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Valorization of Beer Brewing Wastes by Composting

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***Abstract*—**The aim of this work was to study the viability of recycling the residual yeast and diatomaceous earth (RYDE) slurry generated by the beer brewing industry by composting with animal manures, as well as to evaluate the quality of the composts obtained. Two pilot composting trials were carried out with different mixes: cow manure/RYDE slurry (Pile CM) and sheep manure/RYDE slurry (Pile SM). For all piles, wood chips were applied as bulking agent. The process was monitored by evaluating standard physical and chemical parameters. The compost quality was assessed by the heavy metals content and phytotoxicity. Both piles reached a thermophilic phase in the first day, however having different trends. The pH showed a slight alkaline character. The C/N reached values lower than 19 at the end of composting process. Generally, all the piles exhibited absence of heavy metals. However, the pile SM exhibited phytotoxicity. This study showed that RYDE slurry can be valorized by composting with cow manure.

***Keywords*—**Beer brewing wastes, compost; quality, valorization.

I. Introduction

THE brewing industry generates increasing quantities of liquid and solid wastes, which disposal and recycling represent an environmental problem. The RYDE slurry is a solid waste generated by beer production in the different steps of fermentation and clarification [1]. RYDE is an organic waste that must be valorized. In order to use it as soil conditioner a composting process should be applied to accomplish the organic matter (OM) decomposition and toxicity decrease. Composting is a biological treatment in which aerobic thermophilic and mesophilic microorganisms use OM as substrate. The main products of this process are mineralised materials (CO_2, H_2O, NH_4^+) and stabilised OM (mostly humic substances). The final product of composting can be defined as a stabilised material that can be used as an amendment in agricultural soils. Compost quality can be evaluated with several techniques, but there are two fundamental issues that should be considered before its agricultural or horticultural use: Its stability and maturity.

The aim of this work was to study the viability of recycling the RYDE slurry by composting with animal manures, as well as evaluate the quality of the composts obtained.

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II. Materials and Methods

A. Materials

The beer brewing waste studied was slurry with RYDE. The animal manures used as conditioning agent were cow and sheep manure. Wood chips were used as bulking agent. Two cone-shaped composting piles were made with 1.5 m high and 2 m base diameter. Pile CM contained cow manure, RYDE slurry and wood chips. Pile SM had sheep manure, RYDE slurry and wood chips. The raw materials were mixed allowing the final C/N ratio range between 20 and 35. The composting piles were turned manually every 3 days and slopped with water, in order to prevent excessive high temperatures, anaerobic conditions and dryness. Temperature was registered daily with a probe (HI 762PWL; Hanna Instruments) at three points of the piles. Samples of about 2 kg were collected and stored at 4 °C for further analysis. The sampling was done at the beginning of the composting process (T0), during active degradation (day 6 - T1 and day 23 - T2), at the cooling phase (day 35 - T3) and at the end of the process.

B. Methods

The monitoring process involved the evaluation, through time, of several physical and chemical conventional parameters. The analyzed parameters included: pH, electric conductivity (EC), moisture [2], organic, and ash matter content [3], total carbon [4] and total nitrogen content [5], C/N ratio and heavy metals. The heavy metals (Cd, Cr, Cu, Ni, Pb and Zn) were quantified using a Perkin Elmer atomic absorption spectrophotometer after digestion of calcined samples with HCl 3N for 16 h at room temperature, followed by ebullition and filtration. All analyses were performed in triplicate. The phytotoxicity was assessed through germination index (GI) with the aqueous extract obtained from the compost and was calculated based on the following equation:

$$GI = \frac{\overline{GS_s} * \overline{RL_s}}{\overline{GS_c} * \overline{RL_c}} * 100 \quad (1)$$

where $\overline{GS}$ represents the average number of germinated seeds and $\overline{RL}$ the average root length (mm) of seeds in samples – s, and the control – c tests.

III. Results and Discussion

A. Raw Materials

The cow manure, sheep manure and RYDE slurry were used as raw materials and the physicochemical characteristics are presented in Table I. These materials were non-acidic wastes. The RYDE slurry had the lowest value for almost all parameters analyzed, except for the ashes content and consequently inorganic fraction. Moreover, the animal manures showed similar values for almost all parameters studied. The slurry TN and TOC content were approximately 2 and 9 times lower, respectively, than in the others raw materials. Thus, the C/N ratio of RYDE slurry was the lowest (8.3). Heavy metals such as chromium and cadmium were not detected in the raw materials. The highest concentrations of heavy metals were zinc and copper. The levels of heavy metals found in sheep manure were in the range of those reported before [6]. According to the literature, the composition of the animals feed and the efficiency of their conversion contributed for the heavy metal contents in animal manures [7]. The mineral elements are usually added as mineral additives to the animal feed because they act as growth-stimulating [8].

