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THE IMPACT OF MICRO-ORGANISM ACTIVITY ON THE BIODRYING PROCESS

Abstract
The biodrying process was carried out in a bioreactor with a capacity of 240 dm^3. The research utilized digested sludge from a sewage treatment plant and an organic fraction of municipal solid waste. The dry mass, dry organic mass, temperature, and respiration index of the dried material were determined during the biodrying process. Because of the waste biodrying process for ten days, the amount of moisture removed was 51.7%. The greatest activity of microorganisms in the waste was on the fourth day of the process, when the temperature reached the maximum value of 58°C in the top layer of waste in the middle of the bioreactor.

Key words
Respiration index, biodrying, composting

Introduction

Every year a large amount of organic waste is generated in the world. This applies to all countries, including EU countries, and is a major waste management problem. Therefore, from the point of view of modern waste management, the properties of waste should be used as efficiently as possible. Council Directive 1999/31/EC from April 26, 1991 on the landfill of waste has obliged the member states of the European Union to limit deposits of biodegradable waste in landfills [1]. Organic waste can be processed by composting, anaerobic digestion, and combustion. The net calorific value of organic waste can be increased by reducing water content.

The most energy efficient way to remove moisture from organic waste is the process of biodrying, which is a process like composting. Humidification and mineralization occur, which is the oxidation of organic substances into CO_2, CH_4, nitrates, sulfates, phosphates, and other components with the highest degree of oxidation. Humidification, by contrast, is the process of synthesis of multi-molecular humic compounds from organic matter which has undergone partial decomposition [2, 3]. The presence of oxygen in the space between waste is an indispensable factor during the biodrying and composting process. Its concentration within the pile should not be less than 5% by volume [4]. During the decomposition of organic matter under aerobic conditions, heat is generated in an autothermal process, which facilitates the removal of moisture from waste. During disintegration of one mole of glucose in the oxygen sediment, as much as 850 kJ of heat is emitted [5].

The difference between the composting process and the biodrying process is that water is added to the composting process to ensure adequate humidity. In contrast, in the process of biodrying, the water is removed from organic waste. Reducing the moisture content of waste generates less heat due to the low activity of microorganisms. The optimal moisture content in waste is 45 to 65% [6]. Conversely, when the moisture content of waste is below 15%, biological processes are stopped [7, 8]. Humidity above 65% leads to the formation of anaerobic zones due to obstructed airflow and diffusion of oxygen. The highest rate of oxygen uptake by microorganisms occurs when the moisture content of the waste is 60% [4].

Topics related to the biodrying of organic waste are dwelled upon by such authors as: Adani et al. [9], Domińczyk et al. [10, 11], Grillia et al. [12], Ragazzi et al. [13], Sugni et al. [14], Tambone et al. [15], Velis et al. [16, 17], Wagland et al. [18], Zawadzka et al. [19], Zhang et al. [20, 21]. However, biological biomass activity was not measured using the respiration index (AT_4) in the hitherto conducted studies.

The respiration index (AT_4), the respiratory quotient (RQ), and the specific oxygen uptake rate (SOUR) can be used to determine the biological activity of biomass. In this article, the respiration index (AT_4) was used to evaluate the biological activity of the digestate sludge from a sewage treatment plant together with the organic fraction of municipal solid waste [22].

The purpose of this paper was to determine the effect of biological activity of biomass on the digestion process of digestate sludge from a wastewater treatment plant together with the organic fraction of solid municipal waste, and to determine the relationship between the impact of temperature and humidity on biological activity of organic waste.

Materials and methods

Organic waste was dried in a horizontal bioreactor insulated with a 6 cm layer of polyurethane foam to reduce possible heat losses to the environment. The total capacity of the bioreactor with a width of 45 cm and a length of 145 cm was 240 dm^3. The tested organic material was placed on a perforated polycarbonate plate having 387 holes of 0.5 cm in diameter. The height of the waste layer in the bioreactor was about 20 cm.

