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Study of the Feasibility of Guts Waste Valorization by Composting

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ABSTRACT

In this research, a hot composting experiment was carried out with a mixture of three waste fractions; guts 50%, manure 30% and dead leaves 20%. The experiment showed that the resulting compost has a high-level organic substance content and a minor salt content that can be a healthy soil amendment. However, the experiment did not evaluate the compost mass evolution during 45 days of the mechanism. The main aim of this work tried to improve the performance of valorization by reducing the duration of composting, evaluating its economic efficiency (monitoring of mass), and improving the qualitative efficiency. To this effect, the feasibility study aimed to rapidly compost a mixture of 50% underground guts waste and 50% manure over a period of 23 days. The results proved that the C/N rate and electrical conductivity of the compost obtained is above the limits requested by most standards. Moreover, the temperature recorded of the heap did not exceeded 39.53°C at any day of composting. Nevertheless, the economic efficiency reached 47.9%.

Keywords: Berkeley rapid composting, guts, sheep manure, valorization, physical efficiency.

INTRODUCTION

The huge demographic growth and industrialization that has taken place across the globe have caused in a high production of industrial wastes, posing a serious challenge to researchers (Varjani et al. 2021) and decision-makers. Most of those industrial wastes are generated by agro-industrial activities. These wastes may be inorganic or organic residues. Disposing of them in the environment without any treatment will lead to the deposition of pollutants in the ecosystem, which will affect humans and other living beings (Saravanan et al. 2017; Varjani 2017). However, several economic benefits can be derived from agro-industrial waste management, including: lower waste treatment costs, prevention of environmental contamination (He et al. 2019), as well as the conversion of waste into enriched products such as pet food, biofuels and biofertilizers (Mishra et al. 2020; Patel et al. 2021). This management can be divided into 4 classes, namely waste minimization or waste reduction, conversion, segregation and utilization (Yaashikaa et al. 2022). The first type to be considered in the various stages of such management is waste reduction and minimization (Hiloidhari et al. 2014; Rao and Rathod 2019). Furthermore, waste conversion is viewed as an important and effective step in waste reduction (Mostafa et al. 2018).

Materials that are obtained from various processes of industries related to agriculture, such as the production of agricultural products like fruit, meat and vegetables, are qualified agro-industrial waste (Yaashikaa et al. 2022). In addition, a scientific research has summarized all the value-added products that can be obtained from meat waste used for fertilization (Sharma et al. 2020). The composting process is one of the conversion techniques that transform organic waste into nutrient-rich fertilizers. This technique is considered as a bio-oxidative mechanism implying oxidation and partial humification of organic substance, resulting in a stabilized final output, exempt from phytotoxicity and pathogens as well as presenting some humic characteristics (Ayed et al., 2021). Air supply is the main factor influencing the rate of the composting operation (Raut et al., 2008). The process begins by forming the pile. In many situations, the temperature rises rapidly to 70–80°C over the first two days. At the beginning, mesophilic organisms, whose optimal growth temperature is between 15 and 45°C, multiply rapidly (Finore et al., 2023; Pellejero et al., 2015). They produce heat by their own metabolism and lead to a situation where their own activities are restricted. Then, many thermophilic bacteria, whose optimal growth temperature is between 45 and 70°C, continue the process (Finore et al., 2023; Pellejero et al., 2015). This temperature increase is crucial for the quality of the compost, because the heat eliminate harmful pathogens and weed grains. The active phase of composting come to end when a maturation period begins and the temperature of the heap gradually decreases. The beginning of this phase can be recognized, when turning of the pile no longer increases the temperature of the mixture.

