

Stabilization of Spent Grains by Composting: Case of the BB Brewery in Lomé (Togo)

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How to cite this paper: Magnoudéwa, B.B., Mèhèssa, K.S.-A., Lankondjoa, K. and Dihéénane, B.D. (2022) Stabilization of Spent Grains by Composting: Case of the BB Brewery in Lomé (Togo). *American Journal of Analytical Chemistry*, 13, 175-185.
<https://doi.org/10.4236/ajac.2022.135012>

Received: March 29, 2022

Accepted: May 20, 2022

Published: May 23, 2022

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Abstract

Brewery grains have a long history in animal feed. This use in animal feed nevertheless poses a problem, that of bad odors due to the sometimes too long shelf life of spent grains. The objective of this work is to recover spent grains from the BB brewery in Lomé by composting in order to stabilize them. A compost based solely on spent grains was produced after 5 months. The physico-chemical and spectroscopic characterizations at the end of the composting process revealed that the compost obtained has interesting properties with a pH = 7.01; a C/N ratio of 13.7 and a low level of heavy metals (Pb = 1.23 mg/kg, Cd = 0.04 mg/kg etc.).

Keywords

Spent Grains, Compost, Composting, Agriculture, Heavy Metals

1. Introduction

One of the problems, and not the least, during the production of beer is the large amount of solid waste (spent grains) generated. This quantity of waste is now accentuated by the constantly growing number of breweries around the world, *i.e.* up to 300 grams of spent grains for 1 liter of drink [1]. Togo now has two large breweries (the “Brasserie BB Lomé” created since 1964 and the “Société Nouvelle de Boissons” SNB which was created in May 2020), which increase the production of spent grains nationally.

Several sectors of implementation of spent grains from the brewery have been identified. We can cite: the production of biofuel, amendment and compost, an-

imal feed, production of biogas, use as an adsorbent, etc. [2] [3]. In Togo, spent grains from the brewery are used more in the feed of pigs and poultry according to a field survey. However, conclusive trials of co-composting spent grains and water hyacinths have been carried out on the composting platform of the NGO ENPRO “Ecosystème Naturel Propre” in Lomé. The experiments were not repeated because of the excessive access costs (collection, purchase, transport) [4].

Even if the composting of spent grains proves to be difficult and expensive, their transformation into compost before spreading has more advantages because the compost, by its high content of humic matter, promotes the formation of clay-humic complexes and contributes to the good structuring of the soil, thus favoring root penetration. It plays a role in soil fertilization but also in the transport, immobilization and degradation of organic and mineral species such as pesticides, polycyclic aromatic compounds and heavy metals in soils or water [4] [5].

Composting has now become one of the most widely used means in developing countries (DCs) to recover fermentable waste and reduce waste volumes [6]. This work is part of this perspective with a view to valuing the spent grains of the brewery. The challenge to be taken up in this research is to produce a compost based solely on spent grains and to list the techniques allowing a good yield to be achieved.

2. Material and Methods

2.1. Worksite

The site used for composting is the Agronomic Valorization Platform for Poultry By-Products. This platform is located in the premises of the Agronomic Experimentation Station of the University of Lomé. The GPS coordinates of this site are: latitude 6.174244 and longitude 1.210057. This site is laid out to shelter the windrows and protect them from bad weather (see **Figure 1**).



Figure 1. Photo of the worksite.

2.2. Raw Material Used

The spent grains used for this work come from the “Brasserie BB” in Lomé. These spent grains were dried in the sun for 14 days to reduce the humidity in order to avoid their decomposition. Spent grains generally come from cereals such as barley, maize, rice, wheat and sorghum. They are rich in protein and fiber (cellulose, hemicellulose and lignin). The minerals usually contained in spent grains are silicon, phosphorus, calcium, magnesium, sulphide, potassium, etc. [2] [3] [7] [8].

2.3. Conduct of Composting

A total of three hundred kilograms (300 kg) of dried grain was composted. A swath was formed in two fractions of 150 kg each (see **Figure 2**). Each fraction is sprinkled with potting soil to activate the compost with the micro-organisms. About 264 liters of water were needed to moisten each fraction. The swath was covered with plastic sheet with holes drilled to allow good ventilation. The temperature was taken daily. Watering and turning were carried out each time a drop in temperature was observed in the compost. The frequency of reversal varies between three and fourteen days.