The bioreactor used for drying organic waste had a supply air fan under a perforated plate, on which organic matter was located (inlet fan) and an exhaust fan for the air from the upper part of the bioreactor that flows through the layer of the tested material (outlet fan). After the bioreactor was loaded with the tested biomass, the air was heated to 35 for the first four hours to a temperature of 35°C at a rate of 86 m^3/h. In the subsequent hours of operation, the performance of the fans was adjusted according to the bioreactor outlet air humidity. Average aeration rates on individual days are shown in Fig. 1. The algorithm of fan operation is described in Dominczyk et al. [11]. The biodrying of waste was carried out for ten days. Adani et al. [9] observed that conducting the biodrying process for more than ten days at a lower rate is unreasonable because of the greater decay of the organic matter contained in the biomass taking place.

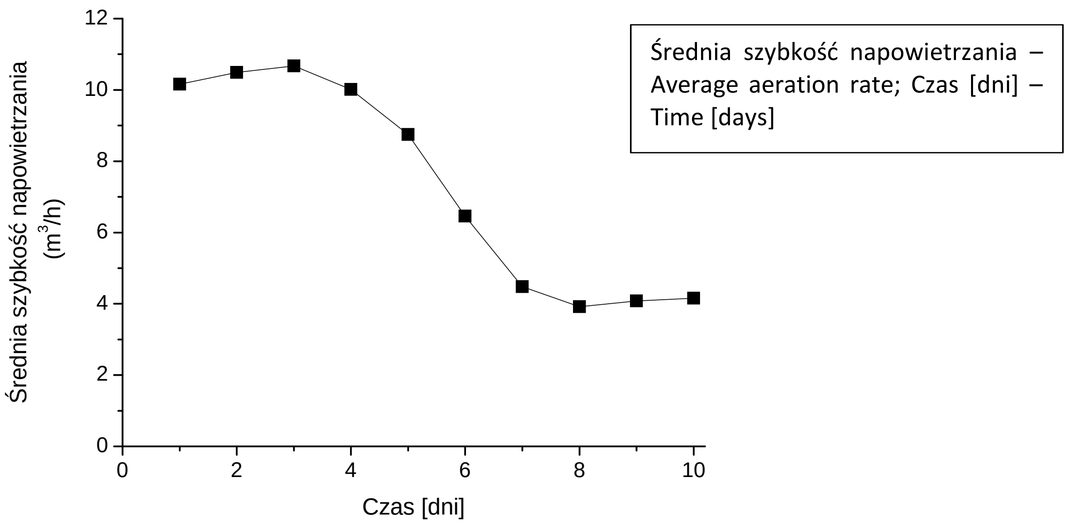
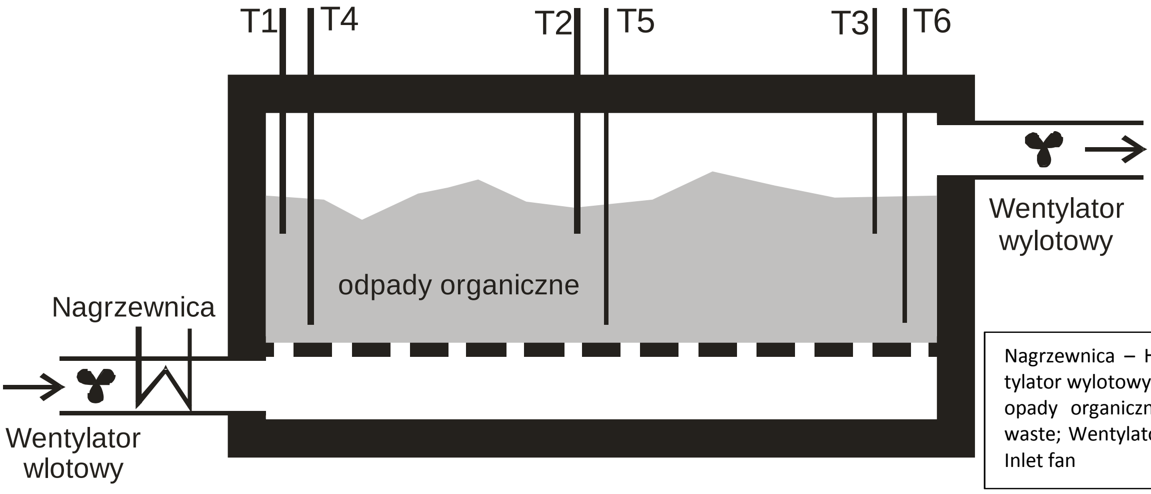


