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COMPOSTAGEM DE RESÍDUOS DE ABATEDOURO E DE PODAS ARBÓREAS URBANAS VISANDO A OBTENÇÃO DE CONDICIONADOR DE SOLO PARA O CULTIVO DE SOJA

COMPOSTING WASTE FROM SLAUGHTERHOUSES AND URBAN TREE PRUNING TO OBTAIN SOIL CONDITIONER FOR SOYBEAN CULTIVATION

Hebert Martins Ferreira
Universidade do Estado de Minas Gerais - UEMG - unidade Frutal
hemafevet@gmail.com
ORCID: 0009-0001-7071-5840

Karen Cristine Santos Galvão
Universidade do Estado de Minas Gerais - UEMG - unidade Frutal
karen.galvao@uemg.br
ORCID: 0000-0002-7376-2159

Osania Emerenciano Ferreira
Universidade do Estado de Minas Gerais - UEMG - unidade Frutal
osania.ferreira@uemg.br
ORCID: 0000-0003-1590-5550

Rodrigo Ney Millan
Universidade do Estado de Minas Gerais - UEMG - unidade Frutal
rodrigo.millan@uemg.br
ORCID: 0000-0002-9324-7330

Eduardo da Silva Martins
Universidade do Estado de Minas Gerais - UEMG - unidade Frutal
eduardo.martins@uemg.br
ORCID: 0000-0002-1320-6329

Resumo
O objetivo deste trabalho foi avaliar o potencial de utilização de resíduos de podas urbanas e de abatedouro em processo de compostagem, visando a obtenção de um composto orgânico que possa ser utilizado como condicionador de solo no cultivo de soja. Para isso, foi utilizada uma mistura de resíduos formada por podas urbanas e conteúdo gástrico de carcaças de bovinos, na proporção de 1:1 (v/v). As análises químicas mostraram elevação dos níveis de macronutrientes, como Nitrogênio, Fósforo e Potássio após a compostagem. A mistura de resíduos apresentou elevadas contagens de bactérias mesófilas e enterobactérias, além de presença de *Salmonella* spp. e *Escherichia coli*, antes e após a compostagem. Os parâmetros índice de germinação, peso fresco e peso seco das radículas de soja não apresentaram diferença estatística dentre as diferentes proporções de condicionador de solo avaliadas. Por outro lado, para o crescimento da radícula, o controle e a proporção de 1 $Ton.ha^{-1}$ apresentaram valores estatisticamente iguais, enquanto para as proporções de 3 e 5 $Ton.ha^{-1}$, houve diminuição no crescimento. Assim, concluiu-se que a compostagem utilizando mistura de resíduos de podas arbóreas e do abatedouro, a 1 $Ton.ha^{-1}$, apresenta potencial para utilização como condicionador de solo, no cultivo de soja.
Palavras-chave: composto orgânico, decomposição, germinação, *Glycine max*.

Abstract
This article aimed to evaluate the potential for using urban pruning and slaughterhouse waste in the composting process to obtain an organic compound that can be used as a soil conditioner in soybean cultivation. A mixture of waste from urban pruning and gastric contents of cattle carcasses was used in a 1:1 (v/v) ratio. Chemical analyses showed an increase in macronutrient levels after composting, such as Nitrogen, Phosphorus, and Potassium. The waste mixture showed high counts of mesophilic bacteria and enterobacteria, in addition to *Salmonella* spp. and *Escherichia coli*, before and after composting. The parameters germination index, fresh weight, and dry weight of soybean rootlets showed no statistical difference among the different proportions of soil conditioner evaluated. As for radicle growth, the control and the proportion of 1 $Ton.ha^{-1}$ presented statistically equal values, while the proportions of 3 and 5 $Ton.ha^{-1}$ had a decrease in growth. Thus, composting using a mixture of tree pruning and slaughterhouse waste, at 1 $Ton.ha^{-1}$, has potential as a soil conditioner in soybean cultivation.

Keywords: organic compost, decomposition, germination, *Glycine max*.

