Journal of Agricultural Science; Vol. 10, No. 9; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Chemical Characteristics of the Use of Gelatine Sludge in Soil Cultivated as Fertilizer

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Received: May 30, 2018 Accepted: July 3, 2018 Online Published: August 15, 2018

doi:10.5539/jas.v10n9p477 URL: https://doi.org/10.5539/jas.v10n9p477

Abstract

Various types of industrial wastes have been tested as a source of pasture fertilization. However, little is known about the sludge of the gelatine industry. This study aimed at testing gelatine sludge as a soil amendment by assessing the chemical modifications caused in the soil profile. The experiment was conducted in Araguaina, Tocantins, using a typical Quartzipsamment soil (Entisols) from February to November 2013. Four doses were tested in experimental plots: 0, 50, 150 and 300 m^3 ha^{-1}. Soil sampling was performed at four depths: 0-5, 5-10, 10-20 and 20-30 cm with collection at the beginning and the end of the experimental period. Five grazing simulations of 21 days of rest of Piatã grass were testes. The gelatine sludge was able to raise the contents of calcium, phosphorus, and sum of bases only in the superficial layer (0-5 cm) and did not alter the pH, potential acidity and saturation by base, indicating that there was no use restriction due to salinization or acidification. Therefore, it was concluded that the maximum tested dose (300 m^3 ha^{-1}) improved the chemical characteristics of the soil, especially in the 0-5-cm layer.

Keywords: phosphorus, calcium, *Urochloa brizantha*, soil fertility

1. Introduction

The improvement of soil fertility should be a priority to support adequate productive indexes of pasture and consequently, animals. Whereas, due to varying pH values and the low levels of calcium, phosphorus, potassium, magnesium and nitrogen, the Amazonian soils are classified as low fertility soils, which require the adoption of a system of low technological level if no fertilization and/or correction are applied (Collier, 2008).

Worldwide, the use of fertilizers for the intensification of agricultural productions is necessary to meet a growing demand for food. In this context, several problems of misuse and/or exacerbated use of fertilizers and correctives have led to soil salinization problems. In addition, the agroindustry has produced a large volume of waste that is often mistakenly discarded in nature, causing serious environmental degradation problems (Guimarães et al., 2012). Therefore, establishing ways of reusing agroindustrial wastes to subsidize the agricultural production and to reduce the use of chemical fertilizers can alleviate the pressure imposed by increasing the necessity of the synthesis of more chemical inputs.

In addition to other types of solid residues, there are several studies on sludge and its application in the agriculture due to its similar characteristics with other organic products (Barbosa et al., 2002, 2007). Thus, the use of sludge from the gelatine industry can aid on the maintenance of soil fertility and crop productivity for long periods due to the residual effect (Guimarães et al., 2012; Barbosa et al., 2007).

The main soil characteristics to be improved are the levels of phosphorus, nitrogen, sulfur, pH, and organic carbon (Guimarães et al., 2012). Thus, by using gelatine sludge at the doses of 0, 100, 200, 300, 400 and 500 m^3 ha^{-1} in the soil, Guimarães et al., (2012) found that the increase of sludge doses was proportional to aluminum and nitrate extraction, followed by increased calcium and magnesium contents and increased soil pH, favoring the improvement of soil fertilization (Wang et al., 2017).

Wastewater, such as from meat (Araujo et al., 2011) and dairy products (Santos et al., 2014) and domestic sewage sludge (Barbosa et al., 2007) have been effectively used as soil amendments due to their plant essential chemical composition. However, some solids residues, such as the sludge from the gelatine industry, still need to be evaluated as a source of plant nutrients.

The objective of this study was to evaluate the changes of the chemical characteristics of the soil under the use of the gelatine sludge as a fertilization source.

2. Material and Methods

The experiment was conducted at the School of veterinary medicine and Animal Science of the Federal University of Tocantins in Araguaina-TO, located at the following geographical coordinates: 07º05′46″ S and 48º12′19″ W, with an average altitude of 243 m. The regional climate is characterized according Köppen, as Aw (hot and humid with summer rains with annual rainfall of 1800 mm and relative humidity of the air and average temperature of 78% and 25 ºC, respectively. The soil was classified as typical Quartzipsamment soil (Entisols). (Embrapa, 2013) with smooth relief and slope inferior to 5%.

