

Biodrying process: A sustainable technology for treatment of municipal solid wastes organic fraction

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Abstract

The Municipal Solid Waste of Agareb (Sfax –Tunisia), characterized by high organic fraction and moisture contents is the most worrying pollution source that must be managed by innovative treatment and recycling technologies. Bio-drying, as a waste to energy conversion technology, aims at reducing moisture content of this organic matter. This concept, similar to composting, is accomplished by using the heat generated from the microbial degradation of the waste matrix, while forced aeration is used. The purpose of this work was to reduce the moisture content of the waste, by maximizing drying and minimizing organic matter biodegradation, in order to produce a solid recovered fuel with high calorific value.

Keywords: *Municipal solid wastes; organic matter; biodrying; composting; energy recovery.*

1. Introduction

The accumulation of municipal solid waste (MSW) is a matter of concern for the developing countries in the present time. The rapid urbanization followed by the industrial development and construction activities is supposed to be the major reason for MSW accumulation [1]. Waste to energy (WTE) technology has the potential to reduce the volume of the original waste by 90%, depending on the composition by recovering the energy [2, 3]. But the net energy yield from waste to energy conversion processes depend upon the density, composition and relative percentage of moisture of the waste [4]. Here comes the importance of biodrying process for the treatment of municipal solid waste with high moisture content. The biodrying process can be promising for treating mixed municipal solid waste containing large proportion of organic compounds, since high moisture content of the organic materials will increase the wetness of the entire MSW matrix. Biodrying is a suitable method to treat very humid waste, which would release high quantity of leachate if waste is directly burned without any pre-treatment [5].

Biodrying is an aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. The major difference of biodrying from composting is that the major objective is not to maximise the degradation process of organic material, but only to degrade the waste enough to generate biological heat to dry the waste [6]. The biodrying process is distinct from composting in that the output of composting process is stabilized organic matter, but the output of biodrying is only partially stabilized. Also biodrying process is of short duration one and hence the emission factors are also short lasting. Process of biodrying utilizes the auto thermal heat generation due to microbial action on waste material instead of thermal treatments in conventional drying process. Hence this is an energy saving process when compared to drying since it effectively utilizes the biological heat energy [7, 8].

Biodrying reactor aims to pre-treat the waste at the lowest possible detention time in order to produce a high quality refuse derived fuel (RDF). Biodrying process increases the energy content of solid waste by maximising removal of moisture present in the waste matrix and preserving most of the gross calorific value of the organic chemical compounds through minimal biodegradation [9]. The solid derived fuel from biodrying process is the best renewable fuel [9, 10, 11, 12, 13]. The strategy based on temperature feedback control will be more promising for biodrying technology and the issue of homogeneity of the output of the biodrying process is a subject need to be improved and hence to be investigated in future ([14]. In biological stabilization processes the temperature parameter is more qualitative than quantitative [15]. The biodrying process is critical for control of physical and mechanical properties [6].



In Tunisia, environmental preoccupations are among the priorities of the Government. Since 1990, Tunisia has triggered an environmental assessment process targeting the definition and implementation of a proactive national strategy and safeguarding the environment. This strategy dealing with the environment preservation was established and strengthened with the implementation of sustainable development. The municipal solid waste (MSW) management, an important task to protect human health, the environment and to preserve national resources was taken into account by the Government. Indeed, the Tunisian Government allocates a huge budget for MSW management and treatment. According to National Agency of Solid Waste Management (ANGed), 2.2 M of tons of household waste are annually generated (0.5 kg/inhabitant/day). These wastes are dumped in the landfills (9 in the country). Such strategy is cost and inefficient solution considering the large dumping land needed and the loss of available resources (68% organic matter in MSW) that could be recycled based on circular economy. Consequently, the ANGed started implementing a strategy where recycled waste is reconsidered, allowing waste reduction and incomes. Also, to boost the waste reduction and the materials recycling, political programs were set in the five-year program of the development plan (2016-2020). Moreover, the Ministry of Environment and Sustainable Development was engaged to improve the solid waste valorization all over the country, based on a partnership between public and private sectors. The Government announced its investment for waste valorization by giving financial support to encourage such strategy, reducing the landfilling of biodegradable waste. The recovery of MSW will reduce greenhouse gas emissions and increases the use of renewable fuels in energy production.

The objective of this work was to conceive a laboratory prototype for the treatment and the recovery of the organic fraction from MSW by an innovative bio-drying process, in order to produce a solid fuel recycling (CSR). In this new bio-drying technology, the exothermic reactions were recycled for the evaporation of the highest part of the waste humidity, with the lowest bioconversion of organic carbon to produce a dry high-calorific fraction. This is usually shredded and can be used either in densified or bulk form as fuel in industrial boilers or in furnaces such as those in the cement plant.