The casing waste that is generated by agri-food industries specializing in the processing of natural sheep casings, such as Boyauderie El Amal, can be valorized by conversion into a value-added product. Therefore, the valorization of casing wastes produced by Boyauderie El Amal Company was initiated for the first time in 2014 through the method of Windrow co-composting. This method has shown that composting can be considered as a solution for the recovery of the factory waste instead of burying it at the landfill of Beni Mellal. This last operation could be in the long term a costly solution for the factory, given that the quantity of waste generated exceeds 10 tons per week. This experiment of valorization, the objective of which was the examination of the qualitative feasibility of composting gave promising results as regards to the quality of the final output, in particular, the lack of certain pathogens like salmonella and the weak concentration of the others, such as fecal coliforms (Makan 2015). This composting experiment confirms that this process allows, in addition to the reduction of environmental pollution, destruction of the majority of pathogens (Erickson et al., 2004).

However, this experiment of windrow co-composting of casings (50%) mixed with manure (30%) and dead leaves (20%) shows that this process requires 45 days to obtain a compost with a turning interval of 3 to 4 days. Nevertheless, the company aims to optimize more the necessary time and to obtain an idea about the economic efficiency (quantitative performance) of the process in order to assess the financial feasibility of a composting waste recovery plant. To this end, the present work aimed to study the qualitative and quantitative feasibility of the process by the Berkley rapid composting method of a mixture of casing (50%) and manure (50%).

RAPID COMPOSTING METHOD

The old method of composting consisted of piling up organic materials and allowing them sit for a long time with or without a turning operation. The principal benefit of this technique is the fact that it does not require much effort for the composter. However, there are many disadvantages, such as; the need for a large space, the possibility of leaching of some nutrients due to their exposure to precipitation, the presence of some weeds and the lack of insects and weed seeds control (Nanyuli et al., 2018). Recently, a new technique solves some of the troubles associated with the ancient method of composting. With this process of rapid Berkley composting, compost can be made in 2 to 3 weeks with a turning frequency ranging from 3 times a week to once a day (Nanyuli et al., 2018).

PARAMETERS INFLUENCING THE COMPOSTING MECHANISM

The composting mechanism of organic matter is influenced by multiple factors. These factors are generally devised in three categories; those depending on the composition of the initial compost mixture such as, the balance of nutrients (C/N), types and sources of these elements; and those related to the environment such as pH, temperature, humidity and aeration; and finally, those depending on the process, rise and fall of temperature, aesthetic changes and molecular changes (Diaz and Savage 2007).

MATERIAL AND METHODS

Characteristics of the casing mixture

The casing wastes are very wet and difficult to handle during the composting operation. This is why another material, mostly dry, must be mixed with these wastes. For this purpose, a fraction of 50% of manure is mixed with these casings to finally obtain two separated piles of 100 kg each one. Then, in order to have a representative sample of the pile, a layer by layer spreading of each fraction was carried out, followed by a slow turning for a good mixing of the two fractions. Afterwards, the mixture was piled into a windrow (Figure 1a) with a height of less than 50 cm and a surface area of no more than 2 m^2. The ambient temperature and humidity recorded at 4:00 o'clock pm were 39.3°C and 26.5%, respectively. On the same day, the samples were taken and sent to the LACQ laboratory in Meknes in Morocco for analysis in accordance with French and European standards. The analytical results of these samples are reported in Tables 1 and 2.

Compost platform preparation

Experiments showed that the best technology for a good composting process is the enclosure of the compost piles inside the halls (JRC 2015). Nevertheless, this technology may present a danger of subjection of workers and local neighbors to gaseous emissions. Under the conditions of composting, carbon monoxide is rarely recorded within the process (Sobieraj et al., 2021). Therefore, in order to ensure good conditions, a platform covered only at the top by a plastic sheet was set up to avoid any incidence of rainwater infiltration to the heap with the use of plasticized wooden plate as support of the heap.

Afterwards, the casing wastes transported by plastic bags, was spread and mixed successively layer by layer with manure in order to have at the end of the process, a heap in the form of windrow of 50 cm height (Figure 1b).

