the annual additions of C to the soil, after 10 years of the first application of turkey litter were 0.669, 1.1034 and 1.123 Mg ha^{-1} year^{-1} for cumulative turkey litter doses of 38.29, 54.79 and 69.24 Mg ha^{-1}, respectively (Table 4). These values are higher than those found in crop-livestock integration systems, where the highest C increments were observed when grazing residues were kept at 0.3 and 04 m heights, equal to 0.307 and 0.308 ha^{-1} year^{-1} (CECAGNO et al., 2018). Therefore, the increase in C stocks, as observed with the use of turkey litter, can contribute to reducing the impacts of organic waste used in agricultural activities. Moreover, the increase in C stocks through agricultural activities can compensate for 34 to 98% of total greenhouse gas emissions in integrated production systems (RIBEIRO et al., 2019b).

Table 4. Annual increments in carbon stocks in the 0-0.2 m layer, in *Latossolo Vermelho distroférrico* (Oxisol) managed under rotational grazing system as a function of accumulated doses of turkey litter, applied from 2008 to 2017.

Doses (Mg ha^{-1})	Annual C increments (Mg ha^{-1})
0	--------------------
38.29	0.669
54.79	1.034
69.24	1.123

The TN stocks, except in the 0.10-0.20 m layer, were increased with the increase in turkey litter doses in all evaluated layers (Figure 4C). In the 0-0.05 and 0.05-0.1 m layers, the accumulated turkey litter dose of 69.24 Mg ha^{-1}, when compared to the control treatment, increased TN stocks by 46%, which were also higher in the 0-0.2 m layer, with an increase of 34%. TN and N-POM stocks can be recovered compared to reference areas of the Cerrado when converted to agricultural activities, which may be related to the residues left by the crops and also to nitrogen fertilization (SILVA et al., 2016;

SOUZA et al., 2016). In this study, the input of N through the turkey litter may have favored the increase in TN and N-POM stocks, particularly at the highest doses (Figure 4C, 4D). Also, the increments in TOC stocks probably influenced the increments in TN, with the use of turkey litter as a source of fertilizer, given that 95 to 98% of TN is present in organic form (CASTOLDI et al., 2019). Another factor that may have contributed to the increase in N and N-POM stocks may be related to the slower release of N present in the turkey litter. Even after 270 days, 85% of the initial N contents can remain in this residue (SILVA et al., 2014). This slow release of N from turkey litter, associated with the perennial cycle of *Urochloa decumbens*, may have favored N increments in the soil in treatments with the use of turkey litter.

The N-POM stocks had the maximum accumulations in the 0-0.05 and 0-0.20 m layers, so that the estimated turkey litter doses of 52 and 66 Mg ha^{-1} promoted the maximum increments, which reached 401.54 and 1113.5 kg ha^{-1}, respectively. When compared to the control treatment, the turkey litter doses of 52 and 66 Mg ha^{-1} promoted increments of 171 and 22% in the 0-0.05 and 0-0.20 m layers. In the 0.05-0.1 and 0.1-0.2 m layers, the N-POM stocks were increased as the accumulated doses of turkey litter increased. When compared to the control treatment, the accumulated turkey litter dose of 69.24 Mg ha^{-1} promoted increments of 103 and 93%, respectively.

Particulate organic matter has greater lability, hence being more decomposable (VEZZANI; MIELNICZUK, 2011), so the increase in N-POM stocks in the soil is very important, as it can serve as a source of N for crops. The conversion of native areas of murundus to no-tillage with annual crops showed efficient recovery of N-POM stocks with only 7 years, which may even be higher, with 11 years of no-tillage adoption (SOUZA et al., 2016). In the pasture area, the addition of turkey litter as a fertilizer source, at the maximum dose of 30.9 Mg ha^{-1}, caused a linear effect on N-POM stocks in the 0-0.2 m layer (PINTO et al., 2012), differing from the results found in the present study. The maximum increments in N-POM stocks, in the 0 -0.05 and 0-0.2 m layers, may be related to the N additions via fertilization with turkey litter, with supply of more than 2000 kg at the highest accumulated dose of organic residue, applied over 9 years in the experimental area.

