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ASSESSMENT OF THE USE OF EWA BIOREACTOR IN THE PROCESS OF BIODRYING OF UNDERSIZE FRACTION MANUFACTURED FROM MIXED MUNICIPAL SOLID WASTE

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Summary

The article presents the results of a research on the processing of undersize fraction, extracted from a stream of mixed municipal solid waste (MSW), into alternative fuel, in the process of bio-drying. The analysis was conducted with the use of an innovative EWA (Ecological Waste Apparatus) bioreactor adapted to carrying out aerobic treatment of waste in such processes as: composting, aerobic digestion/stabilization and bio-drying of waste. EWA bioreactors have been designed and manufactured by AGRO-EKO spol. s r.o. from the Czech Republic.

The subject matter of the analysis was undersize fraction, with particle dimensions ranging from 0 to 50 mm, manufactured in the process of sorting (mechanical processing) of MSW. The main aim of the research was to assess suitability of the use of EWA bioreactor in the process of alternative fuel production from undersize fraction developed from municipal waste (in the process of accelerated bio-drying). Samples were collected between 2011 and 2012. The undersize fraction and the produced alternative fuel were analysed by AGRO-EKO spol. s r.o. and at the University of Agriculture in Krakow, in accordance with the standards for wastes and solid fuels.

It has been concluded that undersize fraction produced from mixed municipal waste might be the energy source for cement plants or commercial power plants. As a result of a 66-hour accelerated process of bio-drying of undersize fraction (the standard time being ca. 7 days), the waste-mass has been lowered by reducing water content (moisture) in undersize fraction by ca. 15 % while increasing its calorific value and the C:N ratio. The process resulted in the increase of non-combustible and non-biodegradable elements. The high C:N ratio and the amount of organic substances at the level of 78 % should enable further aerobic and anaerobic stabilization preceded by substance moisturizing.

Key words: municipal waste, undersize fraction, bio-drying, bioreactor

INTRODUCTION

Optimum use and treatment of waste generated as a result of common activities and by industry are among the most crucial challenges and problems that the 21st century environmental engineering faces. Apart from waste incineration plants, there are also installations for mechanical-biological treatment (MBT) of waste that are growing more and more popular in Europe. Growing interest in such technologies stems from EU policy (2008/98/EC, 99/31/EC) on waste processing and biodegradable waste disposal. Mechanical-biological waste treatment installations combine the processes of mechanical separation (e.g. magnetic or aerobic) and biological processing (e.g. methane fermentation, aerobic digestion/stabilization, bio-drying or composting). Two waste fractions are produced out of a stream of mixed municipal solid waste (MSW) in mechanical treatment process: undersize fraction that is later transferred to waste disposal sites or for biological treatment; and oversize fraction used for energetic recovery. Regulation of the Polish Minister of the Environment (2012) concerning MBT (mechanical biological treatment) determines that biological treatment of waste can be executed at the initial stage in a closed bioreactor with an aeration system and post-process air ventilation to biofilters, for the period of 2 weeks at minimum in the processes of aerobic biostabilization and 7 days at minimum in the processes of bio-drying. There is, however, lack of a description in the published sources of a research project dedicated to the shortening of the process.