Turning and measurement

Once the heap is piled, the biodegradation has started; the only technique to improve air supply is the turning operation. In fact, turning first solves the nuisance of odor encountered over the composting cycle, since a high concentration

Figure 1. (a) Composting platform (b) pile preparation

Table 1. Microbiological characteristics of the pile in the initial state

Bacteria	Unit	Results
Thermotolerant coliforms at 44°C	cfu/g	<10
Salmonella	/25g	Not detected
Escherichia coli at 44°C	cfu/g	<10
Clostridium perfringens	cfu/g	$<4.10^{1}$

Table 2. Physico-chemical characteristics of the pile in its initial state

Parameter	Results	
	Dry	Raw
Dry matter (%)		61.5
Moisture (%)	38.5	
Hydrogen potential (pH)		7.6
Electrical conductivity (ms/cm)		16.7
Loss on ignition of DM (g/kg)	68.2	41.9
Organic carbon (%)	34.1	
Total nitrogen (%)	2.58	1.59
C/N ratio	13.20	
Phosphorus (%)	0.73	0.45
Potassium (%)	1.98	1.22
Magnesium (%)	0.72	0.44
Calcium (%)	2.62	1.61
Zinc (mg/kg)	37.20	22.80
Copper (mg/kg)	11.60	7.10
Manganese (mg/kg)	90.20	55.50
Iron (mg/kg)	2811.20	1728.90

of methane (CH_4) and carbon dioxide (CO_2) has been reported with a low rate of air supply (Bernal et al., 2009). The frequency of turning is also crucial for the composting time (Kumar et al., 2018). While the windrow co-composting method with a 3 to 4 days turn-over requires a minimum of 6 to 7 weeks to be matured, the Indian Coimbatore method, with a single turn-over, requires four months. In addition, three months are required for the Chinese rural method of composting in pits (heap turned three times). In contrast, with a Berkley Rapid Composting method, where turning is done daily, the final compost is obtained after 14 days. In some situations, turning not only disperses air throughout the pile, but also avoids overheating by eliminating microorganisms in the heap and stops decomposition (Nanyuli et al. 2018). In fact, turning too often can be a factor in decreasing the temperature. For this purpose, the pile is turned every day during the 23-day process. The temperature and humidity measured each time before turning the pile are presented in Figures 2 and 3.

Compost analysis

After 3 weeks of composting (23 days), samples of the final compost were taken, which were sent on the same day of collection to the LACQ laboratory for analysis. The results obtained are given in Tables 3 and 4.

RESULTS AND DISCUSSION

Temperature

Temperature and humidity are key factors in the composting mechanism. This exothermic process (composting), which takes place at the pile level, produces a relatively large amount of energy. Part of this energy (40–50%) is utilized by the microorganisms to synthesize ATP, and the remaining is dissipated as warmness in the pile. This heat is the main cause of the temperature increase, which can reach levels of 70° to 90°C (Diaz and Savage 2007). This process is called by Finstein; "microbial suicide" (Zöhrer et al., 2021). However, a temperature of 30 to 55 °C allows a maximum

