Effects of bagasse ash additive on the physiochemical and biological parameters of filter cake and bagasse co-composting process.

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Abstract: *This study was focused on the effects of Sugarcane Bagasse Ash (SCBA) additive on process parameters and compost quality of Co-composting of filter cake and bagasse. Filter cake and bagasse were mixed and sugar cane bagasse ash (SCBA) from a heating power plant of sugar mill. Three compost mixes (M) were obtained: MA with 0%, MB with 10% and MC with 20 wt % of fuel ash. These three different mixes were composted in an experimental composter as three parallel experiments for 3 weeks each. The physical, chemical and biological parameters were monitoring during composting. Significantly, ash additives decreased the total organic carbon; measured by mineralization the breaking down of the organic matter was more rapid in the MC than in the MA, as well as increased the pH during composting. Interesting, the pH decreased was most important in MA and attend 5 for the first week of composting, and then it gradually increased to pH around 8 at the end of the process. The results indicated that ash inhibits the pH drop due to production of organic acids during composting. The acidity of the material was reported as affects the process during the initial phase of rising temperature and quality of the final product. The temperature reached up to 50-55^oC during thermophilic phase, the greater temperature was obtained for MC. At the end of composting, the electrical conductivity increased in the MC, especially in MC, but don't exceed limit (4 mS/cm) for prevent phytotoxicity of the compost. The SCBA additive was likely to speed up the composting process of bagasse with filter cake from 44 days to 33 days.*

Keywords*: Composting, Ash, Additive, Organic fertilizer, Sugar mill waste*

I. Introduction

Global sugar production was nearly 100 million tonnes in 2002 from sugarcane in over 130 countries (FAO, 2003). On an annual basis, the sugar production process releases filter cake and bagasse by-products at a rate of 3.4% and 25–30% of the fresh sugar cane input, respectively. 302400 tonnes of bagasse and 1700 tonnes of filter cake were released annually from SOSUCAM (Cameroun sugarcane factory). Bagasse is used as a fuel and produce ash but no market for filter cake. Currently, the only option for filter cake utilization is as an organic soil amendment or as landfill. Direct incorporation of raw agro-industrial waste into the soil may cause undesirable effects such as phytotoxicity and soil nitrogen immobilization (Negro et al., 1999).

Composting is considered to be one of the most suitable ways of converting organic wastes into products that are beneficial for plant growth (Stantiford, 1987). Improvements are needed for enhanced performance at composting facilities using sugar mill by-products, particularly to conserve plant nutrients, prevent pH drop during process. The C/N ratio needed for effective composting is between 25 and 40, depending on the particular organic substance (Golueke, 1991). The C/N ratio of filter cake is approximately 14, but for bagasse it is approximately 100 (depending of pedoclimatic and process conditions). Therefore, the composting of filter cake may result in considerable N loss, but N must be added to promote composting of bagasse (Meunchang et al 2005). The composting process effectiveness and product quality are affected by the substrate quality (Chiumenti et al., 2005; De Guardia et al., 2010). Acidification occurs during composting can cause process problems, The acidity in substrates results from an early production of fatty acids (Smårs et al., 2002; Sundberg et al., 2004). Similarly, when the decomposition process of acid biowaste begins, the number of mesophilic microorganisms such as lactic-acid bacteria and yeast increases (Kurola et al., 2011). A number of authors have noted stagnation or decline in microbial activity in the transition from mesophilic to thermophilic conditions in laboratory-scale compost reactors (Day et al., 1998; Schloss and Walker, 2000; Beck-Friis et al., 2001; Weppen, 2001) due to high acidity. Different phases of the composting process can be studied by monitoring temperature, pH, and various physical and chemical parameters. Alkaline ashes (SCBA) as buffer material for pH reduction during the composting process are suggested by different authors (Koivula et al., 2004; Kuba et al., 2008; Kurola et al., 2011; An et al., 2012). Addition of SCBA effectively increased the macro- and micro-nutrients of the final products including phosphorus, potassium, magnesium, calcium, copper and zinc. In addition, the color of the final products will be darker when ash is used in composting and no odor (Carpenter and Beecher, 1997). The quantity of ash to add should not exceed certain value in order to avoid slow down of the biological activity and prevent a higher presence of salts (EC) and phytotoxic compounds in the product. In the present study we examined the effect of SCBA additives on the composting process of sugarcane mill by-products (Temperature behavior, pH levels, Electric Conductivity (EC)) and the physicochemical quality of the product.