1. Introduction

In recent decades, population growth has increasingly accentuated the problems arising from the accumulation and inadequate disposal of organic solid waste (RSO) produced in urban environments (Vasconcelos *et al.*, 2021).

Urban forestry plays an important role in beautifying the landscape, reducing air pollution and temperature, moderating the municipality's energy balance, and reducing the surface runoff of rainwater. On the other hand, waste management from urban pruning disrupts public management, and more sustainable alternatives are essential (Silva Filho, 2006).

In this sense, the agroindustry also shows that slaughterhouses have a great polluting/degrading potential since the waste generated when slaughtering animals has high concentrations of organic load, which can attract insects and other disease vectors, contributing to the spread of pathologies to humans and animals (Pardi *et al.*, 2006).

Composting is an effective and sustainable alternative. It is a biological process that stabilizes waste, reducing the effects of poor solid waste disposal and its volume (Paritosh *et al.*, 2017; Vasconcelos *et al.*, 2021). Organic fertilizers and soil conditioners have been widely used to replace chemical fertilization and have demonstrated satisfactory results, increasing fertility, soil biodiversity, and the production of various crops (Finatto et. al., 2013; García-Orenes *et al.*, 2016; Souza *et al.*, 2016).

With the incessant search for sustainability in agricultural production, companies and institutions have been looking for technologies that can increase productivity with less impact on the environment. In this sense, soil conditioners and biostimulants are promising for the grain production indicator, stimulating plants to better respond to challenges against diseases and abiotic stresses, in addition to increasing their physiological, biochemical, and genetic performance. Better germination rates, vegetative and root growth, an increase in dry mass, and, consequently, an increase in final productivity were also observed in soybean cultivation that received the addition of soil conditioners (Alcântara; Porto, 2019).

Soybean - *Glycine max* (L.) Merrill - is a cereal of extreme economic importance, with a high impact on the global financial scene. Holding a very high diversity of exploitation, both fresh and processed, it contributes to the nutritional composition of food, mainly as a source of protein, and nowadays is indispensable for global food security (Matsuo; Fukami; Tsuchiya, 2016).

Given the above, this study aimed to evaluate the potential for using urban pruning and slaughterhouse residue in the composting process to obtain organic compost that can be used as a soil conditioner in soybean cultivation.

2. Material and Methods

The first stage in the development of this study was the obtaining and physical-chemical and microbiological characterization of tree pruning and slaughterhouse residues in the municipality of Frutal, Minas Gerais. Frutal is located at geographic coordinates 20° 1'29.00" S (Latitude) and 48°56'25.00" W (Longitude).

A company outsourced by Frutal supplied the urban pruning waste (UP) used. This study does not have data on pruning volume per period, but the rainy season (summer) has a greater volume of plant mass production and, consequently, a greater volume of pruning. The slaughterhouse called Frutal Butchers Association (in Portuguese, Associação dos Açougueiros de Frutal - ASSAF) supplied the waste from the municipal slaughterhouse, consisting of Gastric Content of Carcasses (GCC).

Shortly after the start of treatment, which took place on May 03, 2023, three samples were collected from each test and sent to the LabiTech LTDA Laboratory, located in Frutal, for physical-chemical analyses. The following were determined: pH, humidity, conductivity, solids, organic carbon, nitrogen, C/N ratio, phosphorus, potassium, calcium, magnesium, molybdenum, boron, sodium, total iron, and toxic metals: total chromium, lead, zinc, Cadmium, Copper, and Nickel.

Microbiological analyses of the waste were conducted at the Microbiology Laboratory of the State University of Minas Gerais (Frutal unit), evaluating the presence or quantification of total bacteria and enterobacteria (with the presumptive determination of *Escherichia coli* and *Salmonella spp*).

Approximately 100g of material was collected from each test and taken in a Styrofoam box with ice to the laboratory; 10g of each sample was weighed and diluted in 90g of 0.1% peptone water, thus obtaining a 10^{-1} dilution. The others were made from this sample by serial dilution in test tubes, transferring 1mL of each dilution into 9mL of peptone water until 10^{-6} dilution.

