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AGRICULTURAL ENGINEERING

Treatment of organic solid waste generated at agricultural research corporation via composting under natural and controlled conditions

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ABSTRACT. The study of composting technique becomes relevant to management of organic waste generated in an undertaking agricultural research. Therefore, this paper aimed to evaluate the efficiency of stabilization of organic matter in two composting systems: controlled (plowings and irrigations fortnightly) and natural. It has been tested two piles (controlled and natural) during 120 days in four treatments: soy straw (T1), wheat straw (T2), tree pruning (T3), mixture of soy and wheat straw and tree pruning (T4) with organic residues from the recycling program + soybeans. There was monitoring of temperature, moisture, pH, electrical conductivity (EC), C, N, C/N ratio and reduction of mass and volume. In the controlled treatments, the thermophilic phase was lower, the moisture was in the ideal ratio for the process (with lower values in the natural treatments), and there was a decrease of 3-4 times of the values of EC and the higher reductions of mass and volume. In all treatments, the values of pH were neutral and the C/N ratio declined 37-50%, assuming final values of matured composts. It has been concluded that regardless of mixtures of waste, the controlled treatments, in the period of 120 days, were more efficient in stabilize the organic material.

Keywords: organic residues from the recycling program, soybeans, wheat straw, soybean straw, pruning trees.

Tratamento de resíduos sólidos orgânicos gerados em instituto de pesquisa agropecuária via compostagem em condições natural e controlada

RESUMO. O estudo da técnica de compostagem se torna relevante para gestão dos resíduos orgânicos gerados em um empreendimento de pesquisa agropecuária. Sendo assim, este trabalho objetivou avaliar a eficiência da estabilização da matéria orgânica em dois sistemas de compostagem: controlado (revolvimentos e irrigação quinzenalmente) e natural. Foram testadas duas leiras (controlada e natural) durante 120 dias em quatro tratamentos: palha de soja (T1), palha de trigo (T2), poda de árvore (T3) mistura de palhas de soja e trigo com poda de árvore (T4) com resíduos orgânicos da coleta seletiva + grãos de soja. Monitorou-se temperatura, umidade, pH, condutividade elétrica (CE), C, N, relação C/N e redução de massa e volume. Nos tratamentos controlados a fase termófila foi menor, a umidade esteve na faixa ideal para o processo (valores abaixo nos naturais), houve diminuição de três a quatro vezes dos valores de CE e as maiores reduções de massa e volume. Em todos os tratamentos os valores de pH foram neutros e houve redução de 37 a 50% da relação C/N, assumindo valores finais de compostos maturados. Conclui-se que, independente da mistura de resíduos, os tratamentos controlados no período de 120 dias, foram mais eficientes em estabilizar a matéria orgânica.

Palavras-chave: resíduos orgânicos da coleta seletiva, grãos de soja, palha de trigo, palha de soja, poda de árvores.

Introduction

In Brazil, agriculture is an economic activity of paramount importance, contributing with 22.5% of PIB (Gross Domestic Product) and 37% of the workforce (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 2015).

Due to the population growth in along with the expansion of agricultural production, there is a growing relationship in solid waste generation in this sector. Face of this problem, the composting is a technique considered by the Brazilian Solid Waste Policy (PNRS), in its Article 3, section VII, an environmentally suitable way to final destination of organic waste (Brasil, 2010).

Composting provides the stabilization of organic matter and the elimination of pathogens, transforming waste into organic compost, which can be applied to the soil. Some factors must be taken into consideration so that the process can occurs efficiently by microorganisms: temperature, moisture, aeration, C/N ratio, time, particle size of the material and content of nutrients (Díaz, Madejón, López, López, & Cabrera, 2002)

In agricultural research, enterprises such as Embrapa Soja (a Brazilian research institute about soybean) generate organic agricultural waste (rest of cultures and research material) and organic waste from the institution itself, which resembles the organic fraction of municipal solid waste.

Studies concluded that the intensification of plowings in the piles decreased the composting time, since the presence of oxygen in mass increases the speed of oxidation, accelerating the degradation of organic matter. On the other hand, it can represent an increase in the cost of labor and makes it an economically unviable activity, although the decrease of the composting time with plowings allows dimensioning a smaller area for the composting yard (Zhu, Deng, Xiong, & Quian, 2004, Wang et al., 2011, Guo et al., 2012).