II. Materials and methods

2.1. Raw material and pre-treatment

The study was developed at laboratory-scale compost reactors. The substrates were obtained from a Cameroun sugar factory (SOSUCAM). Both by-products were air dried to a moisture content of 10% and been characterized as shown in Table 1. Bagasse was manually crushed, until particle sizes between 5 and 7 cm were achieved. These are the recommended sizes.

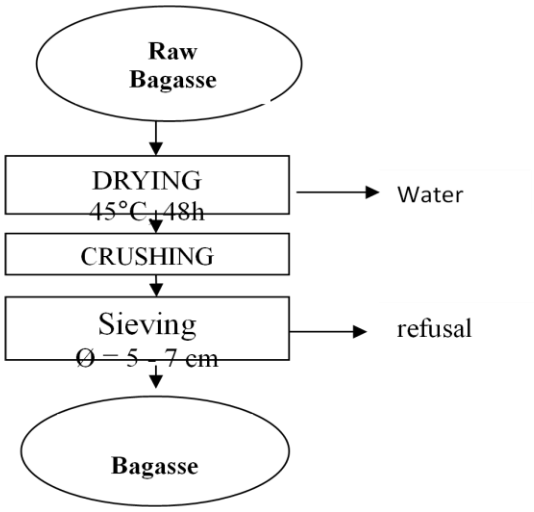

Fig.1. Bagasse pretreatment

2.2. Characterization of the Raw material

Analyzed parameters included: pH, EC, moisture, Total Oxidizable Organic Carbon (TOC), Potassium and Phosphorous. pH was measured using a pH-electrode connected to a pH-meter (Hanna Instrument, **Romania**). The sample was diluted using distilled water in a 5:1 (V/V) ratio. EC was measured using a conductivimeter WTW model 325. The organic matter (OM) content of the compost was analyzed by weight loss on ignition at 430°C for 24 h and total organic carbon (TOC) was calculated from OM according to the following equations (Navarro et al., 1993):

W_{105}=Oven dry weight of mass at 105°C
W_{430}=Furnace dry weight of mass at 430°C
%OM=((W_{105}-W_{430})/W_{105})x100 %TOC=0.51x %OM + 0.48

Total-N was determined by the micro-Kjeldahl method following digestion in sulfuric acid with catalysts (Bremner and Mulvaney, 1982). The ash content at the beginning(X1) and the ash content at any particular time during composting (X2) were used to calculate % organic matter lost according to the following formula (Paredes et al., 1996). OM_{loss}(%)=100-100(X1(100-X2))/ X2(100-X1)).

Heavy metals (Potassium and Phosphorous) were analyzed by the spectrophotometry of HNO3/HCl (1:1) solution (AFNOR, 1993).

2.3. Experimentation and analysis

The composting experiment was carried out in an experimental composter at the laboratory.

Fig.2. Experimental composter.

Bagassse was used as a bulking agent to the filter cake. Filter cake and bagasse (2:1 ratio by weight). The purpose of adding filter cake to bagasse was to increase the starting C/N ratio of filter cake from 14 to 22 to provide a wider C/N to conserve N during composting (Table 1). Proportion of the ash to the compost mass was 0, 10 and 20 wt. %, creating compost mixes (Ms) A, B and C, respectively. The treatments were:

MA: Filter cake and bagasse (2:1 ratio by weight). + 0% of SCBA

MB: Filter cake and bagasse (2:1 ratio by weight). + 10% of SCBA

MC: Filter cake and bagasse (2:1 ratio by weight). + 20% of SCBA

To homogenize the compost mixtures, bagasse as bulking agent was first crushed and then ash and filter cake were mixed. The composting time in the composters was 3 weeks. The moisture levels of the mixtures were measured gravimetrically every 3 days and an appropriate amount of water was sprinkled onto the pile to increase the moisture content to 60% by weight. The mixture was return to uniformly distribute the water. The control parameters for the composting process were temperature, pH and EC. The organic matter (OM) content was also monitored. During the first week, pH was measured daily and later on, at least three times per week. EC was measured using a conductivimeter (Hanna instrument, Romania). Temperature was measured in the three size of mixture using a 70 cm length dial thermometer and means was recorded.

