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Substrate Production for Lettuce Seedlings Through Biomass Biodegradation of Sugarcane

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The objectives of this work were: to evaluate the physico-chemical properties in the composting process of the organic residues, filter cake and sugarcane bagasse, as well as to evaluate the time necessary for the organic compound to reach maturity, and to evaluate the performance of the different substrates in the germination of lettuce seeds. The temperature inside the pile, electrical conductivity (EC) and pH were evaluated in composting process. To evaluate the maturation of the compounds the stabilization of the temperature and EC values and the C / N ratio at the end of the process were analyzed. The data were analyzed in DIC (4x3). The treatments were: T0 - 100% FC (filter cake); T1 -100% sugarcane bagasse (SB); T2 - 50% FC and 50% SB; and T3 - 70% FC and 30% SB. For the production of the substrates from the organic compounds, the treatments were: S1 = 100% of the compound T0, S2 = 50% of T0 and 50% of the ashes of the boiler, S3 = 100% of T1, S4 = 50% of T1 and 50% of boiler ash, S5 = 100% of T2, S6 = 50% of T2 and 50% of boiler ash, S7 = 100% of T3, S8 = 50% of T3 and 50% of boiler ash, S9 = Commercial Substrate (Lupa®). The design was DIC (9x30). The percentage of germination of lettuce seeds in each of the substrates was evaluated weekly, until 30 days after sowing. At the end of each stage the data were submitted to analysis of variance and the means were compared by the Scott-Knott test, at the 5% level of significance. It was concluded that the compounds reached maturity at 90 days for treatments T0, T2, T3 and T4 and it is possible to formulate substrates for the making of lettuce seedlings from the residues of the sucroenergy sector evaluated.
Keywords: sugarcane; sustainable production; byproduct.

1. Introduction

The generation of large amounts of vegetal biomass, with special emphasis on sugarcane bagasse and filter cake, is a bottleneck in the sugar cane (*Saccharum officinarum* L.) processing (Padua, 2014). However, few actions have been carried out for the commercial use of waste from the agro-energy industry.
The reuse of by-products in productive processes brings savings of natural resources and reduces environmental impacts (Schneider, 2013). In this context, sugarcane bagasse has been used in energy generation, filter cake and vinasse for fertilization of sugarcane plantations (Gasparotto et al., 2016).
Composting is one of the treatment techniques for organic solid waste that uses decomposition by aerobic and anaerobic microorganisms, and is notable for its low cost (Lim et al, 2017a), reduction of pollutant potential and contamination of the residues, as well as by converting them into a safe organic compost (Lim et al., 2017b) with potential to improve soil physical and chemical conditions (Dominguez; Gómez, 2010).
Among the organic residues in the sugarcane sector, filter cake and sugarcane bagasse are those that have the necessary characteristics for their use in the production of organic compounds, such as high organic matter and can be used as substrates in the production of vegetable seedlings. However, studies are needed to establish critical physicochemical parameters during the composting process of the filter cake and sugarcane bagasse, and the efficiency of the substrate produced from these compounds (Gonzáles et al.,

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2014). In this context, the objectives of this work were to evaluate the physico-chemical properties in the composting process of organic residues, filter cake and sugarcane bagasse, as well as to evaluate the time required for the organic compound to reach maturity, and to evaluate the performance of the different substrates in the germination of lettuce seeds.

2. Material and methods

2.1 Composting process

Two residues derived from sugarcane biomass, filter cake and bagasse were used as raw materials for composting. Both were collected at the Santa Terezinha Sugar Cane Processing Plant, located in Maringá city, Paraná, Brazil. The experiments were conducted at Centro Universitário Cesumar (Unicesumar), Maringá, PR - Brazil.

Compounds with cylindrical shape were made for the assembly of compost heaps, using a plastic screen, with 1.0 m hight and 0.5 m of diameter.

The experimental design was completely randomized, with 4 treatments and 3 replicates. The treatments were: T0 - 100% cake filter; T1 -100% of sugarcane bagasse; T2 - 50% of filter cake and 50% of sugarcane bagasse; and T3 - 70% of filter cake and 30% of sugarcane bagasse.

After mixing, the composts were stored in a greenhouse, where they remained for 90 days.

The oxygenation of the cells was performed every fifteen days by rotating the material out of the compound in plastic canvas. Cell moisture was measured weekly and maintained at 55% in all treatments.

2.2 Process of physical-chemical characterization and maturation of organic compounds

For the chemical analysis of the macronutrients, pH and C / N ratio (carbon / nitrogen), a sample from each replicate was collected at the beginning of the composting process, as can be observed in Table 1, at time 0 for each treatment.