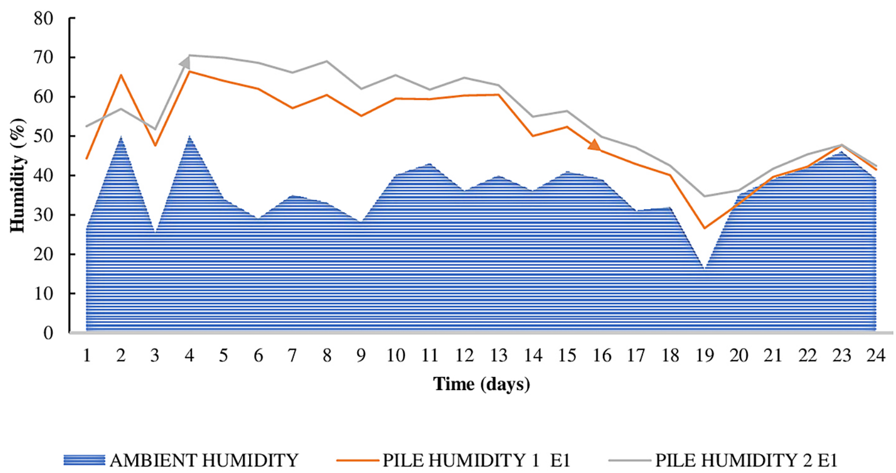

Figure 2. Humidity evolution of piles

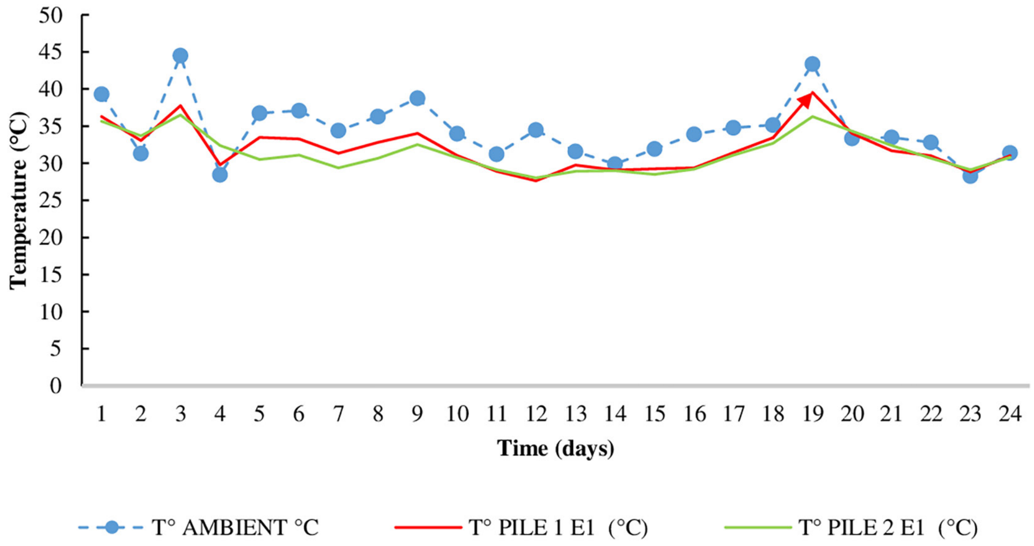

Figure 3. Temperature evolution of piles

of microbial activity and also a high rate of biodegradation (de Bertoldi et al. 1983; Papale et al. 2021). The maximum temperature recorded during this process did not exceed 39.53 °C (Figure 4) and this is against the recommendations of the regulations, which specify that the composting ingredients must be exposed to a temperature of 65 °C over 3 consecutive days (Miller 2002).

Humidity

The existence of water in the pile during composting is essential for microorganisms to biodegrade the organic matter. This water, represented by the humidity level, is crucial to transport the dissolved nutrients necessary for the physiological and metabolic operations of the microorganisms (Liang, Das, and McClendon 2003). This moisture content is related to the properties of the composted substances, including specific physicochemical parameters and biological characteristics (Guo et al., 2012) (Table 4). To this end, several studies have shown that there is a relationship between the C/N ratio, aeration and optimal moisture; since during composting of poultry manure with wheat straw, the optimal moisture was 70% (Petric and Selimbašić 2008), while the optimal moisture during composting of green waste and food waste with low C/N rate (19.6) was 60% (Kumar et al., 2010). On contrary, the authors' experience showed that the humidity of the piles was high over the first days of the operation and above 50% until the last day of the second week (Figure 2).

Table 3. Microbiological characteristics of the compost

Bacteria	Unit	Results
Thermotolerant coliforms at 44°C	cfu/g	<4.10[1]
Escherichia coli at 44°C	cfu/g	<10
Clostridium perfringens	cfu/g	<10

Physical efficiency of composting

The physical efficiency of a waste treatment and recovery process is considered a primary parameter to study the technical feasibility of the process. The reduction of dry mass and volume and the composting time are significant parameters to

Table 4. Optional moisture contents of various composting process

Optimum moisture content	Raw materials	Reference
Less than 80% Swine	Swine manure and corncob	(Zhu 2006)
69%	Poultry manure with wheat straw	(Petric, Šestan, and Šestan 2009a)
65–70%	The solid fraction of poultry manure with straw	(Kalyuzhnyi et al. 1999)
60–70%	Sewage sludge	(Liang, Das, and McClendon 2003)
50–60%	Pig manure with sawdust	(Tiquia and Tam 1998)

advance the optimization of composting plants (Costa et al., 2017). Reductions in dry mass and volume result from the decomposition of organic substance throughout the composting operation (Bernal et al., 2009; Petric et al., 2009). For this purpose, the monitoring of the quantity is essential at the beginning and at the end of the process. After 23 days of rapid composting, the physical yield of the process reached 47.9% with a loss of mass of the material of 52.1% (Figure 4).