Initially, the soil was prepared by removing vegetative residues from the area. A mesh irrigation system was then fitted with low-pressure sprinklers. Irrigation control was based on the maintenance of field capacity throughout the experiment period (from February to November, 2013). Soil samples were periodically collected for moisture content analysis, which was kept around 40%.

Seeding was carried out in March using 4 kg of viable pure seeds per hectare of *Urochloa brizantha* cv. Piatã. After 40 days of emergence, grazing standardization was done by cutting plants up to 15 cm in height, followed by the manual elimination of invasive plants. Productive cycles were performed simulating the rotational management system with a rest period of 21 days, leaving a height of 20 cm.

The amount of cycles collected was determined until there was no significant effect of the gelatine sludge on total dry mass, indicating that it did not promote any more gains to the pasture. Thus, five productive cycles were collected.

The treatments consisted of four doses of gelatine sludge: 0, 50, 150 and 300 m^3 ha^{-1}. All treatments were applied in a single dose three days before the standardization cut by using plastic irrigators. This strategy was used to avoid that part of the sludge remained adhered to the leaves. After two days of the standardization cut, potassium fertilization was carried out with 50 kg ha^{-1} of K_2O, as potassium chloride. The gelatine sludge was provided by Geonex, located in Araguaina-TO.

The sludge has adequate amounts of calcium, phosphorus and nitrogen as well as micronutrients such as zinc and sulfur for its use as a fertilizer (Table 1). The doses were calculated based on total phosphorous: 0, 25.2, 37.8 and 75.6 kg ha^{-1}.

Table 1. Chemical analysis of the gelatine sludge used as fertilization source

Parameter	Value	Parameter	Value
pH	6.65	Silver (mg L^{-1})	< 0.0015
Total phosphorous (mg L^{-1})	54	Copper (mg L^{-1})	< 0.0015
Total nitrogen (mg L^{-1})	1541	Barium (mg L^{-1})	< 0.5
Potassium (mg L^{-1})	24.1	Selenium (ug L^{-1})	< 2
Sodium (mg L^{-1})	100.3	Lead (mg L^{-1})	< 0.005
Calcium (mg L^{-1})	6134	Cyanide (mg L^{-1})	< 0.0003
Zinc (mg L^{-1})	0.101	Arsenic (ug L^{-1})	<1.5
Magnesium (mg L^{-1})	93.59	Mercury (ug L^{-1})	<0.05
Sulfur (mg L^{-1})	18.20	Aluminium (mg L^{-1})	<0.2
Organic matter (%)	3.22	Manganese (mg L^{-1})	< 0.0015
Moisture (%)	58.49	Ashes (%)	38.29

Soil samples were collected at four depths (0-5, 5-10, 10-20 and 20-30 cm) in two sampling periods: the first period was defined as the initial period (collected four days after the application of the sludge from the gelatin industry), and the second period was considered the final period (collected one day after the last productive cycle).

The following soil chemical analyzes were performed: pH in $CaCl_2$. Mehlich-1 available phosphorus (mg dm^{-3}), and exchangeable potassium (mg dm^{-3}), sodium ($cmol_c$ dm^{-3}), aluminum ($cmol_c$ dm^{-3}), calcium ($cmol_c$ dm^{-3}), and magnesium ($cmol_c$ dm^{-3}), according to Embrapa (2005). Pasture samples were separated in the first and the fifth cycle to analyze calcium in the plant tissue, according to the Embrapa (2005) methodology.

After the periodic sampling, the data were submitted to analysis of variance and regression to verify the significance of the effects of the sludge doses of the gelatin industry on the evaluated attributes. The choice of the regression equation was based on the coefficient of determination and the significance of its coefficients. Between the initial and final periods, a repeated measure was performed at time 17 to verify statistical differences, which were considered different when significant at the level of probability ($p < 0.05$).

3. Results and Discussion

The tested gelatine sludge did not modify the pH between the doses, indicating that there was no restriction of the use of the sludge concerning the acidification or salinization of the soil. In the final analysis, as well as the initial analysis, higher pH values were observed in the superficial layer (0-5 cm) with a reduction of pH in all subsequent depths, characterizing higher acidity at the greater depth ($p < 0.01$). In the last collected soil sample, the soil presented higher acidity in all depths. The greatest difference between two periods was in the 20-30 cm layer (Table 2).