Fig. 1. Average rates of aeration of waste
Source: The author's own study

The bioreactor was equipped with six sensors for measuring the temperature (T1 - T6) of the tested matter inside the bioreactor. The sensors were located at the inlet, outlet and in the middle part of the bioreactor, in the upper and lower layers of the biomass. The markings of the individual measuring points are shown in Fig. 2. Data recording and fan performance control were performed through the AdcantechGeniDAQ Development computer program series 4.11.000.



Nagrzewnica – Heater; Wentylator wylotowy – Outlet fan; opady organiczne – organic waste; Wentylator wlotowy – Inlet fan

Fig. 2. Simplified diagram of the bioreactor's structure
Source: The author's own study

Digestate sludge from the Collective Sewage Treatment Plant in Łódź and the organic fraction of fresh solid municipal waste of a model composition were used for the tests. The morphological composition of the organic solid fraction of urban waste by weight was vegetables (40%), fruits (10%), and 50% other (coffee, tea, pasta, cereal, and flour). The total weight of the batch was 30 kg and it was prepared immediately before loading the bioreactor. The digestate mass accounted for 20% of the total weight of the batch. The mixture of the above waste was disintegrated into approximately 2 to 3 cm pieces. The bioreactor was placed in a laboratory where the temperature was about 23°C and the pressure was approximately 994 hPa.

During the process of biodrying, samples were collected for analysis prior to the loading of the bioreactor on the third and seventh day of the process, as well as after the unloading of the bioreactor. The biomass samples collected had the dry mass (SM), dry organic mass (SMO) and the respiration index (AT_4) determined. Dry mass and dry organic mass were made according to the PN-EN 12880:2004 and PN-EN 12879:2004 standards, respectively. The respiration index test (AT_4) was carried out in a WTW OXITOP with a volume of 1 dm^3 according to the ÖNORM S 2027-1:2004 standard (StabilitätsparameterzurBeurteilung von mechanisch-biologischvorbehandeltenAbfällen - Teil 1: Atmungsaktivität (AT_4)).

Results and discussion

Removal of moisture from waste was determined by measuring dry mass. The content of dry biomass of the waste placed in the bioreactor at the beginning of the process was 59.7% (Fig. 3). On the third day of the process, the moisture level in the dried material decreased by 14.5%. The removal rate of moisture was the greatest between the third and the seventh day of the waste drying. After seven days of the process, the moisture content decreased by 47.6% relative to the initial value. At the end of the drying process, the dry mass was 80.5% and the moisture content in the waste decreased by 51.7% relative to the initial value. Adani et al. [9] and Sugni et al. [14] achieved a very similar result (about 50%) in the research on the process of waste degradation. The time of aeration of the biomass in the tests carried out by Adani et al. [9] was 17 days, and in the studies carried out by Sugni et al. [14] 9 days. Comparison of the results obtained with other authors is difficult due to the non-homogeneous composition of the waste, the amount of the waste in the bioreactor, the fragmentation of the waste, the construction of the bioreactor, and the rate of aeration.