Structure of the composting pile

The casings used in the composting process are large pieces of different sizes (Figure 5a), mixed with dry sheep manure of medium fine structure (Figure 5b). At the end of the process, it was found that some pieces of casings are more or less dry, but not totally degraded, despite the fact that the mixture has undergone turning and biological degradation operations (Figure 5c).

C/N Ratio

Compost quality is often qualified by its stability and maturity (Moral et al., 2009). Stability usually refers to microbial mechanism and maturity makes reference to the amount of decomposition of phytotoxic organic ingredients (Said-Pullicino, Erriquens, and Gigliotti 2007). Evaluation

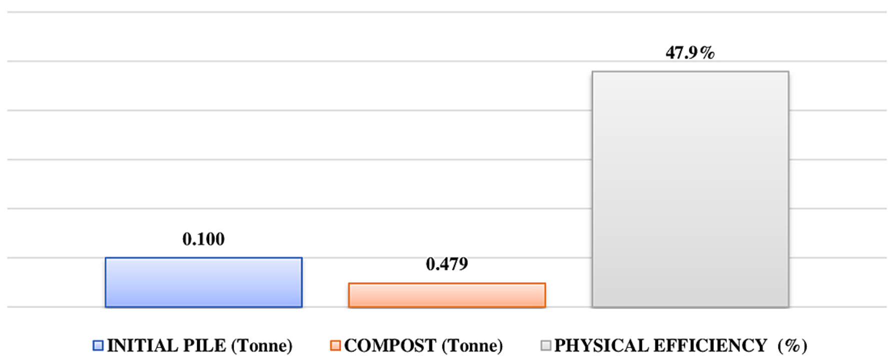

Figure 4. Physical efficiency of composting

Figure 5. (a) Casings in the initial state (b) sheep manure (c) final pile

of this composting maturity can be done by two indicators; the C/N ratio (total organic carbon to total organic nitrogen) and the WSCO/TON index (water soluble organic carbon to total organic nitrogen). In fact, the WSCO/TON ratio includes mainly short molecules of sugars, organic acids, amino acids and peptides. Also, it is preferably used by microorganisms before the total organic carbon (Zhang and Sun 2018; Zhou et al., 2020). Furthermore, it has been reported that carbon C is mineralized faster than nitrogen N (Onwosi et al. 2017; Yang et al., 2015). The preferred C/N index for a composting substrate exists within a range of 25 to 35 (Morisaki et al., 1989).

The C/N ratio of the initial sample tested was 13.2 (Table 2). Therefore, the compost obtained at the end of the operation has a C/N ratio of 21.3 (Table 5). It is well known that a C/N ratio lower than 20 indicates a good maturity of the compost, with a rate of 15 or less is recommended (Van Heerden et al. 2002). Obtaining a C/N ratio of 21.3 reflects that the activity of the microorganisms was low. This explains the drop in temperature recorded during the process (JRC 2015).

Heavy metals

The feasibility and maturity of a compost depends on the concentration of certain heavy metals linked to the standards, as it is cited in Tables 5 and 6. These heavy metals are considered among the elements that are difficult to eliminate from nature. Their toxicity is a serious constraint for environmental, food as well as ecological considerations (Adimalla, Chen, and Qian 2020). They negatively impact microorganisms during composting and the biochemical and physiological function of plants such as restriction of photosynthesis and inhibition of the respiratory activity (Ashraf et al. 2018).