Thus, it has been aimed to apply the composting technique for the treatment of various organic waste generated in the Embrapa Soja Institution, as well as to test the process efficiency in stabilizing organic matter in two systems: one which had the recommended control for process (aeration and moisture) and other, natural.

Material and methods

The experiment has been conducted at Santa Terezinha Embrapa Soja Farm, located in Londrina, Paraná, Brazil. The waste used for composting has been generated at Embrapa from the: organic wastes from the recycling program (W1) consisting of rest of meals, fruit peels etc., and organic matter uncontaminated from research labs; soybeans (W2); soy straw (W3); wheat straw (W4); tree pruning (W5) and a mix of soy and wheat straw with tree pruning (W6).

For the experiment, it was used a mixture of a waste rich in nitrogen (W1 and W2) with one waste rich in carbon (W3, W4, W5 and W6), totalizing four treatments. For each treatment, it was assembled two similar piles (quantity/organic matter). In one of them, it was applied controlled conditions, as moistening and plowing, with the support of a Bobcat® every 15 days, and in the other one, the piles didn't receive artificial irrigation or plowing. These piles received water only when it rained. The experiment has been set up in a non-waterproofed place and under similar weather conditions (ambient temperature, relative humidity, precipitation and solar radiation), and the treatments were: T11 and T12; T21 and T22; T31 and T32; T41 and T42 (Table 1).

Table 1. Scheme of treatments.

Treatments							
T1		T2		T3		T4	
W1 + W2 + soy straw		W1 + W2 + wheat straw		W1 + W2 + tree pruning		W1 + W2 + soy and wheat straw tree pruning	
T11	T12	T21	T22	T31	T32	T41	T42
Controlled	Natural	Controlled	Natural	Controlled	Natural	Controlled	Natural

Each pile was assembled with 85 kg of organic wastes from the recycling program (W1), which corresponds to the quantity generated during one week at Embrapa Soja. The assembly was divided into four weeks in alternating layers of 10 kg of soybean and 57 kg of straw waste in piles with trapeze format and with dimensions of 1.25 m width and 1.5 m length.

The piles were structured with a C/N ratio around of 15/1, below the ideal range recommended by Kiehl (2004), which is 25/1 to 35/1, due to the low quantity of organic wastes produced by the recycling program, when compared with the volume of straw waste produced during one week at Embrapa Soja.

Temperature was monitored during 120 days with a 15 cm stem thermometer. It was found a reduction of mass and volume at the end of the process. The compost was weighted and the results were expressed in dry basis. The volume reduction was evaluated by putting the compost into a container with known volume.

Sampling, physical and chemical analyses

Sampling followed the manual quartering method of NBR 10007 (Associação Brasileira de Normas Técnicas [ABNT], 2004). The physic-chemical analysis of moisture, pH, electrical conductivity, total carbon and nitrogen and C/N ratio happened with wastes and compost on the 15^{th}, 30^{th}, 60^{th}, 90^{th} and 120^{th} day of the experiment.

The moisture content was determined in triplicate by the difference between wet and dry masses according to the methodology of Silva (2009). The pH and electrical conductivity were obtained in triplicate by the method of Tedesco, Gianello, Bissani, Bohnen, and Volkweiss (1995).

The analysis of the total organic carbon, nitrogen and the total carbon and nitrogen ratio (C/N) were determined in duplicate by the method of dry combustion by Carmo and Silva (2012), in a Termo Scientific® analyzer, model 2000 Series Flash.

Statistical analyses

There has been held a comparison of average between treatments controlled and natural through the t - Student test, using Microsoft Excel®. Between treatments (T1, T2, T3 and T4) the variance analyses were performed at 5% significance level, using the Sisvar 5.4 software, and the means were compared by Scott-Knott test.

Results and discussion

The organic wastes were physically and chemically characterized according to the pH, moisture, EC, C, N and C/N ratio (Table 2).

The organic waste from recycling program (W1) presented moisture of 66.9%, value between 70-80% found by Kumar, Ou, and Lin (2010). The remaining waste presented moisture lower than 45-70%, which indicates the need for irrigation in the piles assembly to a successful composting process.