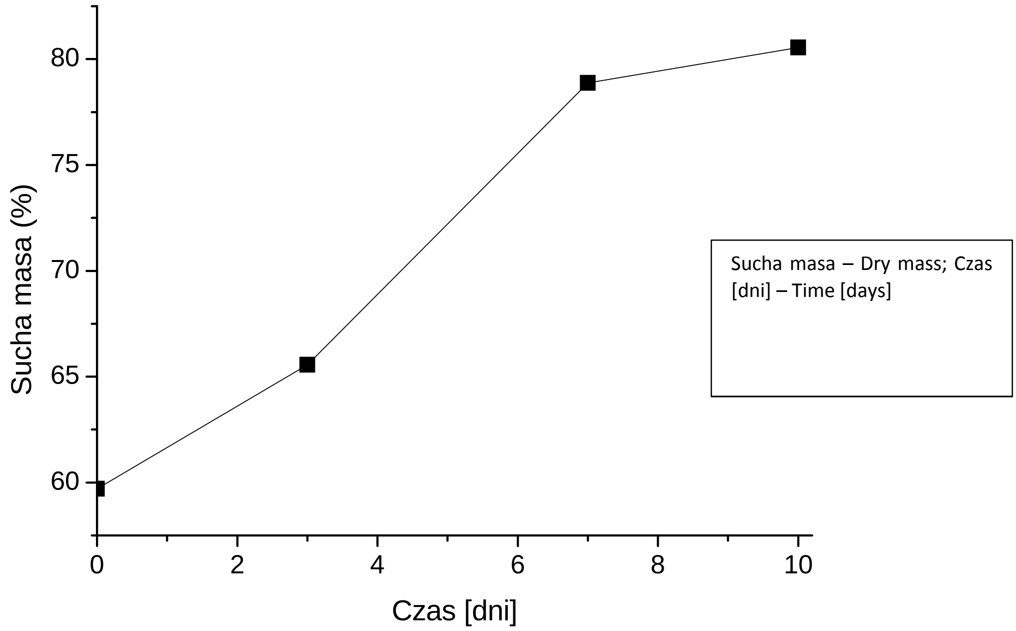


Fig. 3. Changes in dry mass content during the biodrying of waste
Source: The author's own study

The dry organic mass was determined to specify the amount of organic waste decomposition during the biodrying process. The decomposition of an excessive amount of organic carbon contained in carbon dioxide waste is not recommended due to the reduction of the calorific value of the dried material. At the start of the process, the dry organic mass content was 91.3%. The highest dry mass loss occurred between the third and the seventh day of the biodrying process (Fig. 4). After ten days of the process, the organic mass content in the waste was 85.9% and the organic mass loss was 5.9%. This work resulted in a small organic matter loss in the dried biomass compared to the data contained in the literature. In the research of Sugni et al. [14] and Adani et al. [14] the dry organic mass loss ranged from 4.3 to 25.5% and 16.2%, respectively.