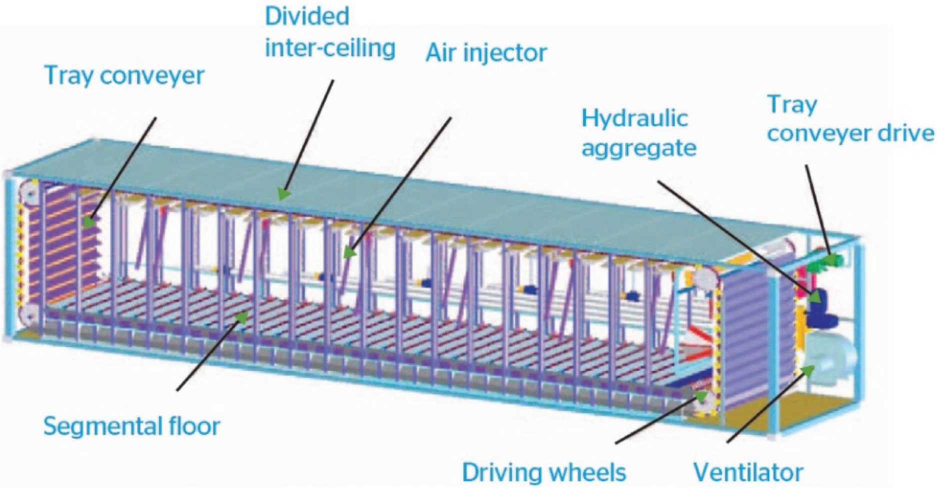
Bio-drying is one of the means of biological waste processing as a result of which alternative fuel is produced that can be used for energy production. Białowiec and Templin (2010) define bio-drying as a process whose main aim is to produce at short notice high-quality substitute solid fuel through biological processing. Bio-drying takes place in sealed bioreactors or in heaps placed in closed warehouses. The process involves heating the charge material up to between 55°C and 70°C which is a result of heat being produced at the initial stage of biological decomposition of organic matter (self-heating phase). It is expected that charge material moisture content is reduced by 15 to 20 % as a result of bio-drying. Apart from the noncomposted waste fraction, these are steam and traces of CO2 that are the products of biological transformations taking place in the process. In addition, small amount of water might condense, soak through waste mass and drain from reactors as effluents. In Europe, biodrying of mixed municipal waste is researched by, among others, Adani et al. (2002), Sugni et al. (2005), Tambore et al. (2011); whereas in Poland these are Dębicka et al. (2013), Domińczyk et al. (2012), Jędrczak, Haziak (2005), and Zawadzka et al. (2010). The major advantages of bio-drying are waste mass reduction, reduction of CH4 i CO2, SO2, NOx emission and dust emission from waste landfills into the atmosphere. Another advantages of bio-drying are the possibility of conducting the process both in aerobic and anaerobic environment, and the possibility of utilizing the installations used for composting and waste digestion/stabilization.

Malinowski (2012) stated that the amount of the undersize fraction obtained from mixed municipal waste depends greatly on the origin of waste and the season. Smallest amounts of undersize fraction are obtained in spring and summer, whereas the largest amount of undersize fraction in a stream of mixed solid waste is observed in autumn and winter. It is possible to obtain between 365 and 435 kilograms of undersize fraction out of 1000 kilograms of municipal waste collected within the urban area of Krakow (412 kg ± 32 kg on average). On average, ca. 553 kg ± 59 kg of undersize fraction is sorted out of 1000 kilograms of mixed municipal waste collected in suburban areas. In winter, it is also possible to obtain up to 700 kg.Mg-1 of undersize fraction with particle size up to 50 mm along certain diversionary routes within the rural areas of Krakow agglomeration.

The main aim of the research presented in the article was to determine the suitability of EWA bioreactor in the process of accelerated bio-drying of undersize fraction with particle dimensions ranging from 0 to 50 mm, generated from MSW. The main purpose of the study was then to gain knowledge about the properties and behavior of waste (undersize fraction) during the process of accelerated bio-drying and the assessment of an alternative fuel produced in this process.

MATERIAL AND METHODS

The process of bio-drying has been conducted in EWA (Ecological Waste Apparatus) bioreactor that consists of a thermally isolated operating space, the volume of which is 36 m^2; nozzle system for intense aeration of the charge material; and an impeller system, used for mixing the charge material, consisting of segment flooring, a bucket conveyor located along the inside of the bioreactor circumference and an integrated device used for loading and unloading of the material being used for bio-drying (Fig. 1). EWA reactor is protected by a patent dated 2005, no. 295922, delivered by the European Patent Office (Holusa *et al*. 2005). The working principles of the bioreactor require supplying fresh air to the charge material and periodic mixing of the material that result in better aeration of waste, enabling rapid temperature increase and decomposition of complex organic matter in the waste material. In the initial phase of the process temperature increases to over 70°C, which is the result of high metabolic activity and bacteria reproduction. High temperatures cause protein denaturation and, as a result, the deactivation of bacteria and pathogenic organisms (such as viruses, bacteria, mould, protozoa and other), which in consequence results in the reduction of microbes, the loss of germination capacity by weed seeds and gradual decrease in temperature. It is possible to control the process by measuring temperature (4 measurement points) and oxygen content in waste gases. Intense air supplying leads to the decrease in water content. Humid sub-process air is then released to biofilters.