3. Physico-Chemical Analyzes

3.1. Measurement of pH and Electrical Conductivity EC

For pH measurement, 20 g of dry sample (dried in the shade) was dissolved in 50 ml of distilled water and then subjected to stirring for 30 minutes and then left to stand for 2 hours. For EC measurement, a sample/distilled water mixture in a ratio of 1/5 was stirred for 3 minutes and then filtered. The measurements were taken using a multifunctional device model MP522 (pH: ± 0.002 pH; conductivity: $\pm 0.5\%$ FS).

3.2. Determination of Moisture Content

The compost samples were taken after the maturation period and weighed, then put in an oven at 105°C for 24 hours. After cooling, these samples were weighed again for the calculation of the moisture content.



Figure 2. Steps in the formation of spent grain compost heaps. (a) Weighing. (b) First fraction of the heap.

3.3. Mineralization and Solubilization of Samples for the Determination of Minerals

For the determination of the chemical elements cadmium Cd, lead Pb, potassium K, phosphorus P and arsenic As, the solubilisation method used is mineralization by acid attack (mixture of hydrochloric acid at 35% purity and nitric acid at 67% purity) according to standard NF ISO 11,466 (method with aqua regia) [9]. 10 ml of 10% hydrogen peroxide (H₂O₂) is added beforehand to each sample of compost due to the presence of organic matter before the acid attack after 24 hours. The samples, after acid attack and reflux heating (120°C - 150°C), are filtered using Whatman N°1 filter paper with a porosity of 11 µm. The filtrate obtained contains chemical elements to be dosed. The dosage was carried out using the atomic absorption spectrophotometer (AAS) of the brand iCE 3000 SERIES THERMO FISCHER. The arsenic is notably analyzed using an atomic absorption spectrophotometer (SOLAAR S2 THERMO FISCHER brand) coupled to the VP100 hydride generator.

To dose the nitrogen, 1 g of finely ground sample at 50 µm was mineralized in 4 ml of concentrated sulfuric acid ($\rho = 1.84 \text{ g/ml}$). The samples, after acid attack and heating, are filtered using Whatman N°1 filter paper with a porosity of 11 µm. The dosage was performed using a molecular absorption spectrophotometer (HACH DR 3800).

All reagents used were purchased from Sigma-Aldrich.

3.4. Total Carbon TOC and Organic Matter OM

The method used for TOC determination is that of WALKLEY and BLACK modified [10] [11]. The organic matter content is deduced by multiplying the TOC by 1.724.

4. Results and Discussion

4.1. Temperature Control; Composting Time

Figure 3 shows the evolution of temperatures during composting. Temperatures fluctuated between 45°C and 66°C during the first four months (16 weeks). These temperatures gradually drop during the fifth month to stabilize at a temperature close to room temperature (about 28°C). The highest temperatures (55 to 66°C) were observed in the compost from the fifth to the tenth week. The duration of the temperature peaks observed shows that the compost has had the time necessary for good hygienization. For composting in the open air, a temperature of 55°C for 5 days is necessary for good sanitation [12] [13].

The temperature evolution clearly shows the microbiological activities that have taken place. Indeed, the thermophilic phase (55°C - 60°C) started in the compost from the fifth week. This delay in the thermophilic phase would be due to the low carbon/nitrogen C/N ratio (<20) of spent grains [7]. In the composting process, microorganisms use 15 to 30 times more carbon than nitrogen to produce energy [4]-[14]. It is the production of this energy that is responsible for the rise in

temperature of the compost. Moreover, when the C/N ratio is low, the excess nitrogen is lost in the form of ammonia by volatilization resulting in strong odors [12] [13] [14] [15]. When the excess nitrogen has decreased sufficiently, the C/N ratio increases, which would trigger the thermophilic phase. The choice of activators (bacteria and fungi) also plays an important role in the degradation rate of raw materials rich in lignin and hemicellulose such as spent grains. Adding specific fungi like *Aspergillus* and *Penicillium* would degrade lignin and hemicellulose faster [16].

