Biological Stability Assessment of Selected Types of Separately Collected Kitchen Waste

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Abstract. According to the Regulation on the Minister of Environment of 29 December 2016, four fractions of municipal solid waste has to be collected separately in Poland, including bio-waste. Since such waste has not been considered in currently applied waste collection systems, there is a need to rearrange those systems and provide for infrastructure for bio-waste collection and processing. The paper describes the results of the research on determining selected properties of some types of waste commonly present in kitchen waste generated in households. Such waste is biologically unstable, which means it is prone to fast biological decomposition. The analyzed fruit and vegetable peels are characterized by high values of moisture content (up to 87.97 ± 0.41%), loss of ignition (up to 98.0 ± 0.05%) and four-day respiration activity AT4 (up to 144.4 ± 11.9 $mgO_2 \cdot g^{-1}$ d.m.). Moreover, it was found that respiration activity in mixtures of different types of peels is determined by also other factors than only individual properties of components.

Keywords: Biological stability · Kitchen waste · Bio-waste · Respiration activity

1 Introduction

On 1st July 2017 the Regulation of the Minister of Environment came into force in Poland, which introduced an obligation of separate collection of selected waste types [1]. According to the Regulation, following 4 fractions of municipal solid waste have to be collected separately: (1) paper, (2) glass, (3) metals and plastics, (4) biodegradable waste (with special regard to bio-waste). Municipalities, which, according to other law acts [2], have been obliged to provide a waste management system on their territories, are bound to introduce the new collection system until 30th June 2021. This means a significant change in waste management mostly due to the obligation of separate collection of bio-waste. Prior to this Regulation, municipalities themselves decided which types of waste were collected separately which not. The majority introduced systems including separate collection of such waste as paper, glass, metals or plastics (often as so called "dry fraction"), but with bio-waste going into mixed municipal waste.

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Directive 2008/98/EC defines bio-waste as “biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants” [3]. Article 22 of the Directive states that measures must be taken “to encourage the separate collection of bio-waste with a view to the composting and digestion of bio-waste and the treatment of bio-waste in a way that fulfils a high level of environmental protection” [3]. Introduction of the abovementioned Regulation in Poland responds to the requirements imposed by the Directive.

Food and kitchen waste from households consists mainly of left-over food waste, fruit and vegetable peels, egg shells, used coffee grounds and tea bags, withered flowers etc. [4, 5]. Such waste is biologically unstable, which means it is prone to fast biological decomposition. Its presence in mixed municipal solid waste (MMSW) increases moisture content and organic matter content and contributes to development of pathogens [4, 6]. Kitchen waste constitutes the organic fraction of MMSW, the share of which, according to the research by Malinowski *et al.*, is in the range of ca. 20–35%, depending on the area of waste collection (rural, urban) and the season of the year [7, 8]. During MMSW separation on a drum screen in a MBT plant organics (i.e. kitchen waste) goes mainly to the undersize fraction ($\Phi < 80$ mm), which may contain up to 40% of organics [9, 10]. A large share of organics and other biodegradable waste in MMSW subjected to processing in MBT plants negatively influences the properties of produced alternative fuels (higher moisture content, lower heat of combustion) [7]. A share of organics in alternative fuel derived from MMSW may reach up to 3–4% [11].

Existing systems of waste collection in Poland allow for separate collection of kitchen waste from bigger subjects, such as restaurants, shopping centers, grocery markets, etc. Waste collected in such places are managed in a composting plant or an MBT plant, where kitchen waste can be added to undersize fraction during the biostabilization process. The new law [1] obliges every household to collect separately kitchen waste into a separate, brown bin or bag (marked “BIO”), which requires significant changes in logistics of waste management (more bins are needed, changes in waste collection routes and frequency are to be established, more specialized trucks are necessary, etc.). The change will affect also waste processing technologies – presumably a more emphasis will be laid on bio-waste composting (more supply of waste) and MMSW will change some of its properties (less organic matter). It has to be noted however, that many residents living in detached houses, are already using some of kitchen waste in backyard composters [12]. Of great importance is attitude of residents towards new obligations – how much kitchen waste will be collected and what the quality of such waste will be [13]. The pilot program of bio-waste separate collection launched in Krakow at the beginning of 2018 has not brought expected effects – the majority of Krakow residents taking part in the program are reluctant to collect kitchen waste separately [14]. The obligatory separate collection of bio-waste in Krakow is planned to start on 1st April 2019 [5].