Soil acidification was expected with the increasing doses of the gelatine sludge. A total of 1.54 kg of nitrogen was introduced for every m^3 of sludge. The transformation of ammoniac nitrogen into nitrate in the soil releases H^+ and the dose of 300 m^3 ha^{-1} provided nearly 460 kg ha^{-1} (Table 2). However, the gelatine residue promoted an increase in exchangeable bases sufficient to inhibit soil acidification, giving the desirable characteristic of a source of nitrogen fertilization without the acidification promoted by regular sources such as urea and ammonium sulfate.

It is important to emphasize that continuous or exaggerated applications of the residue can cause elevation of soil pH due to the supply of bases such as calcium and sodium. Increases in soil pH can accelerate the reaction rate of urea hydrolysis, transforming it into $N\text{-}NH_3$, which is easily lost by volatilization. Thus, soil pH ought to be controlled below 6.3, since in soils with lower pH nitrogen volatilization can be avoided by the decrease of urease activity (Tasca et al., 2011).

These losses of total N can reach 35% of the N applied, corresponding to 75% of the total loss caused by volatilization in the form of $N\text{-}NH_3$ (Vitti et al., 2002). Nitrogen losses must be constant evaluated for the best use of the nitrogen present in the gelatine sludge, which has the capacity to raise the NH_4^+ and NO_3^- soil contents by 0.04 and 0.47 mg dm^{-3}, respectively, for each m^3 ha^{-1} of biological sludge added to the soil (Guimarães et al., 2012). Therefore, reapplications of gelatine sludge should not be performed since the soil has a pH close to 6. New applications could raise the pH, creating an unfavorable condition.

Tabela 2. Effect of the sludge of the gelatin industry on pH and exchangeable calcium contents exchangeable magnesium exchangeable potassium and phosphorus available in soil