Source: www.agro-eko.cz

Figure 1. EWA bioreactor cross-section

The analysis of undersize fraction and fuel obtained in the process has been carried out in MIKI Recykling Sp. z o.o. in Krakow and in laboratories at the University of Agriculture in Krakow. Some analyses were also carried out in AGRO-EKO spol. s r.o. The material to be analysed was undersize fraction with particle dimensions ranging from 0 to 50 mm, separated (in a mechanical drum sieve) from mixed municipal solid waste collected in the Krakow urban agglomeration. Samples were gathered in accordance with the standard PN-EN 15443-2011 Solid recovered fuels – Methods for the preparation of the laboratory sample.

The study was conducted between 2011 and 2012. The analysis of the morphological composition of undersize fraction was carried out in accordance with the recommendations of the Minister of the Environment described in the Guidelines (Jędrczak, Szpadt, 2006). The analysis of particle size (fraction) distribution was carried out by categorizing waste into 4 groups with regard to particle size: up to 10 mm, between 10 and 20 mm, between 20 and 40 mm, and over 40 mm; using a modular drum sieve prepared for the needs of the study. 10 samples were analysed, each weighing ca. 100 kg. Furthermore, pH, C:N ratio, combustible and non-combustible elements content and basic fueling properties were determined for the undersize fraction and for the alternative fuel obtained as a result of the bio-drying process, with accordance to the following standards:

1. PN-EN 15400-2011 Solid recovered fuels – Determination of calorific value;
2. PN-EN 15403-2011 Solid recovered fuels – Determination of ash content;
3. PN-EN 15414-3-2011 Solid recovered fuels – Determination of moisture content using the oven dry method; Part 3: Moisture in general analysis sample.

In addition, the fuel obtained as a result of the bio-drying process was analysed with regard to chosen heavy metals crucial for their use in nature or energy production.

RESULTS

Undersize fraction is a heterogeneous mix of waste with irregular granulometric (Table 1) and morphological (Table 2) composition. Table 1 shows that it is undersize fraction with particle size smaller than 20 mm that has the largest share in the mass of the fraction (72.3 %). Within the morphological composition of undersize fraction, these are wastes with particle size smaller than 10 mm, as well as organic waste, paper, cardboard and glass that predominate. Visual examination revealed that fraction with particle size between 0 and 10 mm contained fine glass cullet, soil, organic waste and other kinds of waste (whose manual separation was not possible). The proportion of biodegradable waste in undersize fraction was calculated in accordance with the methodology specified in KPGO 2014 and equals ca. 49.3 %.

The initial stage of self-heating of undersize fraction was rapid. The initial temperature of waste, 16.0 ±1.4°C, reached 65°C within 19 to 27 hours. Jędrczak i Haziak (2005) stated that reaching temperature up to between 45°C and 67°C in the process of bio-processing results in the destruction of majority of pathogenic micro-organisms within the time period shorter that 60 minutes. Within the subsequent 40 hours, fresh air was being supplied to the bioreactor in order to maintain high temperature (fig. 2) and lower the water content. At the same time, intense evaporation of water in the form of steam took place and air rich in CO_2 was ventilated to biofilters. The process was terminated after 66 hours due to reaching a satisfactory level of water content in the waste. Following the termination of the process, the bioreactor was unloaded and samples of alternative fuel were collected in order to carry out detailed laboratory study. Tables 3 and 4 depict the results of the study:

Table 1. Granulometric composition of undersize fraction (Ø<50 mm)

Item number	**Particle grain size [mm]**	**Share g.kg^{-1} w.w**
	[mm]	g.kg^{-1} w.w
1.	> 10	383 ± 64
2.	10 – 20	340 ± 45
3.	20 – 40	222 ± 67
4.	> 40	55 ± 41

Table 2. Morphological composition of undersize fraction (Ø<50 mm)