TABLE I
PHYSICOCHEMICAL CHARACTERISTICS OF THE RAW MATERIALS

Parameters	Cow Manure	Sheep manure	RYDE slurry
Moisture (%)	66.8	62.1	61.2
pH	8.60	8.25	7.04
EC (mS/cm)	4.11	3.03	0.57
OM (%, dm)	90.7	85.1	10.1
Ashes (%, dm)	9.29	14.9	89.9
TOC (%)	45.4	42.5	5.04
TN (%)	1.32	1.64	0.61
C/N ratio	34.4	25.9	8.27
Zn (mg/kg dm)	120	185	6.58
Ni (mg/kg dm)	8.98	11.6	2.80
Cu (mg/kg dm)	29.8	53.0	7.0
Pb (mg/kg dm)	11.2	19.5	2.8
Cr (mg/kg dm)	<LD	<LD	<LD
Cd (mg/kg dm)	<LD	<LD	<LD

TOC – Total Organic Carbon, TN – Total Nitrogen; dm – dry matter; LD - limit of detection (Zn: 1.3 mg/kg, Cu: 2.0 mg/kg, Ni: 0.3 mg/kg, Cr: 2.3 mg/kg, Cd: 0.3 mg/kg, Pb: 3.7 mg/kg)

B. Composting Process

In this study, RYDE slurry was co-composted with organic carbon-rich materials because they behave as conditioning agents, allowing the C/N ratio increase. As reported in the literature, the length of the animal manures composting can be established considering that it is necessary 60–150 days to convert manure into stabilized compost by windrow system with manual turning [9]. The temperature trend during composting was obtained considering the average values registered in three points of the piles (top, middle and bottom) and the results are shown in Fig. 1.

The short-term decrease in temperature is coincident with the days of piles turning (data not shown). The temperature in both piles immediately increased from the beginning, reaching the thermophilic temperature (> 45 ºC) in the first day. Generally, the average temperatures above 45 ºC were sustained until day 6. The presence of additional C-compounds from the organic amendments allowed the achievement of thermophilic phases in both piles, suggesting good microbial growth. In this case, the active degradation ended at day 23, following the cooling phase until day 35. After that, the temperature of both piles reached the ambient temperature, starting the maturation phase. This phase was maintained until day 70. The evolution of the physicochemical parameters during the composting process is shown in Table II.

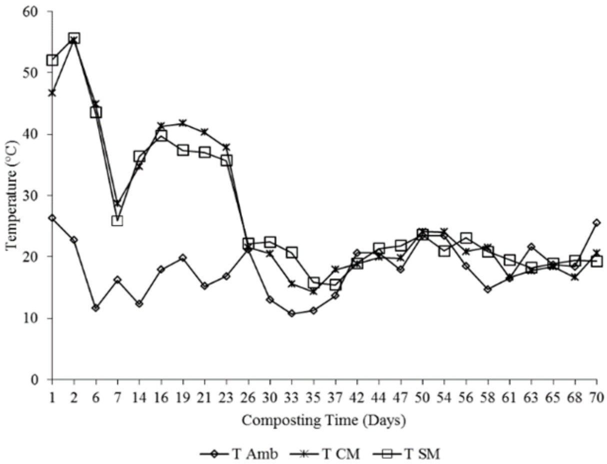

Fig. 1 Temperature profile during composting process

TABLE II
PHYSICOCHEMICAL PARAMETERS DURING THE COMPOSTING PROCESS

Parameters	T0		T1		T2		T3	
	CM	SM	CM	SM	CM	SM	CM	SM
pH	8.22	8.85	8.26	9.23	8.22	8.74	8.50	9.21
EC (mS/cm)	2.96	7.52	3.93	5.44	2.53	5.40	3.52	6.19
OM (%, dm)	72.2	77.1	63.3	63.4	67.2	58.0	61.8	58.5
Ashes (%, dm)	27.8	22.9	36.7	36.7	32.8	42.0	38.2	41.5
TOC (%)	36.1	38.6	31.6	31.6	33.6	29.0	30.9	29.2
TN (%)	1.01	1.87	0.86	1.05	0.85	1.11	1.62	1.37

All the piles showed similar trend in pH profile. Globally, the pH values showed a slight alkaline character. The increase of the pH observed may be related with the ammonium production from the protein degradation, followed by the NH_3 production. Generally, as the composting process develops, the NH_3 volatilization caused by the thermophilic phase [10]. However, these piles did not follow the typical variation for this parameter. Pile SM registered the highest EC, ranging between 5 and 8 mS/cm. The EC variation during the CM pile composting of is the expected, since the EC increases. These values reflect the salt content and ammonium ions from the decomposition of OM. During composting process, the volatilization of ammonia and precipitation of mineral salts promote the EC decrease [11]. This parameter may be important at various levels, namely the inhibition of microbiota, the leaching of salts with the consequent environmental contamination, and the inhibition of germination crops if compost is to be used in agriculture. The OM content decreased during the composting process from approximately 72–77% to 62% and 59% in piles CM and SM, respectively, showing the removal of OM through microbial activity and/or abiotic losses.