CMI was influenced by the use of turkey litter in all layers evaluated (Figure 5), as the increase in turkey litter doses caused increments in CMI values. This behavior in CMI allowed increments in the 0-0.2 m layer of 77, 115 and 124% compared to the control treatment, with the accumulated doses of 38.29, 54.79 and 69.24 Mg ha^{-1}, respectively.

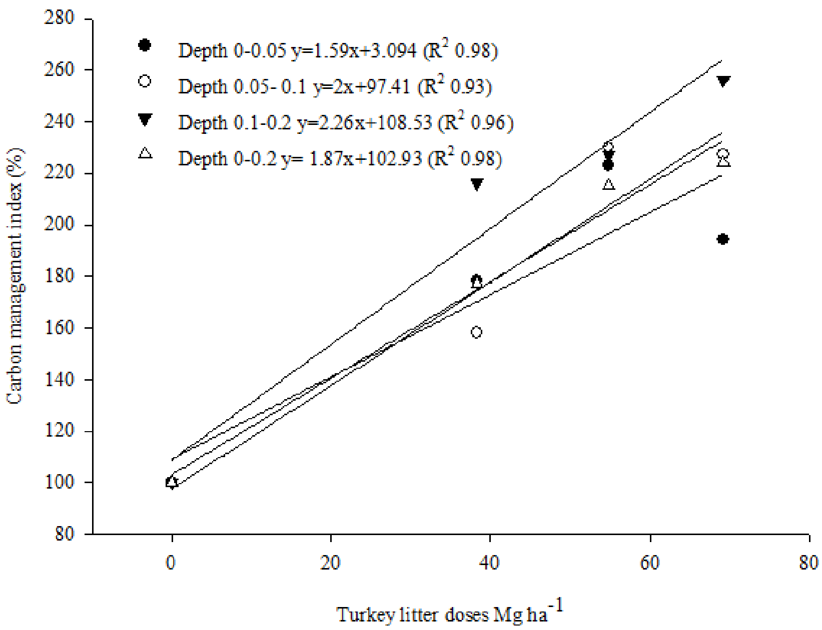

Figure 5. Carbon management index (CMI) in a *Latossolo Vermelho distroférrico* (Oxisol), managed under rotational grazing system as a function of accumulated doses of turkey litter from 2008 to 2017: D0 control; D 38.29 Mg ha^{-1}; D 54.79 Mg ha^{-1}; D 69.24 Mg ha^{-1}.

Higher CMI values mean higher soil quality, whereas lower values indicate lower soil quality (ASSMANN et al., 2014). CMI also indicates increased lability of organic matter, as it is highly correlated with the C-MOP stock (SILVA et al., 2016) and positively correlated with several chemical, physical and biological attributes of the soil (ZANATTA et al., 2019). In this study, all treatments with the use of turkey litter indicated improvement in soil organic matter quality, especially at the highest dose evaluated (69.24 Mg ha^{-1}) and in all layers evaluated, reaching increments of 156% compared to the control treatment, in the 0.1-0.2 m layer. This behavior may be related to the increase in soil fertility, besides direct increments of C present in the turkey litter, and also to the possible increase in the shoot and root biomass production of *Urochloa decumbens*, all factors that may have contributed to the increase in CMI.

CONCLUSION

The use of turkey litter as the only source of fertilizer in *Urochloa decumbens* pasture, for a period of 9 years and in a *Latossolo Vermelho distroférrico* (Oxisol), leads to an increase in soil TOC and TN stocks and improvement in C quality. Compared to the control treatment, the increments in TOC and TN stocks in the 0-0.2 m layer at the highest accumulated dose of turkey litter (69.24 Mg ha^{-1}) were 11.2 and 9.4 Mg ha^{-1}, respectively, while the C management index was increased by 124%.

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REFERENCES

ASSMANN, J. M. et al. Soil carbon and nitrogen stocks and fractions in a long-term integrated crop-livestock system under no-tillage in southern Brazil. **Agriculture, Ecosystems & Environment**, 190: 52-59, 2014.

BAYER, C. et al. Armazenamento de carbono em frações lábeis da matéria orgânica de um Latossolo Vermelho sob plantio direto. **Pesquisa Agropecuária Brasileira**, 39: 677-683, 2004.