	Depth	Period	0	50	150	300	Averages	Equations	R^2	P Value
	--- cm ---		---------------------- m^3 ha^{-1} ----------------------							
pH ($CaCl_2$)	0-5	Initial	6.1	6.1	6.2	6.3	6.2 a	$\hat{Y}$ = 0.0005x + 6.13	0.23	0.08
		Final	5.6	5.9	5.5	5.8	5.7 b	$\hat{Y}$ = 0.0002x + 5.71	0.00	0.77
	5-10	Initial	5.9	5.9	5.9	5.9	5.9 a	$\hat{Y}$ = 0.00006x + 5.90	0.00	0.86
		Final	5.6	5.7	5.7	5.7	5.6 b	$\hat{Y}$ = 0.0004x + 5.63	0.10	0.29
	10-20	Initial	5.8	6.03	5.9	5.9	5.9 a	$\hat{Y}$ = 0.00006x + 5.93	0.00	0.98
		Final	5.5	5.5	5.5	5.5	5.5 b	$\hat{Y}$ = 0.00001x + 5.53	0.00	0.97
	20-30	Initial	5.8	5.9	5.8	5.7	5.8 a	$\hat{Y}$ = -0.0003x + 5.86	0.08	0.35
		Final	5.3	5.5	5.4	5.4	5.4 b	$\hat{Y}$ = 0.0002x + 5.39	0.02	0.61
Calcium ($cmol_c dm^{-3}$)	0-5	Initial	3.98	3.61	4.71	4.63	4.23 a	$\hat{Y}$ = 0.003x + 3.51	0.74	0.02
		Final	3.04	3.31	4.07	4.13	3.63 b	$\hat{Y}$ = 0.003x + 3.17	0.82	0.03
	5-10	Initial	2.98	3.51	3.69	3.92	3.52 a	$\hat{Y}$ = 0.003x + 3.18	0.80	< 0.01
		Final	2.57	3.18	3.20	3.72	3.17 b	$\hat{Y}$ = 0.003x + 2.75	0.84	< 0.01
	10-20	Initial	2.43	3.17	2.76	3.15	2.88 a	$\hat{Y}$ = 0.001x + 2.69	0.08	0.35
		Final	2.94	3.21	2.40	3.08	2.91 a	$\hat{Y}$ = -0.0001x + 2.93	0.00	0.91
	20-30	Initial	2.10	2.27	2.28	2.86	2.37 a	$\hat{Y}$ = 0.002x + 2.08	0.42	0.07
		Final	2.49	2.86	2.07	2.58	2.50 a	$\hat{Y}$ = -0.0004x + 2.55	0.01	0.75
Magnesium ($cmol_c$ dm^{-3})	0-5	Initial	0.95	1.21	0.91	1.04	1.03 a	$\hat{Y}$ = -0.00008x + 1.04	0.00	0.93
		Final	2.43	1.16	0.85	0.84	1.32 a	$\hat{Y}$ = -0.00009x + 0.98	0.00	0.90
	5-10	Initial	1.41	1.50	1.08	0.71	1.17 a	$\hat{Y}$ = -0.002x + 1.50	0.62	0.08
		Final	1.16	0.98	2.22	0.84	1.30 a	$\hat{Y}$ = -0.0009x + 1.09	0.53	0.07
	10-20	Initial	1.09	0.82	0.82	0.69	0.85 a	$\hat{Y}$ = 0.00008x + 0.93	0.00	0.95
		Final	1.08	1.03	0.57	1.06	0.93 a	$\hat{Y}$ = -0.0001x + 1.03	0.00	0.82
	20-30	Initial	0.67	1.01	0.50	0.78	0.74 a	$\hat{Y}$ = 0.00002x + 0.76	0.00	0.81
		Final	0.83	0.49	0.88	0.79	0.75 a	$\hat{Y}$ = 0.0003x + 0.70	0.03	0.56
Potassium ($mgdm^{-3}$)	0-5	Initial	1.66	1.66	2.33	2.00	1.91 b	$\hat{Y}$ = 0.001x + 1.73	0.06	0.42
		Final	4.33	4.33	4.33	3.00	4.00 a	$\hat{Y}$ = -0.004x + 4.55	0.031	0.06
	5-10	Initial	1.33	1.33	1.33	1.33	1.33 b	$\hat{Y}$ = 0.000x + 1.33	0.00	1.00
		Final	2.00	3.00	2.33	1.66	2.50 a	$\hat{Y}$ = -0.002x + 2.54	0.06	0.43
	10-20	Initial	0.66	0.66	0.66	1.00	0.75 b	$\hat{Y}$ = 0.001x + 0.61	0.08	0.35
		Final	2.33	1.66	3.33	2.00	2.33 b	$\hat{Y}$ = 0.0003x + 2.29	0.00	0.92
	20-30	Initial	0.66	0.33	0.00	1.00	0.50 a	$\hat{Y}$ = 0.001x + 0.34	0.05	0.48
		Final	2.33	0.66	0.33	1.33	1.16 a	$\hat{Y}$ = -0.001x + 1.40	0.04	0.52
Phosphosrous ($mgdm^{-3}$)	0-5	Initial	1.18	1.24	1.67	1.97	1.51 a	$\hat{Y}$ = 0.003x + 1.17	0.92	< 0.01
		Final	0.91	0.89	1.49	2.41	1.43 a	$\hat{Y}$ = 0.005x + 0.76	0.96	< 0.01
	5-10	Initial	0.95	0.96	1.52	1.64	1.27 a	$\hat{Y}$ = 0.002x + 0.60	0.51	< 0.01
		Final	0.77	0.58	0.88	1.02	0.81 a	$\hat{Y}$ = 0.002x + 0.35	0.79	< 0.01
	10-20	Initial	0.81	0.61	0.75	1.16	0.83 a	$\hat{Y}$ = 0.002x + 0.34	0.67	< 0.01
		Final	0.53	0.24	0.77	0.48	0.51 a	$\hat{Y}$ = 0.001x + 0.32	0.26	0.08
	20-30	Initial	0.46	0.17	0.33	0.89	0.46 a	$\hat{Y}$ = 0.003x + 0.13	0.76	< 0.01
		Final	0.38	0.19	0.43	0.94	0.49 a	$\hat{Y}$ = 0.0002x + 0.29	0.02	0.65

Increases in calcium and phosphorus levels were observed with increasing doses of gelatine sludge. An opposite effect was verified when comparing these results with the literature. For example, ammonium sulphate was found to cause a reduction of pH, calcium and magnesium with an increase of the aluminum content (Ferrari et al., 2015).

Guimarães et al. (2012) also using gelatine sludge, showed increases in the levels of calcium and phosphorus of 0.04 $cmol_c\ dm^{-3}$ and 0.01 mg dm^{-3} for each $m^3\ ha^{-1}$ of applied gelatine sludge. These authors concluded that since most of the elements are not adsorbed, they remain in solution and can be leached throughout the soil profile.