The W1 presented acid pH and it is in accordance with Kumar et al. (2010) and Sundberg (2013), who characterized food waste and verified pH values ranging from 3.8 to 6.5. The remaining residues resulted in pH close to neutral. Liu, Yuan, Zeng, Li, and Li, (2008) affirm that the waste with pH values approaching neutrality (5.5 to 8) is the best for degradation, since this is an optimal range for microorganism's development.

The W1 and the W4 had high values of electrical conductivity, which indicates organic waste with large amount of salts. If the final compost has this range of salts, it can be harmful to use it as a fertilizer in salt-sensitive crops or saline and alkaline soils (Kayikçioğlu & Okur, 2011).

The W1 and W2 presented the lowest C/N ratio. Abdullahi, Akunna, White, Hallett, and Wheatley (2008) found C/N ratio values for urban solid waste of 23/1, while Liu et al. (2008) observed a C/N ratio of 8.9/1. For soybean, Miqueleto, Dolosic, Pozzi, Foresti, and Zaiat (2010) found a C/N ratio of 11.3/1. This value represents that these wastes are the nitrogen source for the degradation process.

The remaining residues had C/N ratio higher than 20/1. Abreu, Paiva, Abreu, Coldebella, and Cestonaro (2011) found 50/1 C/N ratio for soy straw. Wang, Yang, Feng, Ren, and Han (2012) observed a C/N ratio of 81/1, while Zavalloni et al. (2011) observed 130/1 for wheat straw. Serramiá, Sánchez-Monedero, Fernández-Hernández, Civantos, and Roig (2010) obtained the ratio of 36/1 for olive tree pruning, it is verified, therefore, that the values reported in the literature are superior to those found in the present study. However, there is not a consensus about these values, because they are related to a lot of factors. The consensus that exists is that these materials represent a source of carbonaceous material for the composting process.

Evolution of temperature in composting process

During all process (1- 120 days of composting), in general, all treatments (Figure 1) showed similar behaviors as the typical temperature profile, with heat release, evidencing an exothermic process (Haug, 1993).

There was the occurrence of a phase called thermophilic, with average temperatures varying between 40-70°C, and another mesophilic (20-40°C), always above ambient temperature, thus demonstrating the intense microbial activity in the degradation of organic matter (Kiehl, 2004, Puyuelo, Gea, & Sánchez, 2010, Kulcu, 2016).

However, when it comes to the handling conducted in a controlled/natural and to the composition of the mixtures, it can be observed in Figure 1, that the thermophilic and mesophilic phases occurred in different periods. In the controlled treatments T11, T31 and T41 the decrease temperatures coming in for mesophilic phase happened in a faster way. These treatments were the ones that received plowing, and according to Stanley and Turner (2010), aeration provides increased oxidation and decomposition of organic matter.

On the other hand, in the natural treatments (T12, T32 and T42), it was registered the permanence of high temperatures for a longer period of time, and the microbial activity in degradation of organic matter was slow, justifying a long time to stabilize the biomass (Puyuelo et al., 2010).

It can be observed, also, that there was no variation on the residence time of the thermophilic phase in T21 and T22. Pradhan, Misra, Erickson, and Mohanty (2010) affirm that in aerobic composting the wheat straw is readily degraded by over 70% within 45 days, indication that this type of material created favorable conditions for similar aeration/humidity, regardless of the management. Therefore, this is the reason why in this study there was no control need for treatment composting of wheat straw.

Table 2. Characteristics of the organic wastes composted.

Characteristics	Moisture content (%)	pH	Electrical conductivity (dS m^{-1})	C (dag kg^{-1})	N (dag kg^{-1})	C/N
W1	66.9±9.09	4.20±0.47	1.19±0.84	44.86±2.22	3.01±0.55	15.3/1±2.42
W2	11.4±2.96	6.23±0.03	0.15±0.03	49.72±0.52	7.08±0.25	7.0/1±0.27
W3	13.7±1.40	7.58±0.09	0.72±0.02	40.66±3.03	2.04±0.39	21.3/1±2.57
W4	9.62±1.57	8.82±0.11	1.60±0.11	41.19±2.44	1.67±0.54	26.1/1±7.00
W5	39.9±16.13	6.19±0.35	0.54±0.12	36.92±1.03	1.81±0.47	21.2/1±4.41
W6	25.9±8.59	7.06±0.08	0.78±0.04	38.60±0.75	1.61±0.06	24.1/1±1.17

W1 – organic waste from recycling program; W2 - soybeans; W3 - soy straw; W4 - wheat straw; W5 - tree pruning and W6 - a mix of soy and wheat straw with tree pruning.

