Evaluation of the C/N ratio obtained in the composting of sugar cane residues

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Abstract

The analysis of organic waste is very important for enforcement and advocacy of environment so that it is necessary to establish techniques of control and management of waste. The composting method is used for allows to control the process of decomposition by means of the analysis of parameters of control since an inappropriate process can generate negative effects on crops. The study focused to evaluate the content C/N ratio and identify the influence of the type of waste (bagasse, ash and filter cake), two inoculum (commercial and local) and type of aeration (turning and static pipes) applied on the composting process. The following parameters were determined: organic matter, total organic carbon and nitrogen at 0 and 44 days. The C/N ratio demonstrated a reduction on the process. However, it was noted there is a notorious in bagasse decline although it started with higher C/N ratio of 25%, a little less in the sugar cake and otherwise in the ash. The method of aeration tubes presented a higher content of organic carbon. At the end of the composting process, the content decreased. The nitrogen demonstrated to lower content of bagasse and higher with filter cake, higher content of nitrogen. At the end of the composting process, reduces the content of C/N ratio. The sugar waste combined are an important source of material organic for the improvement of soils, it presented a reduction at the end of the composting process without leaving the appropriate ranges.

Keywords: organic carbon, crops, nitrogen, compost.

Introduction

Agricultural production has profound effects on the environment, are the main source of water pollution by nitrates, phosphates and pesticides, affecting the degradation of the soil, salinization, excessive extraction of water and the reduction of the agricultural genetic diversity [1–3]. There is a greater interest in promoting the valorization of waste, creating alternative ways to manage and prevent that they end up in landfill [4]. The sugar agro-industry residues and their possible uses, is topical because they must conform to the new environmental regulations, as well as diversify and adapt their production systems. The production of compost from industrial waste being carried out for many years and is a well-known and developed technology, today it is an alternative for the management of waste as the laws and standards of sustainability and management environmental [5].

There is interest in the use and management of production systems with the handling of amendments agricultural applied to the soil in order to recover, reuse and/or transform waste into useful inputs, retaining or increasing the fertility of the soil. The quality of the final product of the composting process is determined through physical, hygiene, chemical and biological properties as well as its nutritional content and its ability to supply nutrients to a crop [6]. However, looking forward to obtain high quality compost, the need to evaluate the concentration of nitrogen in these waste materials is one of the most important factors which should be studied in ascertaining their agronomical value [7].

Nitrogen becomes the limiting factor to C/N ratio values, which leads to a decrease of the biological activity. Although, normally if the process was slow would indicate that carbonated organics show low levels of degradation and thus a deficiency of nitrogen. The opposite situation, a low C/N ratio, does not really affect the process, but it produces odors due to ammonia production by the loss of nitrogen. The C/N ratio varies according to the different materials used in the composting process, which should be 25-35 at the beginning of the process [8].

On the other hand, aeration affects the efficiency of the process and is one of the most important parameters to be optimized, because of its effect on the rates of degradation and maturation [9]. The selection of the ventilation method depends on the nature of the substrate, being the most common method the turning or forced aeration; this method have proven to be suitable for a wide range of substrates [10]. Diaz, Savage, Eggerth, & Chiumenti [11] mention that aeration, in addition to supplying oxygen to the composting mass, serves an adequate humidity humidity, thus finding the greatest losses of water in the aeration per turning [12].

Composting systems require the installation of technologies appropriate to the context, such as aeration with turning or forced aeration [13]. Kalamdhad & Kazmi [14] indicate that the turning method has the advantage of exposing fresh material to microbial colonization, leading to the release of NH3 retained in the batteries and when tumbling frequency increase during the process, this shortens the period of active stabilization. However, a higher frequency of tumbling requires intensive attention [15]. Given the high humidity of the substrate of composting, it is necessary to identify operation measures that allow for the control the humidity excess of the initial content during the composting process [16,17].

For this reason, the objective of the research was to evaluate the content C/N ratio and identify the influence of the type of waste (bagasse, ash and filter cake), two inoculum (commercial and local) and type of aeration (turning and static pipes) applied on the composting process.

Materials and methods

The sugar waste (bagasse, ash and filter cake) was combined in different proportions with two sources of microorganisms and two methods of aeration were used. Initially, the materials were evaluated with percentage of humidity, ash content and organic matter (OM) to establish the optimal percentage, which every mix content should contain.

Humidity was determined by the gravimetric method [18], OM by combustion at 550°C [6,10] and ash was calculated from OM content accordingly Isaza-Arias [19].

Eighteen treatments were established with 3 replications each; these were implanted in the field under a three factor design. The composting piles were evaluated for 44 days (duration of the process time), it measured 8 m long by 2.5 m wide and 1.5 m in height with particle size less than 10 cm [20]. Two types of aeration were established, one method using constant turning of the composting batteries twice a week, and the other using static pipes throughout the process. The important thing when selecting the aeration method is to guarantee the presence of oxygen to improve the homogenization of the mixture and to favor the uniformity of the temperature in all the areas of the pile [21].