4.2. Moisture Content

The moisture content measurement was performed on compost samples at the end of the composting process (after 20 weeks). According to the results obtained (Table 1) all the compost samples have a moisture content between 50 and 44%. This should normally allow the micro-organisms to be able to continue the degradation of the organic matter. This is not the case since the stable temperatures close to ambient temperatures (between 27°C and 30°C) prove an absence of decomposition of matter. This stability could be explained by the maturity

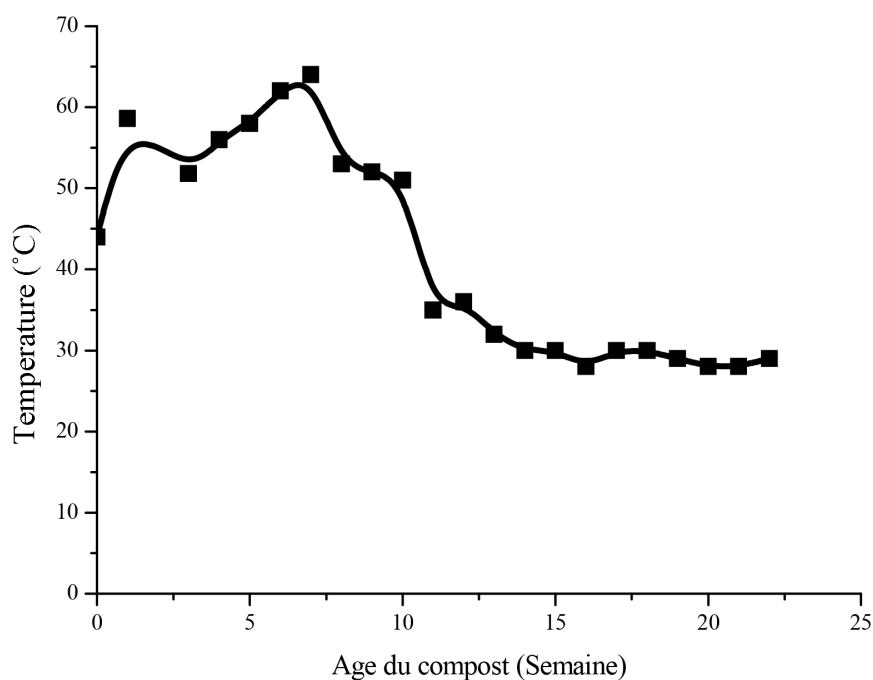


Figure 3. Evolution of temperatures during composting.

Table 1. Moisture content in different compost samples.

Compost	WM	DM	%H
Sample 1	10.00	4.98	50.20
Sample 2	10.00	5.52	44.80
Sample 3	10.00	5.25	47.50

WM: wet matter; DM: dry matter; %H: moisture content.

of the compost which looked like compost. The optimum humidity for the metabolic activity of microorganisms is between 45% and 65%. At the end of composting, it can drop to 30% [17] [18].

4.3. Compost pH

The pH measurement was performed on the raw material and on the compost samples during the composting process (Figure 4).

After approximately 5 months of composting, the compost has a neutral pH of 7.01, which complies with the French standard NFU 44-051 which provides for a pH between 7 and 8. Indeed Figure 3 shows that the mesophilic and thermophilic phases (between 40°C and 70°C) persisted in the compost. This would have allowed a good degradation of the organic matter and led to a higher final pH. It is well known that thermophilic microorganisms drive most composting processes [19].

4.4. Electrical Conductivity EC

The measurement of the electrical conductivity of the samples taken during the 150 days gave the results illustrated in Figure 5. This Figure shows a decrease in

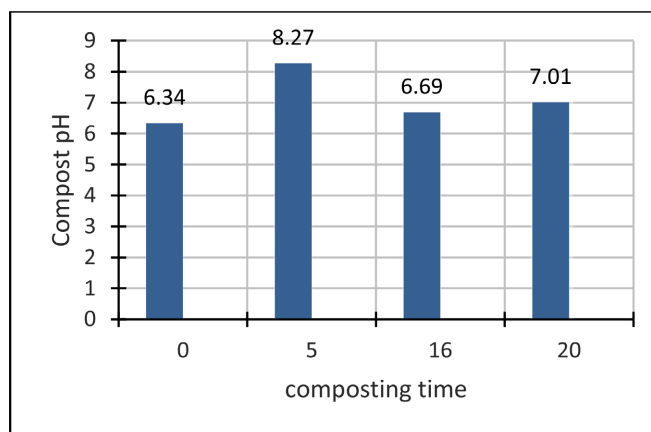


Figure 4. Evolution of compost pH during the process.