2. Materials and Methods

2.1. Raw material

The studied waste was collected from the municipality of Agareb (region situated at 20 km in the West of Sfax city (Tunisia). After removing glass and metal debris from this municipal solid waste the organic fraction and the moisture content were 59% (w/w, in wet weight) and 70% of total solids (w/w) respectively.

2.2. Experimental setup and operation

The conceived prototype (figure 1) is a bed plexiglass reactor of internal dimensions (1 m x 0.5 m x 0.6 m) with a support made of a stainless steel grid to support a capacity of about 60 kg of solid waste.

The drying air is blown by a centrifugal fan of 0.75 kW power, controlled by a timer allowing the automatic operation fuction and shutdown of the system in order to maintain a defined air flow rate. The air flow crosses upward the waste from the bottom, activating the biological reactions and goes out of the biological reactor from the upper side. Finally, the process-air is discharged into the atmosphere after progressin through the bed. The experimental study evaluated and compared different tests according to the air flow rate and the stirring frequency, in order to choose the best working conditions.



Fig.1 The prototype of bio-drying

Each trial lasted approximately 10 days. After adequate waste mixing, the reactor was fed by 45 kg of the selected and homogeized MSW organic matter fraction, having a density of 450 kg/m³. The airflow was set at 0.7 m³ per kg of wet waste per hour for the first test and 0.4 m³ per kg of wet waste per hour for the second and third trials. The temperature was measured by thermometers set inside the bed reactor, at 5 points scanning all the bed. The ventilation was set on a mode working at a frequency ventilation of 10 min on/20 min off. The waste was manually agitated every 2 days for the first 2 tests (tests 1 & 2) and then

every 4 days for the last test (test 3). The waste was sampled every two days. The humidity rate and the organic matter degradation were determined gravimetrically after drying at 105 °C.

2.3. Sampling methods

Waste samples were collected from the bed reactor for analysis 2 days during the biodrying process. The moisture content was determined as quickly as possible to limit evaporative losses. The organic matter, total organic carbon, kjeldahl nitrogen and metals are measured later in the laboratory. All these analyzes are carried out in duplicate. Leachte and condensate water were collected every day and analysed for volume, ph, total organic carbon (TOC) and ammonia concentration.

2.4. Analytical methods

- The moisture content of solid samples was determined by gravimetric method.
- According to the standard (JIS K0102.14.4, 1995), the same crucible used for dry matter determination is placed in a muffle furnace at 550°C for two hours for calcination. The residual mass is weighed and the organic matter and the ASH will be calculated.
- The nitrogen content was measured with Kjeldahl nitrogen analyser.
- The TOC concentration was measured by a total carbon/total nitrogen (TC/TN) analyser.
- In order to get an idea of the lower heating value (LHV), we have chosen to estimate this value by using the CHANNIWALA correlation [16]. and which requires knowledge of the composition of the product in carbon, nitrogen and other compounds:

$$\text{LHV (MJ/kg)} = 0.3491 \text{ C} + 1.1783 \text{ H} + 0.1005 \text{ S} - 0.1034 \text{ O} - 0.0151 \text{ N} - 0.0211 \text{ ASH}$$

with C, H, O, N, S, ASH: product composition of carbon, hydrogen, oxygen, nitrogen, sulfur and ASH in %.

3. Results and discussion

Three tests were carried out in this work: the first has an air flow of 0.7 m³/h kg_{MSW} under a capacity of 46 kg of waste with a manual turning every 2 days. The second and third tests were carried out at a rate of 0.4 m³/h kg_{MSW} under a 50 kg daily turning load every 2 and 4 days respectively for the second and the third test. The three tests were carried out at a ventilation frequency of 10 minutes “on” / 30 minutes “off”, that is to say, the fan runs for a period of 10 minutes and stops for 30 minutes before to start the cycle again.

3.1. Temperature evolution

Figure 2 illustrate the evolution of the inlet and outlet air temperature as well as the mean temperature of waste for three tests.