The parameters measured for the monitoring of the composting process were: the temperature inside the heap (measured every three days), the electrical conductivity and the pH of the solution (measured once a week).

For the determination of the maturity of the organic compounds were considered the stability in the measured values of electrical conductivity and temperature. When these parameters were stabilized, other samples of the treatments and their replicates were collected to perform a chemical analysis with the objective of measuring the macronutrients and the C / N ratio of the compounds.

2.3 Performance of organic compounds as substrates in the production of vegetable seedlings

In the second phase of the experiment, substrates were formulated from the mixture of the resulting compounds in the previous step and the commercial seed germination (Topseed Garden®) of mimosa lettuce (*Lactuca sativa* L.) was analyzed.

For the production of the substrate, the organic compounds were passed through a sieve of 4.8 mm mesh for homogenization and standardization of granulometry. The evaluated substrates had the following compositions: S1 = 100% of compound T0, S2 = 50% of T0 and 50% of boiler ashes, S3 = 100% of T1, S4 = 50% of T1 and 50% of boiler ash, S5 = 100% of T2, S6 = 50% of T2 and 50% of boiler ash, S7 = 100% of T3, S8 = 50% of T3 and 50% of boiler ash, S9 = Commercial Substrate (Lupa®).

After the substrates were prepared, they were placed in styrofoam trays of 200 cells followed by the planting of lettuce seeds.

The percentage of germination of the seeds was evaluated weekly, starting one day after sowing up to 30 days, counting the number of seedlings that emerged in each treatment.

The experimental design was completely randomized, with 9 treatments and 30 replicates, in which each seedlings constituted one repetition.

The data were submitted to analysis of variance and then the means were compared by the Scott-Knott test, at the 5% probability level, using statistical software Sisvar (Ferreira, 1998).

3. Results and discussion

3.1 Physical-chemical characterization

At the beginning of the experiment, the treatment with the highest macronutrient content was T0, followed by T3, T2 and T1 (Table 1). The opposite was observed for the carbon content, where T1 had the highest values followed by T2, T3 and T0.

Table 1. Chemical characteristics of the treatments at the beginning and at 90 days of composting.

Nutrients ($g.Kg^{-1}$)	N		P		K		Ca		Mg		C		C/N	
Time*	0	90	0	90	0	90	0	90	0	90	0	90	0	90
Trat.[2]														
T_0	14,3aB[1]	26,0aA	16,9aB	20,4aA	1,4bB	1,6bA	23,0aB	31,9aA	3,4aB	5,1aA	405,6dA	184,03dB	28,4	7
T_1	7,5dB	10,5dA	0,5dA	0,75cA	1,4bB	1,5dA	10,7dB	13,3cA	3,5aA	3,5cA	487,7aB	517,23aA	64,4	49,1
T_2	11,1cB	20,2cA	9,4cB	14,3bA	1,5aB	1,6aA	16,1cB	26,8bA	3,4aB	4,5bA	442,6bA	306,03bB	40,2	15,1
T_3	13,1bB	21,4bA	11,7bB	14,5bB	1,4bB	1,5cA	19,6bB	26,3bA	3,2aB	4,6bA	428,6cA	210,16cB	35,1	9,8

[1]Lowercase and uppercase letters represent the results of the statistical analysis of the data. The averages followed by the same lowercase letters in the same column do not show statistical differences between them. Averages followed by equal capital letters, in the same row, for each nutrient, do not present statistical differences by the Scott-Knott test at the level of 5% of probability. [2]T0 - 100% cane filter cake (FC); [2]T0- 100% of sugarcane filter cake (FC); T1 - 100% of sugarcane bagasse (SB); T2 - 50% FC and 50% SB; T3 - 70% FC and 30% SB. *Time= days of decomposition.

At 0 days of decomposition, the highest values of C / N were presented in T1 treatment and the lowest was in T0. According to Castillo et al. (2010) the ideal values of C / N ratio for proper decomposition should be between 25 and 30/1, so only treatments T0 and T3 present adequate values with those established as parameters by the author (Table 1).

In the T0, T2 and T3 treatments reductions in the total carbon contents occurred throughout the experimental period (Table 1). Similar results were found by Fialho (2010), and this reduction was accentuated in the first 60 days of decomposition, coinciding with the thermophilic phase of the same.

In contrast, there was a small increase in the total carbon content in T1 (Table 1), whose source material of the compound was only sugarcane bagasse. Contrary results were obtained by Oliveira et al. (2012), whose total carbon content decreased during the decomposition of several organic wastes, including sugarcane bagasse.