Mesophilic aerobic bacteria were counted by deep seeding on standard count agar (PCA) and incubated at 35 ºC for 24 to 48 hours using the standard plate count method.

Enterobacteriaceae were counted by spreading on a MacConkey agar surface and incubating at 37 ºC for 24 to 48 hours. The experiments were carried out in triplicate and were expressed as the average number of Colony Forming Units (CFU) per gram of residue.

Initially, selective enrichment was performed for the presumptive determination of *Salmonella* spp. The initial dilution solution was incubated at 42 °C for 24 hours. After this period, according to Apha (2001), 1mL of each sample was transferred to two test tubes, one containing 10mL of tetrathionate, which was incubated at 42º C for 24 hours. From the selective enrichment broth, one layer was used for surface seeding on two plates, one containing *Salmonella Shigella* Agar (SS) and the other containing MacConkey Agar, incubated again at 37° C for 24 hours. Subsequently, colonies suggestive of *Salmonella* ssp. were selected, with colorless colonies with black centers on SS Agar and colorless colonies with straw-colored basic medium on MacConkey Agar.

The composting experiment occurred at the ASSAF, a non-profit association whose main activity is the slaughter of large and medium-sized animals (cattle, buffaloes, pigs, goats, and sheep), with an average slaughter monthly of 750 cattle/month, 200 pigs/month, and 50 sheep/month.

The waste was composted in polypropylene drums (inert) with a capacity of 200 liters, in quadruplicate, with the equivalent of 60 liters of GCC and 60 liters of UP placed in each drum.

UPs were crushed using a motorized crusher. Branches with less than 8 cm of diameter were selected for the crushing process. The place of origin of this raw material was Praça Getúlio Vargas, located in Frutal, Minas Gerais, at coordinates: Lat. -20.023972° and Lon. -48.931703°. The content collected came from various plant species, including grasses, shrubs, trees, and palm trees.

GCC was collected directly after the slaughter of the animals, and it is necessary to report that it was still at a temperature relevant to ruminal homeostasis, providing all the conditions for the biota to remain active and continuing the fermentation process of the existing organic matter. This compound is placed in a metal container, from where it is sent daily to a rural property and spread on pastures.

After packaging the components in the reactors, according to the proportions mentioned above, the compound was mixed using a Nagano mechanized drill (model NP500S), which mixed the entire compound, moving the lower material to the surface and homogenizing the mixture, which was stirred every three days.

The individual temperature of each test was evaluated throughout the composting process using a 15 cm long digital thermometer. The temperature was measured by inserting the rod until the end of its length and waiting about 2 minutes until the temperature stabilized on the display, thus recording the temperature.

The composted material was reevaluated after completion of the composting process for its physical-chemical and microbiological characteristics to establish its properties.

The effect of the soil conditioning compound formed by composting residues on soybean germination was analyzed following the methodology proposed by Olszyk *et al.* (2018), with some adaptations. To this purpose, soybean seeds were germinated in transparent acrylic boxes (11 x 11 x 3.5 cm) containing blotting paper, soil, and plastic acrylic lids. A total of 25 seeds, in triplicate, were distributed on blotting paper, following a uniform 5 × 5 pattern (Emino; Warman, 2013; Gascó *et al.* 2016).

The seeds were covered with 15 g of sand moistened with distilled water, sufficient to maintain humidity at 60% of the maximum water retention capacity. These procedures were repeated, adding the equivalent of 1, 3, and 5 $Ton.ha^{-1}$ of soil conditioning compound to the sand. The boxes were kept in a growth chamber at 25 °C under an alternating 12-hour light regime. The number of germinated seeds was determined five days after the start of the experiment, and the average radicle growth per box was determined at eight days.

The fresh biomass of the seedlings was determined on a semi-analytical balance. For dry biomass, the seedlings obtained were dried in an oven with forced ventilation at 40º C and subsequently weighed.