The process was monitored until the temperature of the piles was around room temperatures ±5°C and the product had soil smell. Thus, the maturation process was reached (Dulac, 2001). A descriptive analysis of temperature, pH and EC was carried out.

Once the monitoring period was completed, a representative sample was taken. The same parameters measured in samples were measured in the product. Thus, the substrate quality was determined in pH level, moisture, TOC, K, P, Ntotal. Quality results of the product were compared with the limits establish.

III. Results and discussion

3.1. Substrate characterization

The C/N ratio of filter cake is approximately 15, but for bagasse it is approximately 111 (Table 1). Therefore, the composting of filter cake may result in considerable N loss, but N must be added to promote composting of bagasse. Results were conformed to Meunchang et al (2005) and Fotso et al (2014) who worked on sugarcane by-product. But results are closed to those found by Fotso, contrary to Meunchang which are distant, the reason it’s the pedoclimatic conditions. Likewise SCBA contains macro- and micro-nutrients for the final products including phosphorus, potassium. Also his higher pH can serve as buffer for pH drop during process.

Physicochemical analyzes of substrates are presented in Table 1.

Table1. Physicochemical characterization of substrates of the process

Paramètres	Bagasse	Boues	Cendre de bagasse
pH	4.2±0,1	7.5±0.1	11.7±0.01
CE (ms/Cm)	0.018± 0.01	0.9±0.05	3.22±01
MO (%MS)	71±0.3	46±0.8	
Cendre (%MS)	29±0.3	54±0.8	-
COT (% MS)	36.69± 0.03	23.94±0.2	
Total N (% MS)	0.33± 0.03	1.6±0.02	0.12±0.4
C/N	111.18±1	14.96±1.8	
Total P (P_2O_5)	0.035±0.1	1.1±0.3	2.07±0.3
Total K (K_2O)	0.21±0.3	0.44±0.1	-

MS: Dry matter, each value represents mean ± STDEV of three replications, - : not determined

3.2. Development of the composting process

Temperature: Temperatures during the composting runs of the three Ms are shown in Fig. 3.

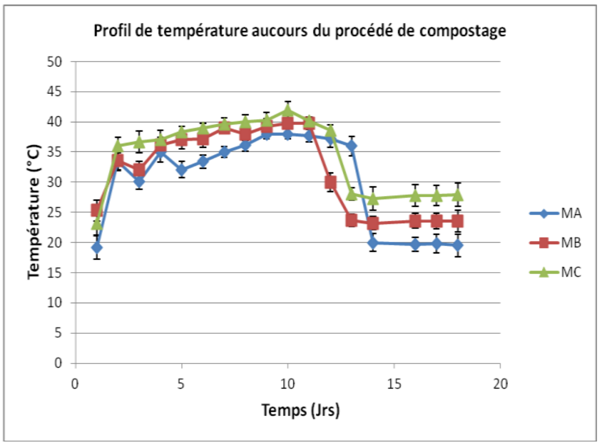

Fig.3. Temperature during composting time

A similar tendency was observed in all Mixtures and the typical composting phases were observed (mesophilic, thermophilic, cooling and maturation). Thermophilic temperature was reached in all Ms during the first and third day of the process. But we note that, the peak of temperature was not high like in common composting process. Due to the small size of the heaps (laboratory scale), so the loss of the heat was greater than in larger compost windrows. Also the ambient temperature was cold. However, higher temperatures were reached during the thermophilic phase for Ms with SCBA, (43, 40 and 38°C for MC, MB and MA respectively). One reason for these high temperatures might be that the ash in MC increased the heat capacity of the mass. Also the rapid degradation of the organic matter in MC.