According to the mix of the different materials, in the beginning of composting, the C/N ratio ranged between 20 and 35 (Fig. 2).

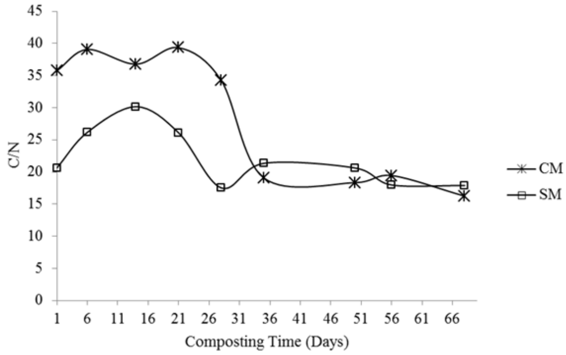

Fig. 2 C/N ratio evolution during composting process

Carbon and nitrogen consumption by the microorganisms and/or abiotic compounds losses throughout the active composting process resulted in changes in the piles C/N ratio. These values decreased to approximately 16 and 18 in piles CM and SM, respectively. Pile CM, with the highest C/N ratio, showed a significantly decrease in the first 31 days of composting. But in pile SM this ratio decrease was gradual. The major C/N decrease occurred at the end of active degradation (Fig. 1), which confirmed the OM stabilization.

C. Compost Characterization

TABLE III
COMPOSTS CHARACTERIZATION

Parameters	Compost	
	CM	SM
Moisture (%)	64.8	63.0
pH	8.80	9.23
EC (mS/cm)	3.54	5.30
OM (%, dm)	46.2	58.0
Ashes (%, dm)	53.8	42.0
TOC (%)	23.1	29.0
TN (%)	1.42	1.61
C/N ratio	16.3	18.0
Zn (mg/kg dm)	151	45.9
Ni (mg/kg dm)	12.4	6.54
Cu (mg/kg dm)	22.1	11.7
Pb (mg/kg dm)	17.4	12.0
Cr (mg/kg dm)	<LD	<LD
Cd (mg/kg dm)	<LD	<LD
GI (%)	61.3	48.2

LD (Zn: 1.3 mg/kg, Cu: 2.0 mg/kg, Ni: 0.3 mg/kg, Cr: 2.3 mg/kg, Cd: 0.3 mg/kg, Pb: 3.7 mg/kg).

After 70 days of composting process, the composts were characterized and its physicochemical properties are shown in Table III. The final pH values of the composts were within the optimum range of 6-9. Pile CM showed EC lower than 4 mS/cm at the end of the process. All final composts presented lower contents of total carbon and higher content of ash than animal manures (Tables I and III), indicative of mineralization of OM. In all piles, a slight decrease in the percentage of total carbon was observed during the maturation phase, and consequently the final C/N decrease. A final C/N ratio of 20 or less indicates a mature compost [12].

The absence of harmful concentrations of heavy metals and the GI value in compost CM are advantageous if it is to be further used as organic amendment in agricultural soils. Nevertheless, the concentration effect due to net loss of dry mass associated with the release of mineral salts from the decomposition of OM may contribute to the rise of EC values. As already said above, the EC showed the degree of salinity in the compost, indicating its possible phytotoxicity if applied in soil. Both composts had higher electrical conductivity than the raw materials. The highest value was found in SM compost (5.3 mS/cm) (Table III), which is higher than 4 mS/cm, the higher limit considered tolerable by plants of medium sensitivity [13], explaining its low GI.

IV. CONCLUSIONS

The composting of brewing beer wastes has been demonstrated to be an effective method for producing stabilized end-products, ensuring their maximum benefit for agriculture. The conditioning agents used were valuable; however, the cow manure seems to ensure the best conditions to the composting process. Both composts have quality; nevertheless, the compost from co-composting with sheep manure should be improved in order to decrease its toxicity and, therefore improve the GI. This toxicity seems to arise from the EC, probably the most critical parameter in the compost.

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