BHERING, L. L. Rbio: A Tool For Biometric And Statistical Analysis Using The R Platform. **Crop Breeding And Applied Biotechnology**, 17: 187-190, 2017

BLAIR, G. J. et al. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. **Australian Journal Agriculture Research**, 46: 1459-1466, 1995.

CAMBARDELLA, C. A.; ELLIOTT, E. T. Particulate soil organic matter changes across a grassland cultivation sequence. **Soil Science Society of America Journal**, 56: 777-783, 1992.

CASTOLDI, G. et al. Eficiência do uso do nitrogênio em agroecossistemas. In: SEVERIANO, E. C.; MORAES, M. M.; PAULA, A. M. (Eds.). **Tópicos em ciência do solo**. 1 ed. Viçosa, MG: Sociedade brasileira de ciência do solo, 2019. v. 10, cap. 3, p. 141-238.

CECAGNO, D. et al. Soil organic carbon in an integrated crop-livestock system under different grazing intensities. **Revista Brasileira de Ciências Agrárias**, 13: 1-7, 2018.

DIEKOW, J. et al. Carbon and nitrogen stocks in physical fractions of a subtropical Acrisol as influenced by longterm no-till cropping systems and N fertilization. **Plant and Soil**, 268: 319-328, 2005.

IBGE - Instituto Brasileiro de Geografia e Estatística. **Censo Agropecuário. 2017. Área dos estabelecimentos agropecuários**. Disponível em: https://cidades.ibge.gov.br/brasil/go/pesquisa/24/27745. Acesso em: 04 abr. 2020.

PINTO, F. A. et al. Atributos de solo sob pastejo rotacionado em função da aplicação de cama de peru. **Pesquisa Agropecuária Tropical**, 42: 254-262, 2012.

RIBEIRO, D. O. et al. Atributos físicos e químicos de um latossolo submetido a aplicações sucessivas de cama de peru em pastejo rotacionado. **Colloquium Agrariae**, 15: 11-23, 2019a.

RIBEIRO, R. H. et al. Managing grazing intensity to reduce the global warming potential in integrated crop-livestock systems under no-till agriculture. **European Journal of Soil Science**, 71: 1-12, 2019b.

SANTOS, H. G. et al. **Sistema brasileiro de**

classificação de solos. Brasília, DF : EMBRAPA, 2018. 356 p.

SILVA, A. J. et al. Replacement of liming and NPK fertilization with turkey litter in degraded areas grown with Urochloa decumbens. **Semina**, 39: 467-476, 2018.

SILVA, V. B. et al. Decomposição e liberação de N, P, e K de esterco bovino e cama de frango isolados ou misturados. **Revista Brasileira de Ciência do Solo**, 38: 1537-1546, 2014.

SILVA, G. N. et al. Management systems and soil use on fractions and stocks of organic carbon and nitrogen total in cerrado Latosol. **Bioscience Journal**, 32: 1482-1492, 2016.

SIQUEIRA NETO, M. et al. Soil carbon stocks under notillage mulch-based cropping systems in the Brazilian Cerrado: An on-farm synchronic assessment. **Soil and Tillage Research**, 110: 187-195, 2010.

SOUZA, E. D. et al. Matéria orgânica e agregação do solo após conversão de "campos de murundus" em sistema plantio direto. **Pesquisa Agropecuária Brasileira**, 51: 1194-1202, 2016.

TEDESCO, M. J. et al. **Análise de solo, plantas e outros materiais**. 2. ed. UFRGS, RS: 1995. 174 p.

TEIXEIRA, P. C. et al. **Manual de métodos de análise de solos**. Brasília, DF: EMBRAPA, 2017. 573 p.

VEZZANI, F.; MIELNICZUK, J. **O solo como sistema**. 1. ed. Curitiba, PR: Edição dos autores, 2011. 104 p.

WANG, X. et al. Impacts of manure application on soil environment, rainfall use efficiency and crop biomass under dryland farming. **Scientific Reports**, 6: 1-8, 2016.

ZANATTA, J. A. et al. Carbon indices to assess quality of management systems in a Subtropical Acrisol. **Scientia Agricola**, 76: 501-508, 2019.