As shown in Tables 5 and 2, the heavy metals analyzed during the rapid composting process were copper (Cu), zinc (Zn) and iron (Fe). The concentration of Zn fell from 37.20 $mg.kg^{-1}$ (initial mixture) to 35.30 $mg.kg^{-1}$ (compost) with an abatement rate of 5%. For Cu, the concentration recorded in the final compost was 8% lower than that found in the initial mixture. On the other hand, the level of Fe in the compost increased by 5% compared with the initial mixture. However, the level of heavy metals found in the compost are beneath the limits required by most standards (Table 5), and the existence of a large proportion of Cu and Zn in the compost is the result of metals incorporated in roughages ingested by cattle and released in the manure mixed with gusts (Kupper et al. 2014).

Agronomic testing

The tests carried out to assess the agronomic value of the compost obtained with regard to international standards are presented in Tables 5

Table 5. Quality of the compost 1

Parameter*	Compost	FAO	AFNOR	French Standard	Swiss Standard
Dry matter (%)	71.00				
Moisture (%)	29.00				
Hydrogen potential (pH)	7.10				
Electrical conductivity (ms/cm)	28.80				
Loss on ignition of DM (g/kg)	77.60	100–300	>50		
Organic carbon (%)	38.80				
Total nitrogen (%)	1.82	0.4–0.5	>0.25		
C/N ratio	21.30	15–20	<20		
Phosphorus (%)	0.76				
Potassium (%)	1.68				
Magnesium (%)	0.65				
Calcium (%)	2.76				
Zinc (mg/kg)	35.30			300	400
Copper (mg/kg)	10.70			100	100
Manganese (mg/kg)	97.20				
Iron (mg/kg)	2961.80				

Note: *dry weight basis.

Table 6. Quality of the compost 2

Parameter	Compost	American compost quality council (2001)	Canadian council of the ministers of the environment (b) (2005)	Japanese ministry of agriculture, forestry and fisheries (2008)	China standard of organic fertilizer (GB 18877-2009)
Hydrogen potential (pH)	7.10	5–9	5.5–8.5	5.5–8.5	5.5–8.5
Electrical conductivity (ms/cm)	28.80	≤ 3	≤ 4	≤ 3	≤ 2.5
Total nitrogen (%)	1.82	>1		> 1.5	> 0.2
Phosphorus (%)	0.76			> 1.5	> 0.4
Potassium (%)	1.68			> 1.5	> 0.8

Note: b – Canadian council of the ministers of the environment (2005): guidelines for grade A compost quality.

and 6. The tests included electrical conductivity, nutrients (NPK), pH and organic matter, etc. The analysis showed that the electrical conductivity of the compost greatly exceeded the limits set by all the standards. However, the pH recorded corresponds to the required values. The nitrogen (N), phosphorus (P) and potassium (K) values reported were 1.82%, 0.76% and 1.68% respectively. The measured NPK ratio is between 1.8 and 0.7 to 1.7. This calculated ratio is a long way from the NPK ratios found in standard fertilizer formulas, and the sum of the nutrients is between 2 and 5, like most compost (Makan 2015). However, the compost obtained can be used to amend and improve soil structure.

CONCLUSIONS

According to the experimental results, the temperature of all piles did not exceed 40°C at any week of composting. This can be explained by several facts: the daily turning of the heaps caused the cooling of the composting materials; the high humidity (>66%) caused low microbial activity, or the volume of the heap underwent to the composting process being less than necessary to store heat. However, the mass of the heap mixture during the process showed a remarkable evolution, since it decreased by 47.9% compared to the initial mass subjected to the rapid composting operation. Odors were strong during the first week of composting, and did not begin to diminish until the last days of the second week. This rapid composting trial of casing waste mixed with a fraction of 50% sheep manure, enabled to conclude that the quality of the compost obtained under the initial conditions did not satisfy the standards cited above, particularly with regard to the C/N ratio, which exceeded 20. To this end, further trials under other hypotheses appear necessary to answer the question of the feasibility of recycling casing waste by rapid composting.

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