The results of germination index, average radicle growth, fresh mass and dry mass from germination trials were subjected to analysis of variance, with treatment averages compared using the Tukey test at 5% significance.

3. Results and Discussion

Table 1 shows the physicochemical characterization of the mixture before and after composting waste. There was an increase in pH from 6.78 to 6.93, corroborating results reported by Dai Prá (2006), who mentions that organic acids and traces of mineral acids that form during composting react with bases released from organic matter, generating alkaline reaction compounds.

Regarding humidity, there was a reduction of 13.72%, from 66.89% to 57.71% (Table 3). Margesin; Cimadom; Schinner (2006) studied the biological activity during the composting of sewage sludge and found that the reduction in moisture content harmed the metabolic activity of microorganisms, thus directly affecting the temperature, justifying the short period of the thermophilic phase of composting in this treatment.

There is a reduction of 25.73% in the C/N ratio, alternating from 16.9/1 to 12.55/1 (Table 3). According to Cooper *et al.* (2010), in the compost maturation phase, at the end of the composting process, and the temperature decreases and stabilizes, the C/N ratio presents values around 10 to 12/1.

The following were observed regarding chemical changes: organic carbon has an increase of 5.78%, going from 6.22% to 6.58%.

Nitrogen has an increase of 29.26%, reaching 0.53% at the end of the treatment, contributing to the hypothesis of nitrogen fixation during the composting process, as described by Berton *et al.* (2021).

Phosphorus, an essential element for plant nutrition, changed significantly, increasing its levels by 50%, going from 0.34 to 0.51 (mol/dm3). According to Iniu (2009), phosphorus-solubilizing bacteria make it available, no longer immobilized in the compound particles, causing the plant to absorb this phosphorus and increase its productivity.

Potassium also showed an increase of 92.85%, reaching 1.35 (mol/dm3). Similar results were found by Fiori; Schoenhals; Follador (2008) and Da Silva (2016), who reported that potassium contents increased at the end of composting agro-industrial waste. According to the authors, the potassium in organic form was mineralized over time, making the element more available in the compound.

Calcium increased by 32.39%, going from the initial 0.71 to 0.94 (mol/dm^3). Magnesium increased by 50% in its concentration, reaching 0.12 (mol/dm^3) at the end of composting. Molybdenum increased by 350% compared to the beginning of composting, going from 0.002 to 0.07 (mg/kg). Boron had an increase of 10.46%. Iron decreased by 5.06%, reaching 20.62 (mg/kg) at the end of composting. Zinc reduced 44.26% at the end of composting, with 3.11 (mg/kg) (Table 1).

The other elements, such as Sodium and heavy metals (Chromium, Lead, Cadmium, Copper, and Nickel), were not detected in any analyses conducted before and after composting (Table 1).

Table 1. Physicochemical characterization of the waste mixture, composed of 50% urban pruning and 50% gastric content, before and after composting.

Parameters	Before composting	After composting
pH	6.78	6.93
Humidity (%)	66.89	57.71
Organic carbon (%)	6.22	6.58
Nitrogen (%)	0.41	0.53
C/N Ratio	16.90	12.55
Phosphorus (mol/dm$^{3)}$	0.34	0.51
Potassium (mol/dm^3)	0.70	1.35
Calcium (mol/dm^3)	0.71	0.94
Magnesium (mol/dm^3)	0.08	0.12
Molybdenum (mg/kg)	0.002	0.07
Boron (mg/kg)	1.72	1.90
Sodium (mol/dm^3)	0	0
Total iron (mg/kg)	21.72	20.62
Total chromium (mg/kg)	0	0
Lead (mg/kg)	0	0
Zinc (mg/kg)	5.58	3.11
Cadmium (mg/kg)	0	0
Copper (mg/kg)	0	0

Nickel (mg/kg)	0	0

Source: prepared by the authors, 2024.

As seen in Figure 1, the temperature remained practically constant at 30 ºC in the first week but quickly rose, reaching a maximum value of 53 ºC after eight days. From this period onwards, the temperature remained above 35 ºC for around 12 days, after which it dropped, varying between 25 ºC and 34 ºC until the end of the process (85 days).