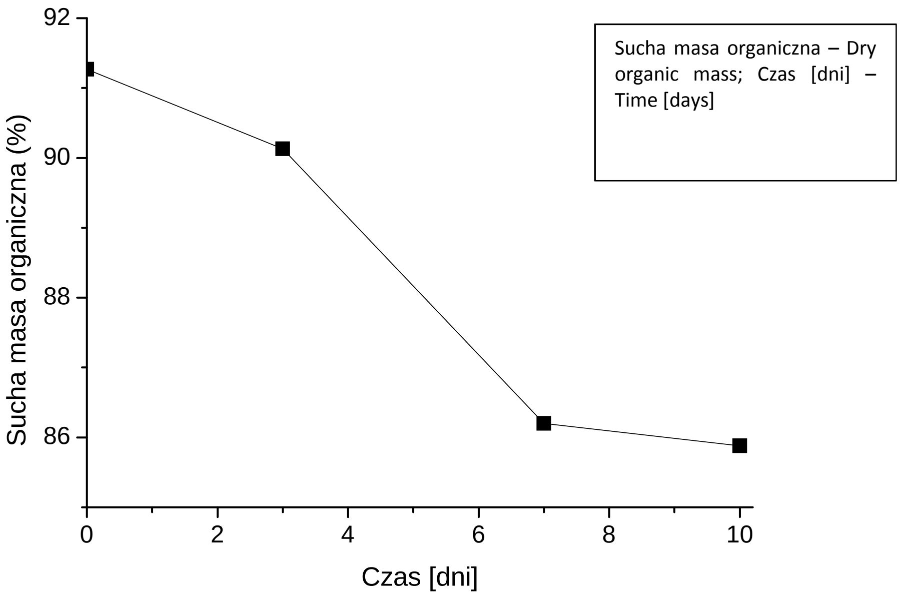


Fig. 4. Change in dry organic mass value during the biodrying of waste
Source: The author's own study

The results of the temperatures obtained in the upper and lower layers of the dried biomass are presented in Fig. 5. The measurements of the temperature of the dried biomass were made at the six points marked in Fig. 2. The increase in temperature during the biodrying process was associated with an increase in the activity of the organisms found in organic waste. There was a relationship that indicated that the higher the temperature was, the more intense the microbiological processes were. However, the temperature cannot be above 60°C because it will destroy the microorganisms. The obtained results of biomass temperatures suggest that the peak activity of microorganisms was reached on the fourth day of the biodrying process. The highest temperature was 58°C recorded in the top layer of the dried waste in the central part of the bioreactor (T2). In the same section of the bioreactor, but in the lower layer of the dried biomass, the temperature (T5) reached a value lower by 10°C. Higher temperatures were usually achieved in the upper layer of the dried biomass, and the lowest temperatures were observed in the lower layer at the bioreactor air outlet (T6). Sugni et al. [14] obtained a similar temperature distribution in one study series in which the waste was not tossed over in the bioreactor.

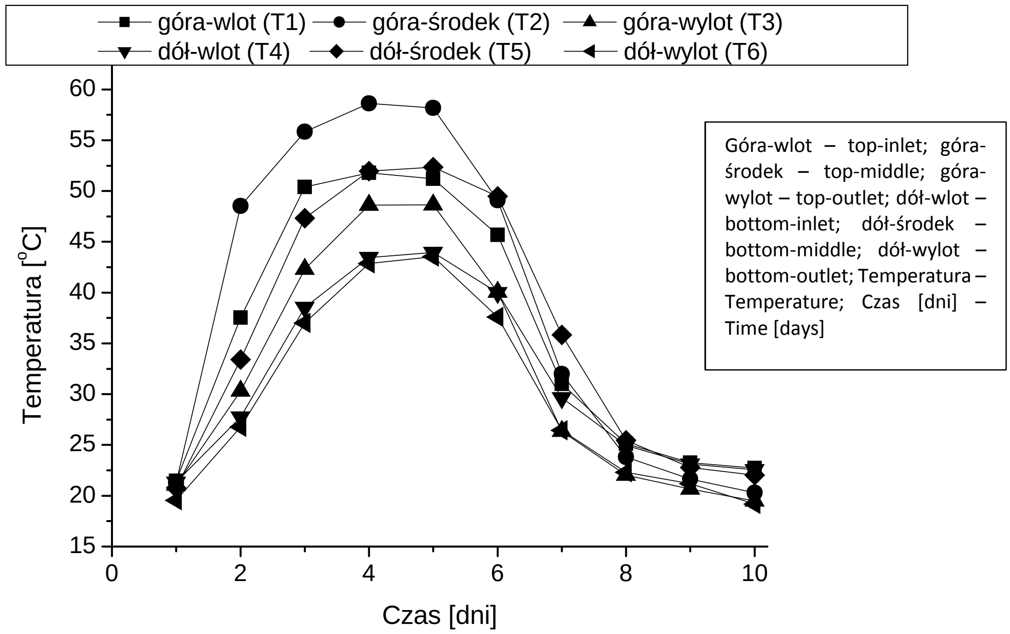


Fig. 5. Temperature changes in upper and lower layers of the dried material
Source: The author's own study

The higher temperatures in the upper layer were caused by the less compact structure of the biomass, which resulted in oxygen reaching the space between the waste more easily. Larger amounts of oxygen caused micro-organisms to accelerate the decomposition of the organic matter and produce more heat. The maximum temperatures of dried biomass obtained by Zawadzka et al. [19] and Sugni et al. [14] were similar to the results achieved in this work. Adani et al. [9] obtained in one study series a maximum temperature of the dried material of more than 70°C.