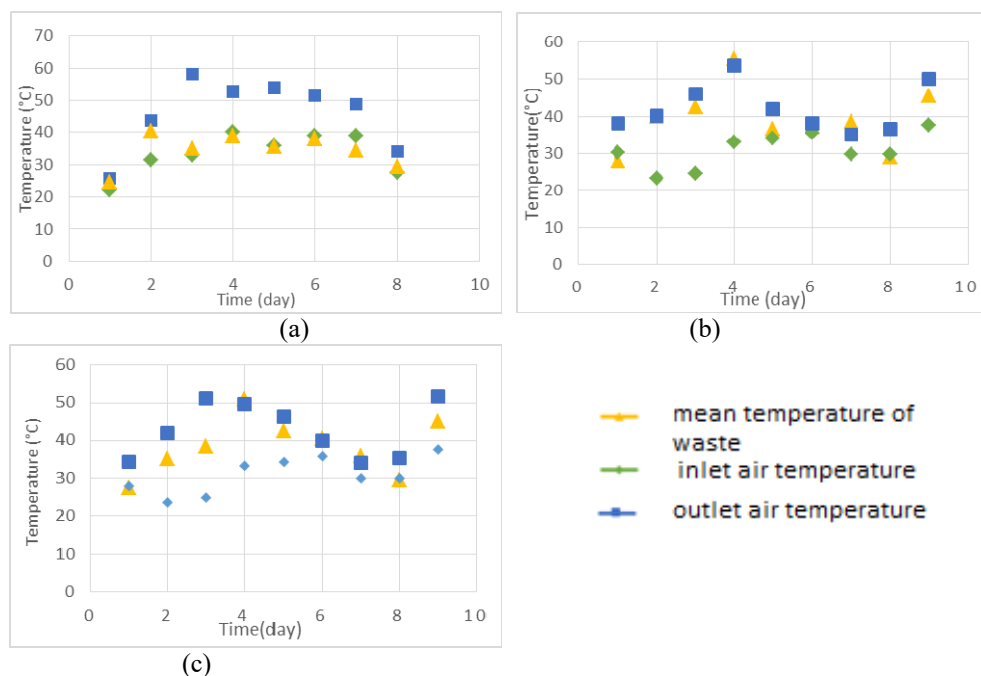


Fig.2 Temperature evolution versus time
a (trial 1) - b (trial 2) – c (trial 3)

For the first (Figure 2-a) test with the highest air flow rate ($0.7 \text{ m}^3/\text{h kg}_{\text{MSW}}$), the waste temperature is practically equal to the temperature of Air at the inlet and does not exceed 40°C , the air is cooling the waste and the phenomenon of bio-drying didn't take place.

For the second (Figure 2-b) and the third test (Figure 2-c) the temperature changes are quite similar. At the end of the 4th day, the waste temperature reached 51°C and 55.5°C respectively in the 2nd and 3rd tests due to the fermentation of waste.

By comparing test 1 and test 2, we find that for an air flow equal to $0.4 \text{ m}^3/\text{h kg}_{\text{MSW}}$ the waste temperature is quite similar to the outlet air during the first days of the experiment. From the 4th day The fermentation phenomenon is reduced and the temperature of wa These results show that the fermentation effect is more figured when using a low air flow rate.

3.2. Degradation of organic matter

Degradation of organic matter is well sought in the case of the composting process, but it has an undesirable effect in the bio-drying process. So we must minimize this degradation. Analyzes were carried out every 2 days to monitor the mass fractions of dry matter, organic matter and mineral matter (ASH content) of the solid waste in Figure 3 illustrates the evolution of degraded organic matter per kilogram of waste. The highest air flow gives the highest degradation of organic matter. Tests 2 and 3 have the same air flow rate but a

different frequency of agitation, the one having the high frequency, undergoes the slight degradation. These results are similar to other research (Zhao et al., 2011).

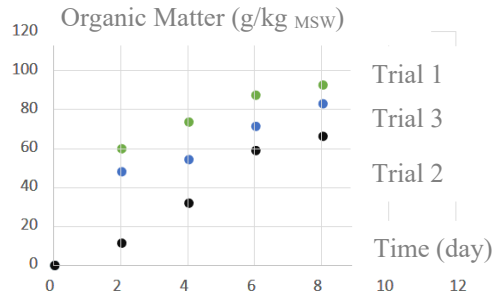


Fig. 3 The evolution of degraded organic matter versus time

4. Conclusions

During the biodrying process, the temperature evolution showed an increase in the second and third trials, and reached 51.0°C and 55.5°C respectively in these experiments, because of the fermentation held. Consequently, the water content was reduced from 70% to 9.0 and 9.1% and 21.4 % (respectively for the three trials. A significant decrease in water was noticed during the 2 first-days, the water evaporation rate begins to decrease from the third day and that with low agitation frequency. The final product 'CSR' has the best water content compared to that of higher agitation. The assessed calorific value of the three trials were 17.1, 19.66 and 19.16 MJ/kg respectively for the three experimented air-flow rate and agitation frequency.

5. References

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