One of the crucial feature of bio-waste treatment, e.g. during composting, is its biological stabilization. There are different methods of determining the rate of biological stability [15] – in Polish regulations the measurement of four-day respiration activity AT4 is recommended [16]. E.g. for compost derived from waste respiration activity has to be less than 10 $mgO_2 \cdot g^{-1}$ d.m [17]. It is of importance to know the properties of waste before submitting it to processing in order to apply proper process conditions. The aim of this study was to investigate the selected properties (moisture content, loss on ignition, AT4) of several types of kitchen waste often present in households as well as to attempt to assess the range of changes in those properties in different waste mixtures. There are no reports of such research scope in the literature, especially concerning AT4 measurements.

2 Materials and Methods

In the research four different types of fruit and vegetable peels were examined, namely apple, carrot, orange and potato peels. They are common components of kitchen waste generated in households in Poland. Each kind of peels was examined separately and in mixtures. Three mixtures were prepared: apple and carrot peels (weight ratio 1:1), orange and potato peels (weight ratio 1:1), and all four kinds of peels (weight ratio 1:1:1:1).

Moisture content in investigated materials was determined by oven drying of material samples at 105 °C till constant weight (according to PN-EN ISO 18134-3:2015-11). Dry matter content was calculated on the basis of moisture content. Loss on ignition was determined by igniting ca. 1–2 g dried material samples in a muffle furnace at 550 °C for 2 h (according to PN-EN 15169:2011). Tests for each type of material were repeated three times.

Respiration activity (AT4) was determined using OxiTop® System according to the procedure described in the Austrian standard *Richtlinie für die mechanisch-biologische Behandlung von Abfällen* (*Guidelines for biological-mechanical treatment of waste*) [18]. The method consists in placing 40 g of the analyzed sample in an air-tight vessel (volume 2.5 dm^3) equipped with a pressure sensor. Inside the vessel there is a small container hung under the lid with CO_2 absorber. Biological processes taking place in the vessel use oxygen and generate CO_2. Since CO_2 is immediately absorbed, the changes in pressure are related to loss of oxygen. A wireless controller allows for reading pressure changes in each vessel. The analysis lasts for 5 days (in constant temperature 20 °C), as the result a 4-day period is taken into account (without so called “lag phase”, which can occur at the beginning of the analysis) to determine AT4. The relation between pressure changes and respiration activity is described by the formula [15]:

$$AT4 = \frac{Mo_2}{R \cdot T} \cdot \frac{V_g}{m_s} \cdot |\Delta p| \tag{1}$$

where:

AT4 – respiration activity [$mgO_2 \cdot g^{-1}$ d.m.],
M_{O_2} – molar mass of oxygen, M_{O_2} = 31 988 $mg \cdot mol^{-1}$,
R – universal gas constant, R = 83,14 $dm^3 \cdot hPa \cdot (K \cdot mol)^{-1}$,
T – temperature, T = 293 K,
V_g – volume of gas in the vessel, V_g = 2.5 dm^3,

m_s – sample dry mass [g d.m.],
$|\Delta p|$ – pressure changes [hPa].
Respiration activity tests were repeated three times for each type of material.

3 Results and Discussion

The results of conducted analyses are shown in Table 1 (for separate types of waste) and in Table 2 (for waste mixtures). The presented values are averages from the results of three individual tests for each type of material, the standard deviation is given after the value.

Table 1. Results of physicochemical tests for different types of kitchen waste.

	Apple peels	Carrot peels	Orange peels	Potato peels
Moisture content [%]	81.70 ± 0.51	87.97 ± 0.41	70.56 ± 1.61	84.80 ± 1.14
Dry matter [%]	18.30 ± 0.51	12.03 ± 0.41	29.44 ± 1.61	15.20 ± 1.14
Loss on ignition [%]	98.02 ± 0.05	91.78 ± 0.57	97.06 ± 0.08	76.86 ± 1.41
AT4 [$mgO_2 \cdot g^{-1}$ d.m.]	56.80 ± 5.37	144.44 ± 11.85	54.10 ± 3.63	59.95 ± 2.60