Samples for analysis collected in the field after the turning were mixed and homogenized according to the treatments that corresponded and then submitted to carbon and nitrogen analysis (TOC) at the beginning and end of the process, and set the value at 0 and 44 days of the process. Total Organic Carbon (TOC) was calculated from OM content according to Isaza-Arias [19]. Total N was determined by Kjeldahl digestion method [22–24].

Data were statistically analyzed using ANOVA and LSD multiple range test at 95% confidence using the STATGRAPHICS© CENTURION XVII software package (Statpoint Technologies, Inc.).

Results and discussion

The initial contents of OM, ash and humidity of the waste used for the composting process are shown in Table 1. OM is higher on bagasse (48.99%), followed by filter cake (10.51%). The filter cake showed the highest humidity percentage (86.75%), followed by ash (53.9%) and bagasse (46.54%).

It started with a humidity higher than the optimum in the filter cake material and lower than the optimum in bagasse because the optimum humidity for microbial growth is between 50-70%. Liang et al. [26] showed that 50% humidity was the minimum necessary for a rapid increase in microbial activity, as well as 60-70% humidity range for a maximum activity. Makan et al. [27] showed that the highest amount of MO biodegradation took place at a moisture content of 70-75%, on the basis that the biological activity decreases considerably when the humidity is below 30% and above 70% because water moves to existing free space.

Table 1. Characteristic of the components used for composting.

	Characteristic	OM (%)	Ash (%)	Humidity (%)
Components	Bagasse	48.99	4.48	46.54
	Filter cake	10.51	2.74	86.75
	Ash	5.96	40.14	53.9

Regarding the factor analysis its interaction used to assess the influence of the C/N ratio, these factors have a statistically significant effect on the C/N ratio (%) with a 95.0% confidence level (Table 2).

Table 2. Analysis of Variance for C/N Ratio (%)

EFFECTS	Sum of square	Square medium	F- Reason	p-Value
Composting time (T)	278,99	278,99	25,52	0,0000
Inoculum (I)	225,376	112,688	10,31	0,0001
Mixture of composting (M)	168,883	84,4413	7,73	0,0009
Aeration (A)	123,462	123,462	11,30	0,0012
Interactions				
TxI	105,495	52,7473	4,83	0,0106
TxM	454,643	227,322	20,80	0,0000
TxA	368,167	368,167	33,68	0,0000
IxM	574,346	143,587	13,14	0,0000
IxA	157,2	78,5998	7,19	0,0014
MxA	907,24	453,62	41,50	0,0000
TxIxM	2382,8	595,699	54,50	0,0000
TxIxA	323,521	161,76	14,80	0,0000
TxMxA	144,242	72,1209	6,60	0,0023
IXMxA	718,343	179,586	16,43	0,0000

The analysis of the influence of each factor and their interactions, it was demonstrated that a reduction in 23.7 C/N ratio starting at 20.5 during the 44 days for a proper process to start [1–3]. However, it was noted there is a notorious decline in bagasse, although it started with a higher C/N ratio of 25 obtaining an adequate value [4], a little less in the filter cake and otherwise in the ash.

Table 3. Analysis of the interactions of factors on the composting process

FACTOR		TOC (%)	N (%)	C/N RATIO (%)
Mixtures of composting	Aeration	<0.05	<0.05	<0.05
B25C50A25	Pipes	14.08	0.66	25.16
	Turning	12.14	0.76	16.12
B40C30A30	Pipes	11.74	0.63	19.44
	Turning	12.28	0.53	24.59
B50C25A25	Pipes	14.12	0.60	24.96
	Tuning	13.18	0.59	22.44
Mixtures of composting	Inoculum	ns	<0.05	ns
B25C50A25	Commercial	14.23	0.84	16.84
	Local	12.87	0.69	24.50
	Control	12.23	0.60	20.58
B40C30A30	Commercial	10.84	0.58	18.68
	Local	13.08	0.57	25.86
	Control	12.10	0.60	21..51
B50C25A25	Commercial	13.95	0.55	25.26
	Local	12.62	0.63	20.98
	Control	14.37	0.59	24.86
Aeration	Inoculum	ns	ns	ns
Pipes	Commercial	12.88	0.65	19.72
	Local	13.65	0.64	26.14
	Control	13.41	0.60	23.70
Turning	Commercial	13.14	0.66	20.80
	Local	12.07	0.62	21.42
	Control	12.39	0.60	20.93

Table 3 shows the interaction of all the factors analyzed in the process to evaluate the influence they have on the TOC content, N and C/N ratio. The interaction between the composting and aeration mixture presented a significant statistical difference in TOC content, N and C/N ratio, which did not occur with the other interactions except in the interaction of the composting mixture with inoculum for N.