To assess the biological activity of the organic waste, the respiration index for the test material was determined. At the beginning of the biodrying, its value was 8.01 gO_2/kgSM (Fig. 6). During the first three days of biodrying, a significant decrease in the respiratory index to the value of 2.89 gO_2/kgSM was observed, which could have been caused by changes in the moisture content of the test material. In the next four days, the respiratory index decreased slightly to a value of 2.28 gO_2/kgSM. The rapid loss of moisture in the waste and the increase in its temperature caused a slow decrease in the respiration index between the third and the seventh day of the biodrying process. On the last day of the process, the value of the respiration index decreased to the value of 0.31 gO_2/kgSM. The decrease in the respiration index between the seventh and the tenth day was caused by a reduction in the moisture and temperature of the dried waste. Organic waste is biologically stable when the value of the respiration index is below 4.0 gO_2/kgSM [23]. The results obtained indicate that after ten days of biodrying, the tested material was stabilized.

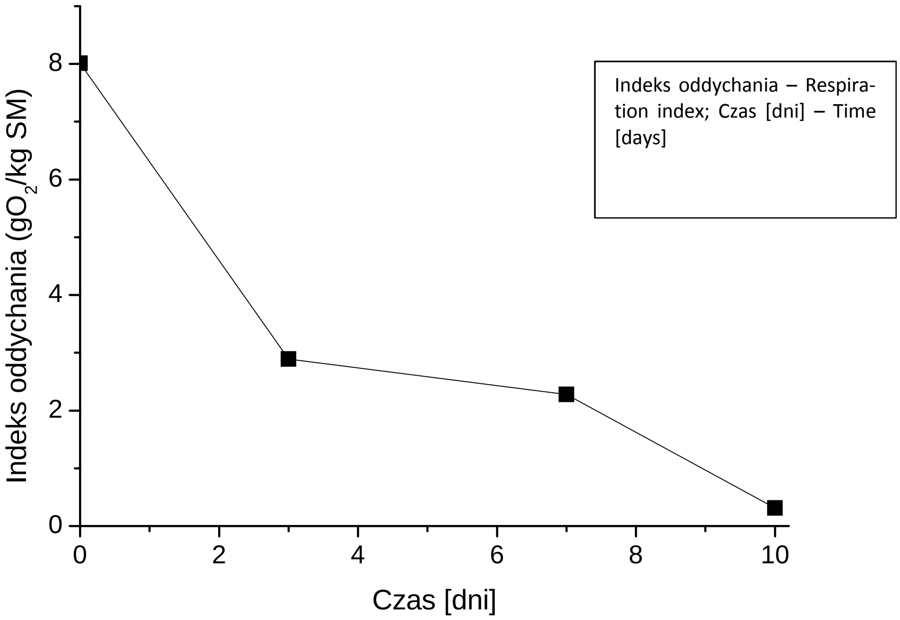


Fig. 6. Change in the respiration index during the biodrying of waste
Source: The author's own study

Conclusion

The research shows that the process of biological drying allows the removal of 51.7% of moisture in the tested material. In addition to the removed moisture from organic waste, carbon in the form of CO_2 was also removed. The loss of dry organic mass during organic waste biodrying was 5.9%. The highest rate of removal of moisture from organic waste was observed at high waste temperatures. Microbial activity decreased when the moisture content of the test material was below 30%. The respiration index of the tested material after a ten-day process of biodrying was 0.31 gO_2/kgSM, which may indicate a decline in microbial activity. The final product can be used as an alternative fuel due to low humidity (19.4%).

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