A temperature above to 40°C was reached during 5 to 7 days in MC and during 2 to 4 days in MB. But MA doesn't reach 40°C. Therefore, an enhancement of hygienization process was observed by using SCBA. However, this temperature level was low no sufficient, as recommended (45-55°C) by for a complete hygienization. This might be explained due to the Size of substrate. Temperature performance during cooling and maturation phases was similar for all piles. First, a sloped decreasing was initially observed (cooling) and then a lower and extended reduction of temperature (maturation). Temperatures decreases from above 26°C for MC, 24°C for MB and 20°C for MA. Maturation phase was slower because the more complex molecules are decomposed during this period. After 3 weeks of composting process, environment temperatures were reached. A tendency to higher temperatures (+4°C) in M with SCBA was observed. It can be attributed to ashes, which increase the thermal capability of the mass, keeping a higher heat in the piles (Koivula et al., 2004).

pH and conductivity

pH levels of substrates were increased by the incorporation of SCBA (Figure 2). Although an acid level in the pH was observed in MA, it was not a limitation for the beginning of the composting process and it might be explained due to the presence of easy biodegradable compounds. In Ms with SCBA, the acids generated by the organic matter transformation were neutralized and minimal decrease in pH values was observed, due to the alkaline compounds presented in the SCBA that buffers the acidity (An et al., 2012). In the case of MA, the initial acid values indicate the progress in the degradation of organic matter at the beginning of the process, which is an evidence of the secondary acid metabolites production in the microbial decomposition of easily degradable elements. During the composting the pH of the MA decreased from 4.7 to 2.9. pH decrease was very slow in MB and MC respectively from 5.4 to 5 and 5.9 to 5.7. The acids generated by the organic matter transformation were neutralized by SCBA. So addition of ash raised the pH values during the composting phase. During the curing phase, the pH value of the all Ms increased and reach recommended value 5.5, 5.9 and 6.7 respectively for MA, MB, MC. The acidification phase of the composting is shorter and milder, when SCBA is used and prevent a quick drop of pH during composting.

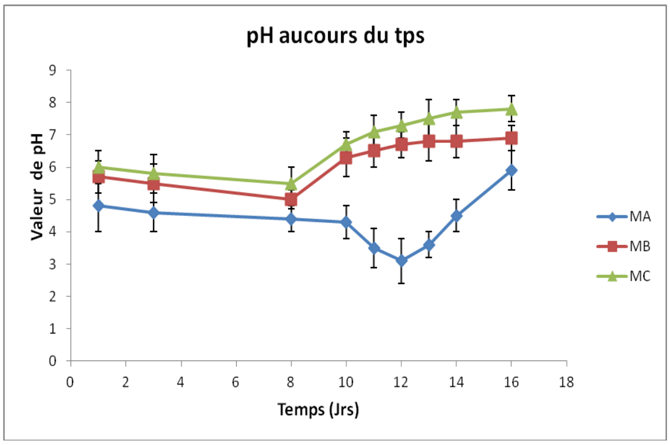

Fig.4. pH profile during composting

Electric Conductivity (EC): Conductivity is determined by ions, among others by sodium-, chloride- and nitrate-ions. The concentrations of soluble ions are relevant to the use made of composts.

A common disadvantage of compost as fertilizer is weakening of the water intake ability of plants through too high salt concentrations. The guideline for the conductivity of the mature compost is below 4 mS/cm (Anon., 1992). The addition of SCBA to the compost appears to raise the conductivity (Figure 3). The conductivities were below guidelines in all Ms, contrasted to what reported by Oviedo *et al* (2014).