As regards pH, Pereira et al (2013) reports that pH values between 6.0 and 8.0 are the most suitable for the action of microorganisms, thus, for all treatments studied in this experiment, the pH values presented close to the proposed values.

In relation to the variations of this parameter, at the beginning and end of the composting, the values suffered a small change during the process (Table 1), presenting statistical difference for the treatments T0, T2 and T3. According to Fialho (2007), values close to neutrality do not interfere in the composting process. In addition, the pH value of the organic compound is dependent on the raw material used.

The temperature values obtained during the experimental period, shown in Figure 1A, followed a typical pattern presented by many composting systems (Sánchez-Garcia et al., 2015; Zhang, Sun, 2014; Pereira et al., 2013; Fialho et al. al., 2010).

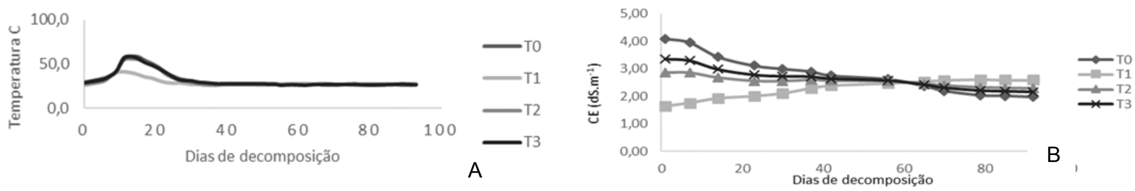

Figure 1. A - Variation of the temperature inside the cells, in the different treatments, as a function of the decomposition time. B - Variation in the electrical conductivity, in the treatments, as a function of the decomposition time. T0 - 100% filter cake (FC); T1 - 100% sugar cane bagasse (SB); T2 - 50% FC and 50% SB; T3 - 70% TF and 30% SB.

The four phases of temperature variation in a composting process were observed for the treatments T0, T2 and T3. The duration time of the thermophilic phase is related to the source material of the organic compound (Trautmann; Olynciw, 2016). The elevation of temperature is an indication of the evolution of the composting process, since it is a consequence of the action of the microorganisms in the organic residues (Raut et al., 2008).

3.2 Electrical Conductivity (EC)

For the four treatments the values of electrical conductivity were below that recommended by the literature (Figure 1B), 4.0 dS.m-1 (Craul; Switzenbaun, 1996) both at the beginning and at the end of the composting.

During the decomposition period for observation the reduction of the electric conduction for the treatments T0, T2 and T3 (Figure 1B) and the treatment T1 followed an inverse trend, since an electrical conductivity increased slightly at the end of the process. Kiehl (2004) affirm that the values of electrical conductivity should decrease by around 50% throughout the composting.

However, the results obtained in this work evidenced the need for use in conjunction with others parameters how the temperature inside the pile and the C ratio / N, to guarantee the final quality of the compound.

3.3 Maturation of Organic Compounds

At 7 days of decomposition all treatments had EC less than 4.0 $dS.m^{-1}$ and the equilibrium at about 40 days of decomposition (Figure 1B). Thereafter, the values remained close to 2.0 $dS.m^{-1}$, this information was used as a subsidy in determining the maturation of the compounds tested at the end of the experiment.
In Figure 1, a stabilization of the values of temperature and electrical conductivity, for T0, T2 and T3, between 30 and 40 days of decomposition occurred, yet this same pattern was not observed in T1. Therefore, it is inferred that as of this date, the composting process has passed from the thermophilic phase to the stabilization stage for T0, T2 and T3. In the results of Gabhane et al. (2012), using different additives to the residues without composting process, this phase started between 10 and 15 days of microbiological activity and an addition of the materials altered the duration of the mesophilic and thermophilic phases of the composting. For Zhang et al. (2016) the stabilization of the compound started at 42 days of decomposition and the addition of unaltered biofuel to the duration of the phases initiated in the process.
A C / N ratio has been used by many authors as a parameter to determine the maturation of organic compounds (Pereira et al., 2013; Selvam, Zhao, Wong, 2012). It is a consensus between them and when it is able to appear C / N near 18: 1 is in the process of biostabilization and the values close to 10: 1 are humid or mature. At 90 days of decomposition, T0 and T3 were considered humidified (Table 1) and T2 is in the biostabilization process. Already T1 had a high C / N ratio.
In relation to the nutrient contents at the beginning of the composting process and at the end, it can be observed in Table 1, that significant increases were observed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) for T0, T3 and T2. In these same treatments there was reduction in the total carbon contents. In T1 there was a significant increase in nitrogen, calcium and carbon contents. According to Oliveira et al. (2012), this high variation can be justified as a function of the quality of the organic compounds and that these contents can act in the maintenance of the soil fertility and the productive potential of the plants.
It was observed an increase in nitrogen content throughout the composting process in all treatments. At 90 days of decomposition, it was observed a statistical difference between all samples (Table 1) and the one with the highest content of this nutrient was T0, followed by T3, T2 and T1, respectively. The same pattern for nitrogen was presented in the results of Zhang and Sun (2014) and according to them, it is natural that this happens due to its mineralization, making it available to the plants.
The lowest carbon contents was observed in T0 followed by T3, T2 and T1, all with statistical difference between them. According to Zhang et al. (2016), microorganisms in a process of composting, use of nitrogen and carbon in the production of energy and for cell growth. In his work, this author demonstrated that the nitrogen contents increased the composting process, as the total carbon content decreased in the same period. Results were obtained for total nitrogen (N) and total carbon (C) of compounds T0, T3 and T2 in the experiment. The inverse occurred, not compound T1, for the carbon, whose values increased at 90 days of decomposition (Table 1).
This fact is evidence that this compound, resulting from the decomposition of 100% of sugarcane bagasse, is not being carried out in the maturation phase, at the moment of composting.
Thus, in general, the compound that mineralized nutrients more efficiently was the resultant of the composition of 100% composite filter cake, i.e. T0.