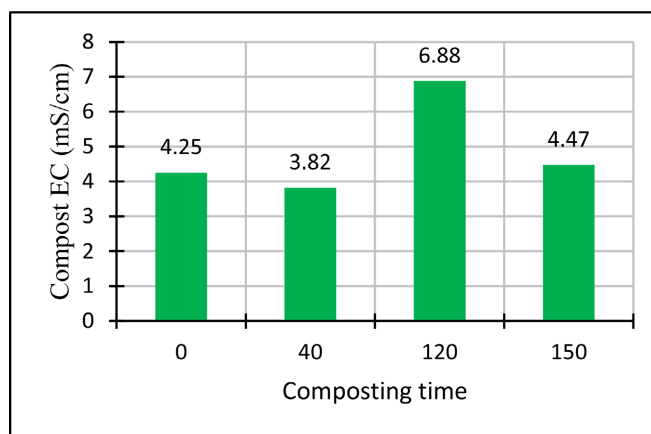


Figure 5. Evolution of the electrical conductivity of the compost.

EC in all the samples of the compost between 0 and 40 days (4.25 to 3.82 mS/cm) then between 120 and 150 days (6.88 to 4.47 mS/cm). This decrease is due to the fixation of the compost salts by the organic matter which was more stable at the beginning and at the end of composting. Another factor in the decline of the EC could be the washout due to rain. This decrease could also be explained by good ventilation during these periods. Michel & Reddy in 1998, starting from a conductivity waste of 2.5 mS/cm, note that: the conductivity is 3 mS/cm in the case of a well aerated compost and exceeds 7 mS/cm in the case of the same aerated composted waste [20].

There is an increase in the EC of all compost samples between 40 and 120 days. This increase could be explained by the mineralization of organic matter which is the main reason for an increase in EC. Indeed, when referring to the temperature evolution curve (Figure 3), the period of intense microbiological activity begins around the fifth week (35 days) and ends around the tenth week (70 days). This is the period during which the microorganisms would have degraded the OM the most, which would explain the elevation of the EC. It should be noted that the salinity of 4.47 mS/cm of the compost obtained is too high and could lead to a delayed growth or “stress” of the plants. The acceptable salinity is about 0.00213 mS/cm [21].

4.5. Total Carbon TOC, Organic Matter OM and Total Nitrogen NTK

These three parameters were determined on compost samples after a period of 150 days according to the protocols described above. The results are grouped in Table 2.

- Evolution of TOC and OM

OM generally decreases during the composting process following the mineralization of organic matter by micro-organisms [22]. The presence of organic matter resistant to degradation therefore contributes to the increase in organic matter. This is the case of lignin, which causes the humus formation of composts and which greatly contributes to the determination of OM at the end of composting [22]. This content also depends on the initial OM content, the humidity and the rotation frequency [23].

The organic matter obtained in the compost is 49.60%, which shows that the compost is rich in organic matter and well above the lower limit provided by the French standard (>20) [24].

Table 2. TOC, OM and NTK assay results.

Chemical parameter	Result (%)
COT	28.77
MO	49.60
N	2.10
C/N	13.70

- Evolution of total nitrogen

The results obtained showed a high nitrogen rate in the compost samples at the end of composting (2.10%). According to Mustin (1987), the increase in the percentage of total nitrogen during the composting process comes from the degradation of proteins in the raw materials under the effect of heat and micro-organisms [25]. The result obtained is therefore coherent, because spent grains are rich in proteins. Moreover, the temperature curve (**Figure 3**) shows that the microbiological activity was intense in the compost, which would have favored the mineralization of organic nitrogen. We can also assume that part of the increase in nitrogen comes from the residues of microbes and bacteria which multiply in particular during the first phase of the composting process.