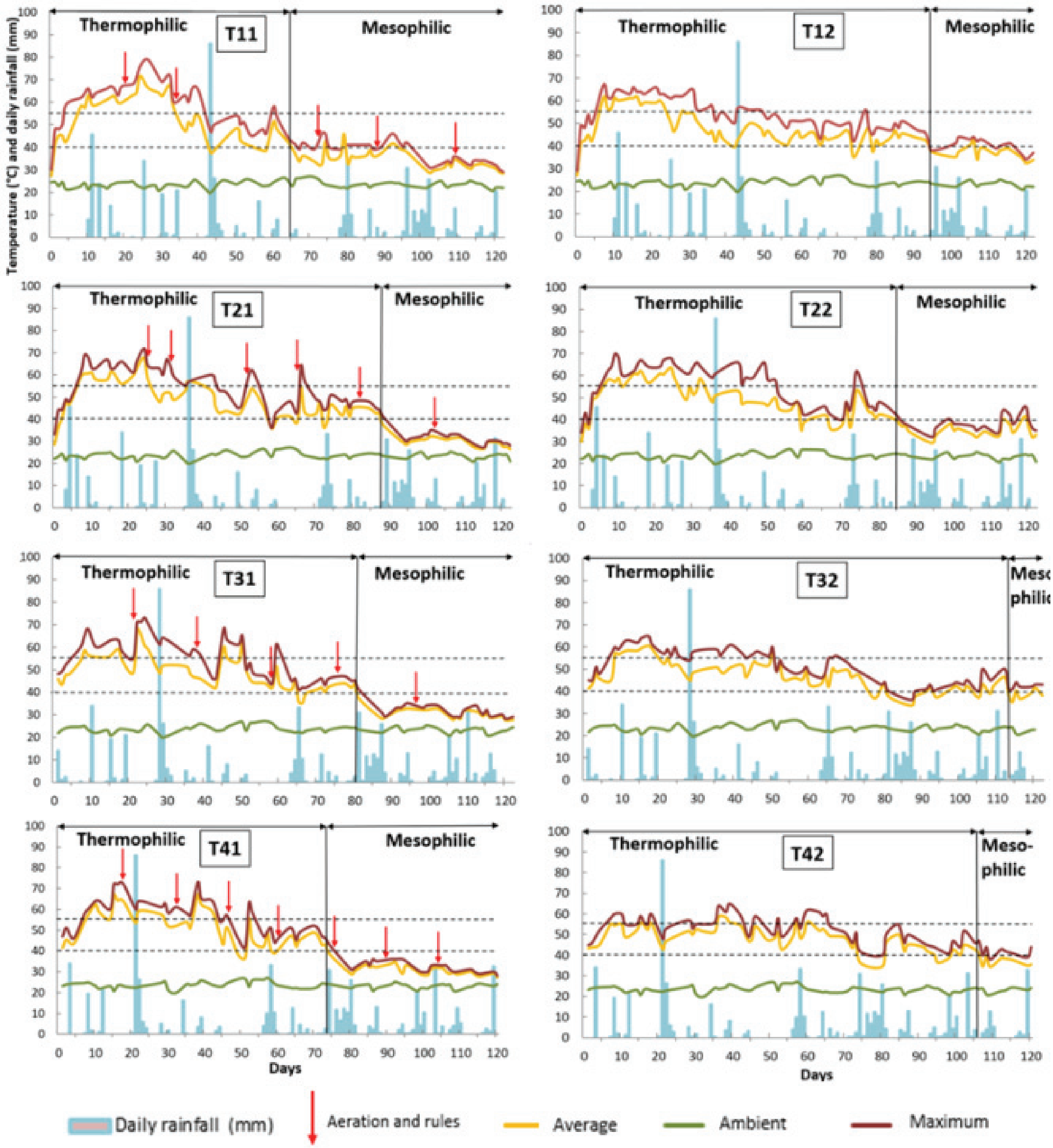

Figure 1.1 Evolution of average and maximum temperatures inside the piles and precipitation within 120 days of the composting process. Note[1]: T11 -Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program+ soybean + mixture of wheat straw with soy and tree pruning (natural).