Miyatake and Iwabuchi (2006) correlated temperature and microbial activity in composting dairy cattle manure. An increase in temperature was observed from 20º C to 70º C, attributed to the growth in the number of mesophilic microorganisms when the temperature reached 40 ºC and the increase in the population of thermophilic microorganisms at 60 ºC.

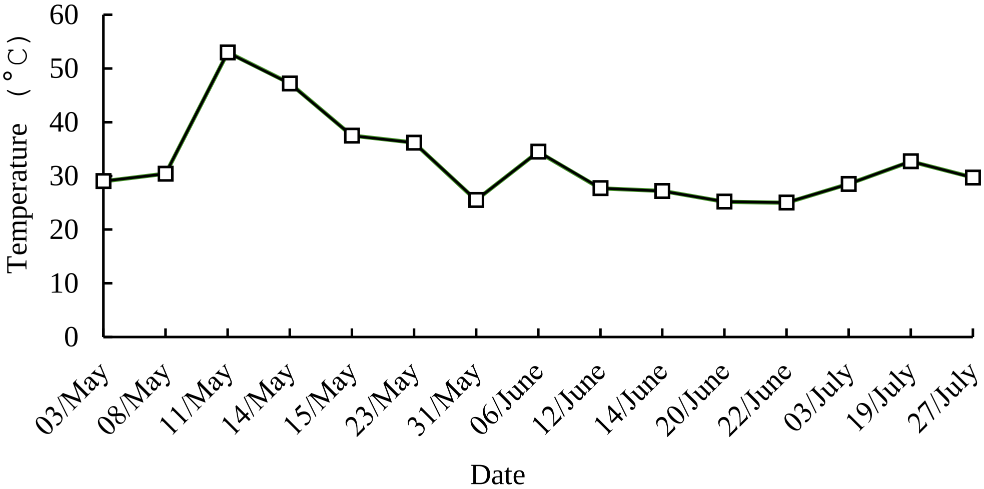

Figure 1. Temperature over the composting time of the waste mixture composed of 50% urban pruning and 50% gastric content obtained from a slaughterhouse. Source: prepared by the authors, 2024.

The composting time in this study was evaluated due to the observation of dark coloration of the compost formed, reached after 85 days of composting the waste. This result is very similar to that found by Rodrigues *et al.* (2015) in a research with composting organic waste in the municipality of Frederico Westphalen, in Rio Grande do Sul, Brazil. According to the authors, the composting time evaluated based on the dark color was 84 days in the compost made from organic waste from a university restaurant and 90 days in the compost with waste from chicken litter, sludge from the flotation process, and solid bovine waste.

The post-treatment count showed that the compound increased the count of mesophilic bacteria. According to a study by Symanski (2005), the recolonization of mesophilic microorganisms is evident after the end of the thermophilic phase of composting (characterized by high temperatures). The enterobacteria count was high at the beginning and end of composting. Likewise, presumptive tests for *E. coli* and *Salmonella* spp. were positive before and after composting (Table 2).

Table 2. Measurement of mesophilic bacteria in the treatments evaluated before and after composting of waste from urban pruning and slaughterhouses in Frutal.

Microbiological parameter	Before composting	After composting
Mesophilic bacteria count (UFC.g^{-1})	$5.57.10^6$	$>3.0.10^8$
Enterobacteriaceae count (UFC.g^{-1})	$1.49.10^7$	$1.14.10^7$
Presumptive test for *E. coli*	Presence	Presence
Presumptive test for *Salmonella spp.*	Presence	Presence

Source: prepared by the authors, 2024.

The composting process was inefficient in eliminating the presence of pathogenic bacteria such as *Escherichia coli* and *Salmonella* spp. because it did not reach a very high temperature in the thermophilic phase of the process. According to Melo (2014), to achieve this, the temperature in the thermophilic phase would have to remain between 65 and 70 ºC for 10 to 15 days. CONAMA Resolution nº 481/2017 (BRASIL, 2017) establishes that the temperature for reducing pathogenic agents is > 60ºC for a minimum period of 3 days, which did not occur in this study. This result is similar to that reported by Bersan, Kelmer, and Almeida (2022) in research on composting organic waste in domestic compost bins.

