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Pre-treatment and utilization of food waste as energy source by bio-drying process

Mutala Mohammed[a]*, Ismail Ozbay[a], Aykan Karademir[a], Mehmet Isleyen[b]

[a]*Department of Environmental Engineering, University of Kocaeli, Izmit 41380, Kocaeli, Turkey*
[b]*Department of Environmental Engineering, Bursa Technical University, Yıldırım 16310, Bursa, Turkey*

Abstract

In this study, three different sets of experiments were conducted with the aim of evaluating the effects of initial moisture content and bulking agent on bio-drying efficiency of food waste as well as weight reduction. Results showed that initial moisture content has a significant impact on bio-drying, affecting temperature and water removal rate as well as volatile solid degradation, with higher maximum temperature obtained in Trial 3 (initial moisture content of 44.95 %) and lowest maximum temperature obtained in Trial 1 (initial moisture content of 69.29 %). The bio-drying index indicated that Trial 2 had higher water removal efficiency (72.96 %) with less organics consumption (bio-drying index = 10.1). On the whole, Trial 1, 2 and 3 saw a weight reduction of 54.63 %, 42.56 % and 35.33 % alongside a moisture reduction of 53.26 %, 47.46 % and 64.51 % respectively. This finding suggests that the use of bulking agent has significant effect on the initial moisture content with subsequent impact on bio-drying efficiency which could provide some promising approach to pre-treat organic waste to reduce the moisture content, weight and volume and increase the energy value for solid recovered fuel generation (SRF).

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Keywords: bulking agent; bio-drying index; moisture content; water removal efficiency; volatile solid degradation

* Corresponding author.
E-mail address: mutbaby@gmail.com

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1. Introduction

One of the main environmental problems in both developed and developing countries is the vast increase in the quantity of municipal solid waste (MSW) generation due to accelerated urbanization [1]. In an effort to deal with problems of MSW management, a number of technologies such as combustion, incineration, landfilling, pyrolysis and gasification has been researched and developed [2]. However, environmental restrictions/regulations have made the application of some of these technologies increasingly difficult. Thus, research focus over the last 20 years has been drifted toward biological treatment of waste. This approach has become an increasing waste management, as a pre-treatment before landfilling/combustion, option particularly in Europe due to the introduction of the European Union (EU) Landfill Directive (LFD) (99/31/EC) which requires a phased reduction in the amount of biodegradable waste (BW) disposed of to landfill because of its potential to produce landfill gas and leachate [3, 4]. Consequently, emphasis in BW management has shifted from its disposal to the beneficial use of it and its products. One such usage is its conversion to solid recovered fuel (SRF) subsequent to combustion [5]. However, the high moisture content of food waste (FW) reduces its efficiency for energy recovery. As a result, bio-drying as an alternative pre-treatment of waste has been developed in recent years [6–8]. Biological drying (bio-drying), aims at removing water from biowaste by taking advantage of the heat generated from microbial degradation in aid of forced aeration [9, 10]. Even though the concept of bio-drying is similar to composting, the technology tends to pre-treat waste at the lowest possible residence time (7–15 days) to produce a high quality bio-dried material [10, 11]. Whereas composting tends to mineralize substrate with high consumption of volatile solids, bio-drying reduce biodegradation in order to preserve the gross calorific value of the waste matrix. Much of the research on bio-drying has focused on the application of this technology for pre-treating garbage residues and sewage sludge [12, 13] and pulp and paper [14, 15] and MSW [16, 17]. It is obvious bio-drying of FW has not received much attention by researchers due to its high moisture content (MC) and low biomass porosity.

The initial MC is paramount in bio-drying process because it influences the biochemical reactions associated with microbial growth and the biodegradation of organic matter during the process [18]. Bio-drying of FW alone results in high generation of leachate which defeats the purpose of bio-drying as a zero leachate generation technology [17, 19]. To achieve efficient bio-drying, it is imperative to ensure high porosity within the waste matrix during bio-drying i.e. reduction in the initial MC of the substrate. A number of researchers have also used bulking agent (BA) to adjust the initial MC and free air space (FAS) of waste which provides structural support and high porosity as well as allowing easier transport of oxygen through the waste matrix [20, 21]. The objective of this study was to bio-dry FW of high MC in combination with different municipal solid waste including paper and plastic. Additionally, BA was utilized in the bio-drying process with the aim of evaluating the effect of BA on the initial MC of the waste matrix as well as bio-drying efficiency.

2. Materials and methods

2.1. Preparation of materials

In the present study, FW (Lactuca sativa) collected from a canteen of University of Kocaeli was the main waste component to be bio-dried, however, due to its high MC; and the high contribution of paper and plastic as component of MSW, these were added in different proportions to initially reduce the moisture component of the FW subsequent to bio-drying. Additionally, pruning waste as BA was added to evaluate its effects on bio-drying process. The raw materials were shredded, FW (15 x 35mm), paper (2 x 14 mm), plastic (5 x 10 mm) and BA of 15mm in diameter. The characteristics of the raw materials are presented in Table 1.

Table 1. Characteristics of the raw materials.

Parameter	Food waste	Paper	Plastic	BA
Moisture content	91.48 ± 0.58	5.40 ± 0.16	0.94 ± 0.05	8.43 ± 0.33
Volatile solids, %	98.51 ± 0.22	78.94 ± 0.20	99.57 ± 0.25	90.62 ± 0.38
Bulk density, kg/m^3	464.18 ± 5.36	100.46 ± 1.01	346.50 ± 3.77	204.14 ± 2.02
Water holding capacity, %	-	43.04	35.77	68.19