The aeration by static tubes presented the highest values in the TOC content and C/N ratio with mixture 1 and 3, reaching average values of TOC (14.08% and 14.12%) and content of C/N ratio (25.16% and 24.96%), which did not occur with mixture 2 because the highest values of TOC and C/N ratio were reached with turning method (12.28% and 24.59%). Aeration is fundamental in the process, scarce aeration can generate a replacement of aerobic microorganisms with anaerobes, with the consequent delay in decomposition due to the microorganisms using or consuming the TOC in the mixture [28], however, the excess of aeration could cause the cooling of the mass and a high desiccation with the consequent reduction of the metabolic activity of the microorganisms [29,30]. In this study, aeration was considered by turning with constant frequencies twice a week, similar to what was done by Muñoz et al. [31] who performed aeration by turning every 15 days Isaza-Arias et al. [19] performed manual aeration twice a week. Huang et al. [22] turned the heaps every three days and Hao and Chang [32] used active aeration turning six times during the composting process.

The content of N, in the interaction of the mixture of composting with aeration, the values of N content are found (≈0.59 - 0.66) except for mixture 1 with turning that presents a higher value (0.76%). In the interaction of mixture 1 and commercial inoculum a higher value was obtained (0.84%), in the other interactions of these factors, the values were found between 0.55 to 0.69%.

Table 3. Evaluation of the interaction of parameters based on the content on mixture (%)

Residues	Content on mixture (%)	TOC (%)	Sig	N (%)	Sig	C/N RATIO (%)	Sig	Interaction
Bagasse	25	13.11	ns	0.71	*	20.64	ns	25 - 40
	40	12.01	ns	0.58	*	22.01	ns	25 - 50
	50	13.65	*	0.59	ns	23.70	ns	40 - 50
Filter cake	25	13.65	*	0.59	ns	23.70	ns	25 - 30
	30	12.01	ns	0.58	*	22.01	ns	25 - 50
	50	13.11	ns	0.71	*	20.64	ns	30 - 50
Ash	25	13.38	*	0.65	ns	22.17	ns	25 - 30
	30	12.01		0.58		22.01	ns	

Subsequently, the influence of the content of each waste in the mixture and its interactions was evaluated, according to the content of the TOC, N and C/N ratio (table 3).

The 50% content of bagasse in the mixture presents significant statistical difference in the influence on the TOC content, this reached a value of 13.65%, the same value was obtained with 25% in the filter cake mixture and also presented a significant statistic difference compared to the other percentages and a slightly lower value (13.38%) with 25% ash in the mixture of the composted material. The values found were lower than those reported by Sanchez Modenedero et al [7], who analyze waste from sewage sludge, municipal solid waste, brewery sludge, sweet sorghum bagasse, cotton waste and pine bark, obtaining values between 26.3% to 53.9%, Zhu [30] 324.17 g/kg and 318.11 g/kg; and Gao et al. [23] who worked with chicken manure and sawdust obtaining values of 21.4% and 51.5%.

The high content of N means that the requirements as fertilizers will still comply with the mature compost. In the present study, the content of N in the final compost was 0.71% in the mixture 25% bagasse, 25% filter cake and 25% ash, however, the percentages 25-40% of bagasse content and 30-50 % of filter cake in the mixture, showed significant statistical differences with the other percentages of these residues, reaching values of 0.58% and 0.71%. Other authors have reported similar values , such as Pérez et al. [33] who studied different combinations of plant materials (0.82-2.28% N), Huang et al. [22] who evaluated different combinations of pig manure with sawdust (0.73-0.98% N), and Rosal et al. [34] who evaluated the incidence of heavy metals in four types of composting with values between (2.4-2.9% of N).

One of the crucial factors for effective composting is the C/N ratio of the raw material (an initial C/N ratio of 20 - 30: 1) [1-3], when the C/N ratio is too low, N can be lost from the system as ammonia. If the C/N ratio is too high, the synthesis of biomass is limited. Eklind and Kirchmann [4] composted household waste only (C/N 13) and in different mixtures: with straw (C/N 28), leaves (C/N 22), wood (C/N 32), wood (C/N 34), paper (C/N 30) or peat (C/N 28). This study, found no difference in the content of C/N ratio of any material or its interactions, the values obtained were in a range of 20.64% to 23.70%, C/N optimal ratio (20-30; C/N ratio).

Conclusions

The composted materials presented important initial characteristics for a correct execution of the composting process, which were maintained until the end of the process at 44 days. The initial humidity content of filter cake was a major inconvenience during the process due to the interruption in the aerobic process, mainly in the treatments using the static aeration constant pipes method, however, the bagasse is an important source of TOC necessary for the action of microorganisms in decomposition. All the materials and their combinations presented values of the analyzed parameters (TOC, N and C/N ratio), within the optimum range for the processing of organic matter by composting.

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