- Evolution of the carbon/nitrogen C/N ratio

According to several authors, the final C/N ratio should be between 10/1 and 15/1 [4]-[17]. The compost obtained has a C/N ratio equal to 13.70 which is within this range. During the composting process, the C/N ratio decreases due to the release of carbon in the form of CO₂ [26].

4.6. Dosage of Phosphorus P and Potassium K

Phosphorus and potassium are important minerals in evaluating the fertilizing value of compost. The results of the assays carried out on samples of compost at the end of maturation are presented in **Table 3**.

We note from the results obtained that the quantity of potassium (K₂O% = 0.1166) in the compost complies with the NFU 41055 standard (<3) but remains low compared to that of the household waste composts obtained by Koledzi in 2011 (1.51 to 1.98) [6].

It can be seen that the compost obtained is very rich in phosphorus (P₂O₅% = 1.3500) compared to the French standard NFU 44051 (0.7 - 0.9) but comparable to the result obtained in 2011 by Koledzi for composts from garbage whose content (%) of P₂O₅ varied between 1.36 and 4.47. This could be explained by the fact that spent grains (wheat and maize) are rich in phosphorus [26]. Phosphorus losses are reduced because spent grains are rich in nitrogen. When a waste is low in nitrogen, it is the phosphorus that the micro-organisms consume for their growth.

4.7. Dosage of Heavy Metals ML: Lead (Pb), Cadmium (Cd) and Arsenic (As)

Analyzes with the atomic absorption spectrophotometer (AAS) made it possible to obtain the contents of elements Pb, Cd and As of the compost obtained. **Figure 6** shows that the Pb, As and Cd rates (respectively 1.2300; 0.08622 and 0.0400

Table 3. Potassium and phosphorus content of compost.

Parameter	Result (%)
K ₂ O	0.1166
P ₂ O ₅	1.3500

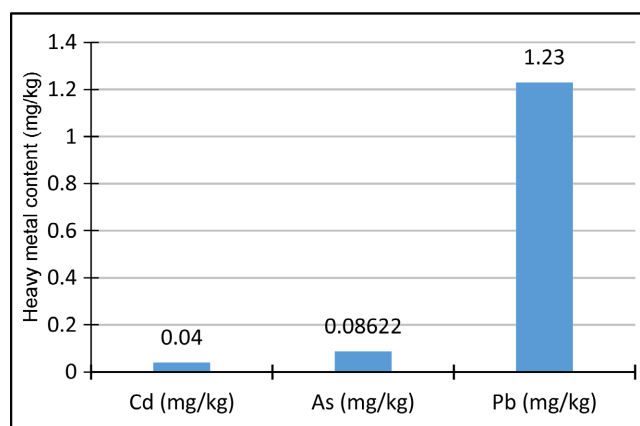


Figure 6. Rate of certain heavy metals in compost.

mg/kg) in the compost obtained are very low compared to those provided for by the French standard NFU 44051, namely: 180; 18 and 3 mg/kg respectively for Pb, As and Cd. The compost obtained does not therefore constitute a source of toxicity of heavy metals for the soil.

5. Conclusions

This work made it possible to carry out the composting of an agro-food product (spent grains from the BB brewery in Lomé). Temperature control during the composting process revealed that the highest temperatures were between 60°C and 68°C. The activity of thermophilic micro-organisms was optimal at these temperatures. After five months of composting, physico-chemical analyzes were carried out to assess the degree of maturity and the agronomic value of the compost. These results show that the pH of the compost obtained is neutral (7.01). The EC measurement (4.47 mS/cm) shows that the compost is rich in minerals like phosphorus and potassium. As for OM (49.60%), it is also high and in line with French standards. All the compost samples have negligible heavy metal contents and are not toxic for agronomic recovery.

These results lead to the conclusion that the valorization of spent grains, from togolese breweries, in composting is possible but would require an input of carbonaceous materials (co-composting) to increase the C/N ratio of the raw materials before the composting.

The contribution of a compost rich in OM, which would contribute to increase the pH of the ground and to decrease the Redox potential would be a solution to retain the ETM in the ground.

Acknowledgements

Thanks to the financial partners (European Union and the World Bank) who financed this project whose work was carried out in the City of Tsévié in Togo.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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