Increasing doses of gelatine sludge caused linear increases in calcium content, especially in the 0-5 and 5-10 cm layers (Table 2). The calcium content increased 0.003 $cmol_c\ dm^{-3}$ to each $m^3\ ha^{-1}$ of applied sludge in the 0-5 and 5-10 cm layers. Regarding the dose of 300 $m^3\ ha^{-1}$, the increase was equivalent to 0.9 $cmol_c\ dm^{-3}$. For the first two layers, there was lower exchangeable calcium contents in the final period compared to the initial period ($p < 0.05$) (Table 2).

The doses had no effect on the mean value between the initial and final collection on the plant tissue ($p > 0.05$), which ranged from 1.18 to 1.29 g kg^{-1}. However, the amount of calcium absorbed by the plant played an important role in the decrease of the exchangeable calcium content of the soil in the final period of the experiment.

The doses of gelatine sludge did not modify the magnesium content of the soil, since no difference was verified between the initial and final periods.

Similar to magnesium, the gelatine sludge did not influence the soil potassium content. Only the sampling periods had significant effects ($p < 0.05$), with the final period higher than the initial one. This effect was due to the fertilization of the cover performed after the first sampling of the soil, which reflected in a higher concentration of potassium in the soil (Table 2).

Sodium and exchangeable aluminum contents were not statistically tested because the value in all the samples was equal to zero.

Between the initial and final sampling, the available phosphorus concentration did not change ($p = 0.01$). The effect of the doses on the 0-5 and 5-10 cm layers had linear increments of available phosphorus with estimated concentrations of 2.07 and 1.2 $cmol_c\ dm^{-3}$ for the initial period and 2.26 and 0.95 $cmol_c\ dm^{-3}$ for the final period, respectively, for the dose of 300 $m^3\ ha^{-1}$. At the depths of 10-20 and 20-30 cm, only the dose effect was observed in the initial period ($p < 0.01$). In the final period, the gelatine sludge had no influence on the available phosphorus content (Table 2).

The increase of Al^{3+} and H^+ increases soil acidity. The higher acidity of the soil caused by Al^{3+} can cause toxicity to the plants. Moreover, Al^{3+} can form ionic complexation with the soil bases at acidic pH. Since complexes formed with PO_4^{-3} reduce the amount of P available to the plant, their productive responses might be compromised (Nolla et al., 2006).

In tropical conditions where precipitation is more intense than evapotranspiration, soil acidification tends to occur continuously and might be intensified by the metabolic activity of plants and animals as well as by anthropic factors (Fageria et al., 1991).

In addition, other chemical reactions are also capable of generating soil acidity: dissociation of carbonic acid, decomposition of organic matter, nitrogen fertilization, leaching and absorption of bases (Nolla et al., 2015).

The extraction of calcium, mainly of the superficial layer, promoted the reduction of pH between the two evaluated periods. Nolla et al. (2015) attributed the soil acidification process on the absorption of basic cations. Therefore, soil cultivated with pasture causes reduction of phosphorus, calcium and magnesium and increases soil acidity because of the nutrient extraction by the plant (Rodrigues et al., 2013).

The gelatine sludge applied only promoted an increase of calcium and phosphorus not increasing potassium and magnesium. Only the increase of calcium caused imbalance of nutrients, as its chemical characteristics is similar (valence, ionic radius, degree of hydration and mobility), its presence in excess can harm the absorption of the other nutrients.

The effect of sludge application on soil profile up to 30 cm was similar to that found with liming: higher nutrient contents in the superficial layer, decreasing with depth (Guimarães Júnior et al., 2013).

It was expected that the applied residue had a more homogeneous distribution of nutrients in the soil profile, since it was applied as a liquid, reducing the heterogeneity between the layers. Therefore, the monitoring of the soil chemistry and nutrient ratios should be carried out frequently and corrections should be made for a better balance of nutrients, so there are no future chemical impediments to plants.

4. Conclusion

Sludge from the gelatin industry is a source of phosphorus, calcium and nitrogen that can be applied to the soil. Its application did not cause soil acidification. However, it was found to cause nutrient imbalances due to the higher amount of calcium in relation to other nutrients.

Acknowledgements

I would like to thank the public notice: 047/2012 Pró-amazônia: Biodiversidade e Sustentabilidade/Capes and the Programa de Apoio a Núcleos de Excelência/Pronex/Sect/Cnpq for financial support to our research group. Additionally, I want to thank the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the financial support and scholarship granted.

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