3.4 Evaluation of organic compounds derived from residues from the sucroenergy sector as substrates in the production of lettuce seedlings

Table 2 shows the average germination percentages for lettuce culture, in the different substrates, up to 30 days after planting.
According to Table 2, at 7 days after sowing (DAS), the germination percentage means of S5, S6, S7 and S8 did not differ statistically from the means obtained by the S9 control. S1 obtained a less favorable performance in this question whose averages occupy second place and the others (S2, S3 and S4) resulted in the worst performances.
However, at 14 DAS, the percentage of germination of S1 increased, approaching those that obtained the most satisfactory averages, equating statistically to them. This pattern of seed germination in the substrates was maintained until the 30 DAS, thus, S2, S3 and S4 remained with their germination indexes below the others.
The substrates S3 and S4 have in their composition the compound resulting from the decomposition of the sugarcane bagasse. On the ninety days of decomposition this material resulted in a C / N ratio of 49.10 (Table

1) and total Carbon contents increased when compared to the levels at the beginning of the process. This set of information indicates that this material did not reach the maturation stage in the study period.

According to Lima (2010), unripe compounds may present phytotoxic substances that inhibit seed germination. According to Silva (2005), one of the main causes of low germination rates in immature compounds is the presence of low molecular weight organic acids, produced during the decomposition of organic matter and degraded over time, showing no maturation of the compound.

Table 2. Mean of germination percentage of lettuce seeds on different substrates at 7, 14, 21 and 30 days after sowing (DAS).

Substrates[1]	Days after sowing			
	7	14	21	30
S_1	16.67b2	87.50a	95.83a	95.83a
S_2	33.33c	66.67b	66.67b	66.67b
S_3	00.00c	00.00b	00.00c	00.00c
S_4	00.00c	54.17b	66.67b	66.67b
S_5	100.00a	100.00a	100.00a	100.00a
S_6	83.33a	86.67a	93.33a	93.33a
S_7	86.67a	100.00a	100.00a	100.00a
S_8	86.67a	100.00a	100.00a	100.00a
S9	80.00a	83.33a	93.33a	93.33a

[1]S_1- 100% T_0 (100% filter cake - composite FC), S_2 - 50% T_0 and 50% BA (Boiler ash), S_3 - 100% T_1 (100% sugarcane bagasse – SB), S_4 – 50% T_1 and 50% BA, S_5 – 100% T_2 (50%FC and 50% SB), S_6 - 50% T_2 and 50% BA, S_7 - 100% T_3 (70% FC and 30% SB), S_8 - 50% T_3 and 50% BA, S_9 - Substrate commercial. [2] Averages followed by the same letter in each column do not present statistical differences among themselves by the Scott-Knott test at the 5% probability level.

4. Conclusion

The use of the parameters of temperature, electrical conductivity and C / N ratio, together, were satisfactory for the determination of the maturation of the organic compounds. The compounds whose treatments contained filter cake, covering the stage of maturation at 90 days of decomposition, are not sufficient for proper decomposition of the residue of pure sugarcane bagasse. The substrates produced from the mixture of filter cake and sugarcane bagasse, in different proportions, after being composted and mixed with boiler ash, did not interfere in the germination of lettuce seeds.

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