Physical and chemical characterization of the evolution of the process

In Table 3, it can be observed the comparison of mean values of the moisture in the controlled and natural treatments along the 120 days of composting.

These moisture levels in the first 15 days did not differ significantly ($\alpha = 0.05$) in treatments T12, T22, T32 and T42, which comprise the piles that did not receive management and demonstrated the lowest averages. The values varied when the process completed 90 days of composting, and moisture was statistically similar in natural piles of T12 and T32, with the lowest average. In the end, the highest values were observed in T11, T21 and T41. Moisture levels were considered above the ideal range for fertilization, which is up to 50% according to the Brazilian techniques specifications for organic fertilizer (Brasil, 2009).

Regarding to ideal moisture values in the process, the controlled treatments always showed values within or even higher than the proposed by Stanley and Turner (2010), that ranged between 40-60%, due to the watering, rain and received plowing, whereas, natural treatments, in some periods, demonstrated moisture values below those from controlled treatments, even by getting rainwater. Water content is essential because microorganisms need to utilize the dissolved nutrients (Kulcu, 2016).

It is also observed, especially in the natural pile of tree pruning (T32), lower moisture values compared to the other along the process. This is probably due the fact that the tree pruning possess water-repellent characteristic of the rain and it is difficult to degrade, thereby requiring a more intense microbial activity and thermophilic phase (104 days), which leads to a higher water loss (López-González et al., 2015).

The pH in the beginning (Table 4) of the composting process had equivalent values ($\alpha = 0.05$) only in the treatments T11, T31 and T42. Kurola, Arnold, Kontro, Talves, & Romantschuk (2011) performed composting of municipal waste to ashes in barrel and found that in the beginning of process of the pH was acid (about 4) and, after 30 days, reached values close to 8. In the present study, the pH values were higher from the outset and after 15 days, the treatments already reached basic or alkaline pH values.

Another factor to be considered is that as long as there is ammoniacal nitrogen, the pH of the compost rises, through neutrality and reaching pH above 8 (basic). This kind of effect is associated to the presence of organic acids and the formation of mineral and humic acids that react with basic chemicals released from organic matter, generating alkaline reaction composts (Maragno, Trombin, & Viana, 2007).

At the 60th day, the treatments T21, T31, T32, T41 and T42 assumed similar pH values, close to 8, while in the T11 and T12, acid values (2.26 and 5.93) were observed. Kumar et al. (2010) explained that during this period a fermentation process could have occurred, with the formation of organic acids, confirmed by Guerra-Rodriguez, Vázquez, and Diaz-Ravina (2003), who observed the decrease in pH values during the thermophilic phase.

As the process progresses, with exactly 90 days, it was observed the stabilization in pH, which indicates the compost maturity. At the end of the process, the pH of the composts, regardless of the received handling or waste mixture, assumed values varying from acceptable range of 5 to 8, recommended by Kumar et al. (2010) and Brasil (2009), which permissible tolerance is pH > 6.

Table 3. Comparison of average moisture values among the eight treatments.

	Moisture content (%)								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	52.26Ba	48.08Aa	57.56Bb	36.15Aa	53.15Ba	40.56Aa	70.05Cb	41.59Aa	11.85
30	57.44Ca	57.60Ca	53.96Cb	26.81Aa	57.80Cb	36.19Ba	55.05Ca	52.47Ca	12.24
60	47.02Ba	53.31Ca	64.57Da	54.83Ca	49.92Cb	30.19Aa	64.93Db	41.48Ba	8.35
90	61.14Bb	29.07Aa	69.28Db	57.07Ba	65.37Cb	33.15Aa	72.21Da	65.38Ca	6.01
120	70.74Ca	50.88Ba	68.41Cb	27.68Aa	59.22Ba	57.67Ba	73.16Cb	36.19Aa	10.48

Note[1]: T11 - Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program+ soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