Item number	**Morphological group**	**Share**± standard deviation **g.kg^{-1} w.w**
1.	Fine fraction[a]	371.7 ± 183
2.	Organics[a]	239.1 ± 68
3.	Wood[a]	10.8 ± 9
4.	Paper and cardboard[a]	116.1 ± 53
5.	Plastic	78.2 ± 30
6.	Glass	119.5 ± 52
7.	Textiles[a]	17.3 ± 12
8.	Metals	12.1 ± 8
9.	Hazardous waste	8.1 ± 8
10.	Mixed material waste[a]	16.3 ± 10
11.	Intimate hygiene products	62.2 ± 33
12.	Inert waste	40.1 ± 29
13.	Other categories	21.4 ± 11
	Total	1000

[a] – biodegradable waste

Table 3. Changes in the measured parameters

Item number	Parameter	Unit	Undersize fraction	Alternative fuel
1.	pH	–	7.38	7.66
2.	C:N	–	28	31
3.	Moisture	[%]	41.3	24.9
4.	Ash content	[% d.m.]	29.7	33.0
5.	Combustible elements	[% d.m.]	66.6	54.8
6.	Heat of combustion	[$MJ \cdot kg^{-1}$]	14.0	13.9
7.	Calorific value	[$MJ \cdot kg^{-1}$]	6.95	9.38

Table 4. Content of heavy metals in alternative fuel obtained in the bio-drying process

Item number	Metal	Symbol	Unit	Heavy metals content
1.	Arsenic	As	$mg.kg^{-1}$ d.m.	1.60
2.	Cadmium	Cd	$mg.kg^{-1}$ d.m.	1.45
3.	Chromium	Cr	$mg.kg^{-1}$ d.m.	46.70
4.	Copper	Cu	$mg.kg^{-1}$ d.m.	96.80
5.	Mercury	Hg	$mg.kg^{-1}$ d.m.	0.204
6.	Nickel	Ni	$mg.kg^{-1}$ d.m.	26.70
7.	Lead	Pb	$mg.kg^{-1}$ d.m.	63.40

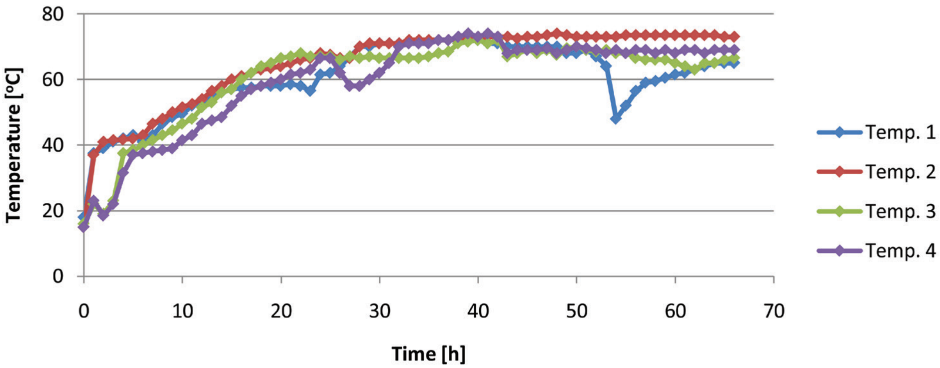


Figure 2. Changes in temperature within EWA bioreactor during the 66-hour bio-drying process of undersize fraction

As a result of the bio-drying of undersize fraction into alternative fuel, pH level, C:N ratio and ash content increased (Table 3). LOI (loss on ignition) factor decreased, however, it was not low enough to determine that waste meets the criteria for stabilized product specified in the Regulation on MBT (2012), similarly to the study conducted by Dębicka *et al*. (2013). Moisture at the level of less than 25 % together with calorific value at the level of 9.4 $MJ \cdot kg^{-1}$ predispose the fuel to be used for energy purposes, e.g. in cement plants.

CONCLUSIONS

Technology described in the article has immediate effects on the reduction of waste mass at disposal sites. As a result of bio-drying of waste in EWA bioreactor, it is possible to produce fuel that meets the requirements for cement plants within less than 70 hours. The described technology, apart from ecological (environmental) benefits, might also bring financial savings to a company that introduces it – such savings result from a decrease in waste mass due to biodrying, reduction of the amount of waste sent to disposal sites (lowering fees for waste disposal) or income from selling the fuel obtained in the process. Accelerated process of biodrying of waste allows to save storage space or space used for maturing of the stabilized product. The authors suggest it is necessary to search for further improvements of the techniques of bio-drying carried out in accordance with the described method.

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