The content of water and dry matter in peels from apples, carrots and potatoes are in the range between 81.70 ± 0.51% and 87.97 ± 0.41%. In orange peels there is more dry matter (29.44 ± 1.61%) and less water (70.56 ± 1.61%) than in other types of peels. Peels from analyzed fruits (apples and oranges) are characterized by very high values of loss of ignition (98.02 ± 0.05% and 97.06 ± 0.08%, respectively), whereas a significantly lower value was noted for potato peels (76.86 ± 1.41%). It indicates that there is a relatively high content of inorganic matter in potato peels (ca. one quarter). Results of respiration activity AT4 for analyzed peels show that apple, orange and potato peels undergo aerobic biodegradation processes at a similar pace (AT4 values in the range of ca. 55–60 $mgO_2 \cdot g^{-1}$ d.m.), while carrot peels are much more biologically active – AT4 reached 144.44 ± 11.85 $mgO_2 \cdot g^{-1}$ d.m.

The results of respiration activity tests indicate that the analyzed materials are biologically unstable, especially carrot peels. For comparison – typical AT4 values for such waste as untreated sewage sludge is ca. 60–70 $mgO_2 \cdot g^{-1}$ d.m. [19] and for fresh digestate form biogas production vary from ca. 50 to 80 $mgO_2 \cdot g^{-1}$ d.m. [15], wheras waste from composting or MBT processing are characterized by lower values (up to ca. 50 $mgO_2 \cdot g^{-1}$ d.m. [15].

Table 2. Results of physicochemical tests for mixtures of kitchen waste.

	Apple + carrot peels		Orange + potato peels		Mixture of 4 types of peels	
	Measured	Mean (calculated)	Measured	Mean (calculated)	Measured	Mean (calculated)
Moisture content [%]	83.26 ± 1.17	84.83 ± 0.33	79.08 ± 1.56	77.68 ± 0.99	82.40 ± 1.93	81.26 ± 0.52
Dry matter [%]	16.74 ± 1.17	15.17 ± 0.33	20.98 ± 1.56	22.32 ± 0.99	17.60 ± 1.93	18.74 ± 0.52
Loss on ignition [%]	94.27 ± 0.46	94.90 ± 0.29	87.85 ± 1.32	86.96 ± 0.71	90.68 ± 0.96	90.93 ± 0.38
AT4 [$mgO_2 \cdot g^{-1}$ d.m.]	109.87 ± 1.38	100.62 ± 6.51	72.10 ± 3.89	57.03 ± 2.23	96.39 ± 5.11	78.82 ± 3.44

Table 2 shows the measured values of analyzed properties of peels mixtures as well as outcomes of arithmetic mean calculations conducted on the basis of individual results for each type of peels (presented in Table 1) and weight ratios. Regarding moisture content, dry matter content and loss on ignition, in all cases for all the analyzed mixtures the measured results are very close to the calculated arithmetic means – the differences between respective values are within the range of standard deviation intervals. It indicates that those parameters are dependent only on actual content of water or organic matter (in the case of loss on ignition) of individual components and during mixing of such materials no processes occur which would change that state. A different situation is observed in the case of respiration activity – for each mixture the measured value is significantly higher than the calculated mean. The differences are in the range between ca. 9 $mgO_2 \cdot g^{-1}$ d.m. (for the apple + carrot peels mixture) and ca. 18 $mgO_2 \cdot g^{-1}$ d.m. (for the mixture of all four types of peels). It indicates that biological stability of bio-waste mixture is not a simple average of susceptibly to biodegradation of each components but other phenomena, such as synergic effects, may take place.

4 Conclusions

Fruit and vegetable peels used in the research are components of typical bio-waste from households. They are characterized by high values of moisture content (up to 87.97 ± 0.41% – carrot peels), loss of ignition (up to 98.02 ± 0.05% – apple peels) and AT4 (up to 144.44 ± 11.85 $mgO_2 \cdot g^{-1}$ d.m. – carrot peels). The research revealed that whereas such properties as moisture content or loss of ignition do not change in mixtures of different types of peels (the parameters of mixtures depend on properties of components and their weight ratio), biological stability (measured using AT4 index) can change due to natural processes and interactions occurring in mixed materials. In the case of examined mixtures the AT4 values rose significantly compared to the values calculated on the basis of arithmetic means of pure components. The fact that there are other factors determining biological stability of bio-waste than just individual properties of each component has to be taken into consideration during processing of such waste.

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