Table 4. Comparison of the mean values of pH between eight treatments.

	pH								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	8.11Ca	8.66Db	6.79Aa	7.47Ba	8.00Ca	7.61Ba	8.67Db	7.85Ca	2.47
30	8.68Ca	8.89Db	8.48Bb	7.51Aa	8.46Ba	8.64Ca	8.34Ba	8.57Ba	1.08
60	2.26Aa	5.93Bb	8.39Db	7.27Ca	8.32Da	8.49Da	8.50Da	7.92Da	4.78
90	8.36Da	8.63Db	7.50Aa	8.00Bb	7.68Aa	8.27Ca	7.86Ba	8.11Ca	1.74
120	8.22Ca	8.47Db	8.15Cb	7.56Aa	7.56Aa	7.93Ba	7.78Ba	7.59Aa	1.78

Note[1]: T11 - Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

About the electrical conductivity on the 15th day (Table 5), period of intense metabolic activity of microorganisms, the levels were equal (α = 0.05) in T11 and T12, and among the treatments T21 and T22. According to Kayikçioğlu and Okur (2011), in tobacco waste compost the conductivity declined in 32 and 46% in the final composts.

After 30 days, the values in all treatments were statistically equivalent, showing the conversion of organic matter to mineralized fraction. From 90 days on, where temperatures have remained lower in the controlled treatments (T11, T21, T31 and T41) due to the plowings that intensified the waste degradation, the electrical conductivity values showed similar (α = 0.05) itself. The electrical conductivity decreased by about 3-4 times more in controlled treatments, comparing them to the natural treatments.

At the end of the process it is still possible to notice the reduction of electric conductivity values, assuming the lowest means for the controlled treatment (T11, T21, T31 and T41), since the held irrigations may have caused the solubilization and leaching of salts. The contrary to what was observed in composting of barley waste with liquid poultry manure, when the EC increased during the process due to release of soluble salts (Guerra-Rodríguez et al., 2003). It can still be seen that the composts of all treatments presented acceptable values for agricultural use, that is, below 4 dS m^{-1} (Kiehl, 2004).

The amounts of carbon (Table 6) were statistically altered between treatments at different periods. This can be explained because, there was observed a reduction of moisture during the process and it can be associated with the low C/N ratio of the initial piles. So, the microorganisms reduced their activity and less CO_2 was produced. Therefore, a lower carbon loss in the pile was observed (Zheng, Gao, Chen, & Luo, 2007). In treatments T21, T12, T21, T31, T32, T41 e T42 there was a reduction of C from the beginning to the end. This reduction is associated to the treatments that presented higher temperatures inside the piles. In composting with organic fraction of municipal solid waste Sánchez-Monedero, Serramiá, Civantos, Fernández-Hernández, and Roig (2010) found that CO_2 emissions decreased gradually due to the increase of the fermentation activity.

Total nitrogen (Table 7) changed during the process, highlighting a growing trend only in the piles: tree pruning (T32); wheat straw (T22) was significantly similar to T42. Leal, Guerra, Espindola, and Araújo (2013) observed that in composting sunn hemp with elephant grass, the N increased for all treatments during the composting process. During the composting process the total nitrogen contained in the organic matter goes through ammonification (NH_2 and NH_3), and then undergoes the nitrification process to nitrite (NO^{-2}) and nitrate (NO^{-3}) (Bech-Friis, Smars, Jonsson, & Kirchmann, 2001, Kiehl, 2004, Kumar et al., 2010).

Table 5. Comparison of the average values of electrical conductivity among the eight treatments.

	Electrical conductivity (dS m^{-1})								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	2.82Ba	2.68Ba	4.58Ca	4.33Ca	2.26Aa	4.14Cb	2.22Aa	5.07Db	8.06
30	2.51Aa	3.37Aa	3.43Aa	3.42Aa	2.14Aa	2.85Aa	2.51Aa	3.85Ab	25.40
60	2.26Aa	5.93Bb	3.47Aa	6.25Bb	2.44Aa	3.91Aa	3.15Aa	3.67Aa	26.56
90	1.74Aa	4.95Db	2.87Ba	1.02Aa	0.94Aa	6.19Eb	1.48Aa	3.53Cb	16.52
120	1.12Aa	4.25Cb	0.92Aa	3.83Cb	0.84Aa	2.50Bb	1.16Aa	3.35Cb	18.01

Note[1]: T11 - Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

Table 6. Comparison of C values among the eight treatments.