Similar results were found by Araújo (2011), who discovered that even with the use of substances that would reduce the population of these bacteria, such as lime, there were still a large number of colonies of enterobacteria in the evaluated composts, suggesting further studies to obtain better efficiency in these treatments.

Even using animal waste in agriculture as a sustainable alternative, this use must be environmentally safe. It is essential to use treatments that guarantee their sanitation and provide quality and safety for the use of this waste, preventing the spread of pathogenic bacteria and, consequently, ensuring public health. Several studies show that it is necessary for additional techniques to guarantee the reduction of thermotolerant coliforms up to the maximum limit established for organic agriculture, such as solarization (Ozdemir *et al.*, 2020).

Souza *et al.* (2019) reported that maintaining a high temperature (above 50°C) for more than 45 days allowed the destruction of pathogens in the animal waste composting process.

The tests for Germination Index, Fresh Root Biomass, and Dry Root Biomass did not show statistical differences in any of the treatments (Table 3). Given these results, and regarding the germination of soybean seeds and fresh and dry biomass, the compound did not show phytotoxicity in any of the dosages evaluated.

The Average Relative Root Growth test showed a statistical difference, with the treatments using 3 Ton.ha^{-1} and 5 Ton.ha^{-1} of soil conditioner causing a decrease of 17.48% and 50.05%, respectively, in root growth compared to the Control treatment. The control (without conditioner) and the treatment with 1 Ton.ha^{-1} of conditioner had no statistical difference, indicating that the compound can be used in this proportion (Table 3).

Table 3. Germination of soybean seeds in the presence of soil conditioner within five days; Average Relative Root Growth, Fresh Root Biomass, and Dry Root Biomass over eight days, at concentrations 1, 3, and 5 Ton.ha^{-1}.

Treatments	(a) Germination Index (%)	(b) Average Radicle Growth (cm)	(c) Fresh Root Biomass (g)	(d) Dry Root Biomass (g)
Control	86.66a	9.21a	12.36a	3.01a
1 Ton.ha^{-1}	92.00a	9.03a	12.92a	3.33a
3 Ton.ha^{-1}	92.00a	7.60b	11.88a	3.29a
5 Ton.ha^{-1}	94.66a	4.61c	10.59a	3.35a
DMS(5%)	12.4485	1.24	2.41	0.51

(a) Germination Index (%) of seeds grown for five days, **(b)** Average radicle growth (cm) after eight days, **(c)** Fresh biomass (g) after eight days, **(d)** Dry root biomass (g) of soybean seedlings grown for eight days in sand with different doses of soil conditioner from composting of slaughterhouse waste and tree pruning. Equal lowercase letters do not differ according to the Tukey test at 5%. Source: prepared by the authors, 2024.

Magalhães (2017) shows in his research that productivity in organic soybean cultivation systems tends to reach maximum efficiency from the fourth year of cultivation, being favored by the presence of organic debris and greater humidity and the nutrient absorption process by plants occurs through the decomposition and mineralization of organic matter, which occurs slowly and has a lasting effect, improving soil carbon and physical conditions. Thus, he demonstrates that the beneficial effects of using soil conditioners need to be evaluated over a broader period of time.

4. Conclusion

The compost formed by composting the mixture of slaughterhouse and urban pruning waste presented physical-chemical conditions compatible with a soil conditioner formed via composting, thus enabling its potential use.

As the compound formed still presented a high count of Enterobacteria, it is necessary to optimize the initial conditions of the process to maximize microbial activity and consequently obtain higher temperatures for a longer period to eliminate these bacteria.

The addition of 1 Ton.ha^{-1} of composted material did not show phytotoxicity for any of the variables evaluated in soybean seeds, making it clear that this dosage is the most promising in laboratory tests, opening the possibility for field tests in soybean cultivation.

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