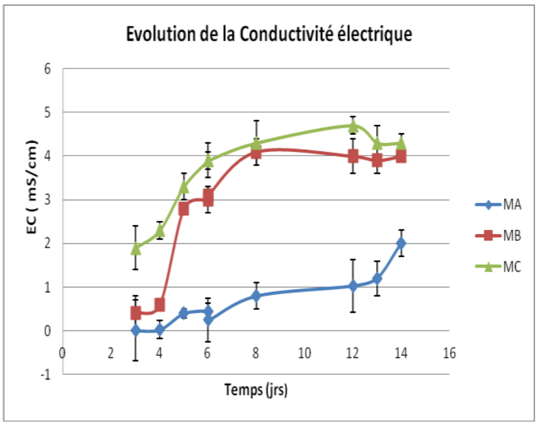

Fig.5. EC evolution during composting

Mineralization (Ash content)

Mineralization of the different mixtures “Ms” can be seen in Fig. 5. The relative increase of the ash content in the remaining mass through the degradation of the organic matter was 13% in the MA, 17% in the MB, and 23% in the MC. So mineralizations in MB and in MC were faster than mineralization in MA. During mineralization of compost the absolute ash content remains the same and organic matter decreases while CO_2 and H_2O are generated.

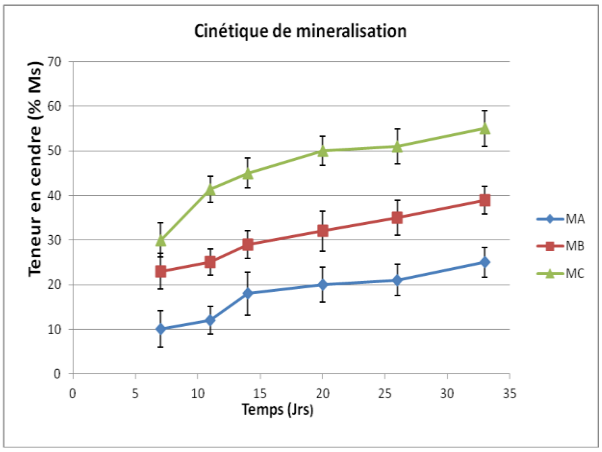

Fig.6. Ash content during composting

Nutrients: Product quality

The product quality is presented in Table 2

All Ms reached maturation and had soil smell. In addition, the color of the final products will be darker when SCBA is used in composting.
High values of pH were found in MB and MC, but all Ms don't exceeded limit value. Addition of SCBA effectively increased the macro- and micro-nutrients of the final products including phosphorus, potassium. The total P content was higher in the MB and C, but the phosphorus was in sparingly soluble form.
The total N content in younger samples was clearly lower in the MB and MC than in the MA. This might be attributed to the dilution by mixture with SCBA and by an improved mineralization. When the pH and temperature of the compost increases, the evaporation of ammonia increases (Koivula et al., 2004). The total N content of all composts exceeded the limit; it is recommended that the nitrogen content of the compost product should be greater than 0.8% of the dry matter (Anon., 1992).

	N (g/Kg MS)	P (g/Kg MS)	K (g/Kg MS)	pH
MA	**28±1.2**	**3.1±1,1**	**3.5± 0.08**	**5.6**
MB	**25±0.9**	**5.5±0.6**	**3.6± 0.37**	**5.9**
MC	**19±1.1**	**6.5± 0.2**	**4.3± 0.2**	**6.7**

IV. Conclusions

The acidification that occurs during composting can inhibited process. The results of our investigation demonstrate that addition of SCBA can jugulated it. SCBA increased the rate of mineralization of compost. Rapid degradation of the organic matter of MC was also observed. SCBA increments the pH level, buffering affect to the acid generated in the first phase of the process and improvement on the nutrient content and reduces the need to add mineral matter to the mature compost later. However an excessive increment on the pH level associated with thermophilic temperatures can propitiate losses of N by means of volatilization. The amount of ash in compost should not be too high (According to our experiment it seems that the amount of 20% is still acceptable). Increments on the presence of salts and phytotoxic elements during the process were observed with addition of SCBA. This can limit the product use for agricultural activities.
To further verify the compost quality as a suitable fertilizer, future work on some detailed as Heavy metal contents, if this don't exceed recommended values, other physicochemical and microbiological parameters, as well as the studies on larger scale process are needed.

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