	C (dag kg^{-1})								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	27.75Aa	40.21Cb	41.71Da	42.13Da	39.17Ca	45.66Eb	36.31Ba	46.37Eb	2.21
30	31.87Aa	38.42Ca	35.25Ba	38.70Ca	32.69Aa	37.58Cb	35.66Ba	34.54Ba	3.48
60	26.90Aa	35.08Ba	28.89Aa	38.95Ca	35.21Ba	38.31Ca	29.99Aa	39.17Cb	3.75
90	24.57Aa	34.90Ca	25.26Aa	38.49Cb	30.78Ba	37.10Ca	28.96Ba	38.02Ca	4.97
120	37.36Ba	26.63Aa	23.78Aa	42.36Bb	29.06Aa	38.58Bb	28.56Aa	40.80Bb	5.55

Note[1]: T11 - Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

The initial values of C/N were 15/1, which is less than the ideal (30/1), and with each passing day it decreased 47-50% (Table 8). The reduction is related to the high temperatures inside the piles, transforming: small fraction of C in CO_2 and most of the total nitrogen for nitrite and/or nitrate fraction, or under undesirable conditions, it can be lost by ammonia volatilization (Jiang, Schuchardt, Li, Guo, & Zhao, 2011).

The nitrogen is lost by the volatilization of ammonia in alkaline pH, which begins with the hydrolysis of nitrogen composts by microorganisms that degrade organic N, leading to the formation of NH^{+4} - N (ammonification) (Orrico et al., 2012).

However, the C/N ratio is not alone defining whether there is great loss of N during the composting process. One should be aware of the quality of the carbon fraction, which will serve as indicative of the ease of degradation of the material, and the greater the resistance to the degradation of the substrate used as source of C, the greater the losses of N (Orrico Júnior, Orrico, & Lucas Júnior, 2010).

Table 7. Comparison of N values among the eight treatments.

	N (dag kg^{-1})								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	2.99Aa	4.01Cb	3.45Ba	4.03Cb	3.42Ba	4.63Db	3.05Aa	4.86Db	4.10
30	3.48Aa	4.27Cb	4.78Da	4.67Da	3.32Aa	3.82Ba	3.97Ba	3.67Ba	3.84
60	2.96Aa	4.14Ba	3.41Aa	4.92Cb	4.24Ba	4.36Ba	3.46Aa	3.98Ba	5.39
90	2.82Aa	4.33Ca	3.50Ba	4.47Cb	3.55Ba	4.55Ca	3.33Ba	4.18Cb	3.99
120	4.54Ba	2.90Aa	3.15Aa	5.56Cb	3.45Aa	4.34Bb	3.26Aa	4.98Ca	6.49

Note[1]: T11 -Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

The C/N ratio is also used as an indicator of the final compost quality. Values (Table 8) were statistically equivalent between the controlled treatments and natural. From the 60th day until the end, in all treatments, the values were similar (α = 0.05) and indicated that the composts were matured, because the ranges were between 8/1 to 10/1 (Cabeza, López, Ruiz-Montoya, & Díaz, 2013).

Mass and volume reduction

Comparing the mass and volume reduction between the controlled and natural treatments (Figure 2), it can be stated that the controlled treatments showed the highest reductions, which is in accordance with the observed by Yue et al. (2008).

It can be noticed similarities in mass and volume reduction between the piles controlled and natural for the treatment with tree pruning (T3). This can be associated to the fact that the pruning of trees has complexes structure such as lignin, hemicellulose, cellulose and waxes hard broken by microorganisms, which requires greater composting time (Paradelo, Moldes, & Barral, 2012).

With an overview, it is observed that the treatment with wheat straw, the natural pile (T22) showed the lowest reduction index of dry mass, while the controlled pile (T21) presented the highest index. The other treatments showed ideal values of reduction according Kiehl (2004), which indicates a mass reduction of approximately 50%.

The reduction volume showed similar values between controlled and natural piles, especially to treatment with wheat straw that showed the greatest reduction in controlled pile. Factors such as aeration, substrate degradation, temperature and C/N ratio can interfere in this behavior (Orrico et al., 2012).

Decharacterization of the composts

At the final of the 120 days of composting process, the controlled treatments obtained a more uniform decharacterization and decomposition of waste than the natural treatments, showing still dark final composts, odor-free and integrity waste, in other words, the composts were matured.

Table 8. Comparison of the values of the C/N ratio among the eight treatments.

	C/N ratio								
Period (days)	T11	T12	T21	T22	T31	T32	T41	T42	CV (%)
15	9.3/1Aa	10/1Aa	12.1/1Ba	10.5/1Aa	11.5/1Ba	9.9/1Aa	11.9/1Ba	9.5/1Aa	3.76
30	9.2/1Ca	9/1Ca	7.4/1Aa	8.3/1Ba	9.9/1Ca	9.9/1Ca	9.0/1Ca	9.4/1Aa	4.17
60	9.1/1Aa	8.5/1Aa	8.5/1Aa	7.9/1Aa	8.3/1Aa	8.8/1Aa	8.6/1Aa	9.8/1Aa	3.34
90	8.7/1Ca	8.1/1Ba	7.2/1Aa	8.6/1Ca	8.7/1Ca	8.1/1Ba	8.7/1Ca	9.1/1Ca	2.98
120	8.2/1Aa	9.2/1Aa	7.6/1Aa	7.6/1Aa	8.5/1Aa	8.9/1Aa	8.7/1Aa	8.2/1Aa	3.56

Note[1]: T11 - Organic waste from recycling program + soybeans with soy straw (controlled); T12 - Organic waste from recycling program + soybeans with soy straw (natural); T21 - Organic waste from recycling program + soybeans with wheat straw (controlled); T22 - Organic waste from recycling program + soybeans with wheat straw (natural); T31 - Organic waste from recycling program + soybeans with tree pruning (controlled); T32 - Organic waste from recycling program + soybeans with tree pruning (natural); T41 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (controlled); T42 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning (natural). Note[2]: Capital equal letters between the columns of the treatments imply statistical equivalence of values at 5% significance level, by Scott-Knott test. Note[3]: Lowercase equal letters between the columns of natural and controlled treatments imply statistical equivalence of values at 5% significance level, by t-student test.

The final composts of natural treatments, due to lack of the aeration that would provide mixture of the waste and moistening, resulted in a material with odor and the presence of dry lumps that had a stable appearance.

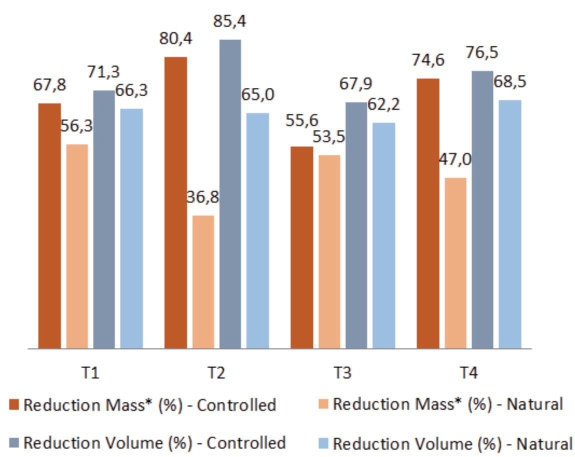

Figure 2. Reduction of mass and volume of the composting process. *Material on a dry basis (105°C). Note: T1 - Organic waste from recycling program + soybeans with soy straw; T2 - Organic waste from recycling program + soybeans with wheat straw; T3 - Organic waste from recycling program + soybeans with tree pruning; T4 - Organic waste from recycling program + soybean + mixture of wheat straw with soy and tree pruning.

Conclusion

The plowings and the irrigations applicable to controlled piles interfere in the behavior of temperature curve, in the mass and volume reductions, however, the C/N ratio didn't differ between systems controlled and natural, but decreases over the days in all treatments, due to low initial C/N.

It has been concluded that the 120 days of composting were sufficient for stabilization of organic matter and controlled treatments resulted in less time for waste maturation of the material, resulting in composts for agricultural use, demonstrating that this is an effective technique for the treatment of organic waste generated in the Embrapa Soja.

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