Małgorzata KRASOWSKA, Małgorzata KOWCZYK-SADOWY
Białystok University of Technology, Faculty of Civil and Environmental Engineering, Department of Agricultural and Food Engineering and Environmental Management
ul. Wiejska 45E, 15-351 Białystok, Poland
e-mail: m.krasowska@pb.edu.pl

Received: 2018-10-31 ; Accepted: 2018-11-22

EVALUATION OF THE POSSIBILITY OF USING APPLE POMACE FOR FERTILIZING PURPOSES

Summary

This work presents the results of research on the physical and chemical properties of apple pomace. Laboratory tests included the analysis of water content, sodium, potassium, calcium and magnesium cations as well as phosphorus, nitrogen and carbon. Apple pomace was obtained from two plants (A and B) producing apple juices. Both plants are located in north-eastern Poland, Podlasie province. Plant A is engaged in fruit and vegetable processing, while plant B in a fruit juice pressing. Based on the obtained results, it was found that the physical and chemical properties of apple pomace differ from each other, and the quality of the raw material, species and variety of apples as well as habitat conditions may influence it. Examining the fertilizing properties, it was found that the ratio of carbon to nitrogen (C: N) can be very diverse (from 5 to 22). However, the analysis of selected parameters indicates that apple pomace can be used for fertilizing purposes, primarily as a substrate for the production of compost.
***Key words**: apple pomace, fertilizers, agro-food industry*

OCENA MOŻLIWOŚCI WYKORZYSTANIA WYTŁOKÓW JABŁKOWYCH DO CELÓW NAWOZOWYCH

Streszczenie

W pracy przedstawiono wyniki badań właściwości fizyko-chemicznych wytłoków jabłkowych. Badania laboratoryjne obejmowały analizę zawartości wody, kationów sodu, potasu, wapnia i magnezu oraz fosforu, azotu i węgla. Wytłoki z jabłek otrzymano z dwóch zakładów (A i B) wytwarzających soki jabłkowe. Oba zakłady zlokalizowane są w północno-wschodniej Polsce, województwo podlaskim. Zakład A zajmuje się przetwarzaniem owoców i warzyw, podczas gdy zakład B zajmuje się tłoczeniem soków owocowych. Na podstawie uzyskanych wyników stwierdzono, że właściwości fizyczne i chemiczne wytłoków jabłkowych różnią się od siebie, a wpływ na to ma jakość surowca, rodzaj gatunek i odmiana jabłek oraz warunki siedliskowe. Badając właściwości nawozowe, stwierdzono, że stosunek węgla do azotu (C: N) może być bardzo zróżnicowany (od 5 do 22). Jednak analiza wybranych parametrów wskazuje, że wytłoki jabłkowe można wykorzystać do celów nawozowych, przede wszystkim jako substrat do produkcji kompostu.
***Słowa kluczowe**: wytłoki jabłkowe, nawozy, przemysł rolno-spożywczy*

1. Introduction

In the agri-food processing a relatively large number of by-products are produced, which are mainly organic residues of plant and animal origin. They are created all over the country, in farms, gardening farms, livestock farms, sugar factories, distilleries, dairies, and other plants involved in the production and processing of food. The sugar, dairy, fruit and vegetable industry is characterized by the largest annual amount of production residues [2, 8]. The amount of waste produced from the processing of fruit and vegetables is 10 to 35% of the weight of the raw material used, and the largest part of them is expressed in pomace. They are an unstable material with a high water content. Especially in the case of apple pomace, in which water can be up to 73% [16, 25]. A good way to stabilize them is drying, which allows the inhibition of microbial growth and reduction of the volume and weight of the material [19]. However, large food processing plants with appropriate technological and financial resources can afford such a solution.

Poland is one of the largest producers of apple juice and concentrate in Europe. Modern production technologies allow to obtain juice reaching even 80 to 90% [22]. The by-product in the form of pomace, arising in the apple processing process has a great potential for further use and processing, due to its physico-chemical properties. It is very interesting for nutritional reasons because it contains significant amounts of dietary fiber and polyphenolic compounds [14]. Dried and shredded pomace can be directly used as an ingredient in various types of bakery and confectionery products [12, 17, 22]. In addition, pomace is a rich source of many valuable ingredients, such as saccharides, proteins, minerals, pectins, lipids, organic acids, vitamins, aldehydes, alcohols and color and aromatic substances. Therefore, it should be treated as an intermediate for further processing [10, 25]. Despite the wide range of use of apple pomace, a part of this by-product is still treated as waste. It is related to the specificity of the industry, seasonality, production dispersion and the overwhelming number of small and medium fruit and vegetable plants [25].

Due to the widely discussed problem of waste management and management of by-products, attention was paid to the agri-food processing industry as a part of the Circular Economy assumptions. The use of waste in the world is moving towards the transformation of the largest possible amounts into useful products, for example through processes involving microorganisms. Currently, the main research activities are carried out on ways to minimize exposure of the environment not only by getting rid of waste, but that through its conversion into useful components [21].

One of the ways of developing apple pomace consists in its allocation for agricultural purposes, both forage and fertilizing, as well as for the production of biogas. The data obtained in the last decade have shown a high fertility of waste from fruit processing, because it can be used as a fertilizer for specific plant species [11, 15, 22]. For fertilizing purposes, it can be used both as an additive to compost and in dry or powdered form [2].Considering that organic fertilization is one of the oldest and most valuable methods of soil cultivation, already in the seventies composts were marred with the addition of organic fertilizers. Through 15 years fertilized apple orchard to give increased yields of. Research has been carried out on the effect of grape marc for fertilization on yield and vine health. Coffee plantations in Mexico use compost from coffee pulp for reclaiming wasteland [5].

2. The aim of the research

Organic fertilization plays a key role in improving soil fertility and plant nutrition, which is why it is necessary to use by-products from agri-food processing for fertilizing purposes. However, it requires constant research on their fertilizing properties. Therefore, in order to determine the fertilizing properties of apple pomace, its selected physicochemical properties were examined. The results were compared for two fruit and vegetable processing plants located in the Podlasie Voivodeship.

3. Research methodology

Apple pomace for laboratory tests was obtained from two plants (A and B) producing apple juice located in the vicinity of Białystok, in the Podlasie voivodeship. Plant A deals with fruit and vegetable processing, while plant B deals with fruit juices. The obtained pomace was a mixture of seeds, pieces of flesh and peels.

The analyzed pomace was subject to laboratory tests and the following physicochemical parameters were defined in it:

- moisture,
- cation: calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}),
- nitrogen (N) and phosphorus (P),
- carbon (C).

Table 1 presents the test methods used.

Table 1. Methodology of laboratory tests
Tab. 1. Metody badań laboratoryjnych

Parameter	Method
Moisture	drying and weighing method
Ca	spectrophotometry
Mg	spectrophotometry
Na	spectrophotometry
K	spectrophotometry
N	Kjeldahl method
P	spectrophotometry
C	catalytic oxidation by combustion (TOCl-L)

Source: own elaboration / Źródło: opracowanie własne

The tests were carried out on samples of obtained pomace with a five-fold repetition.

4. Results and discussion

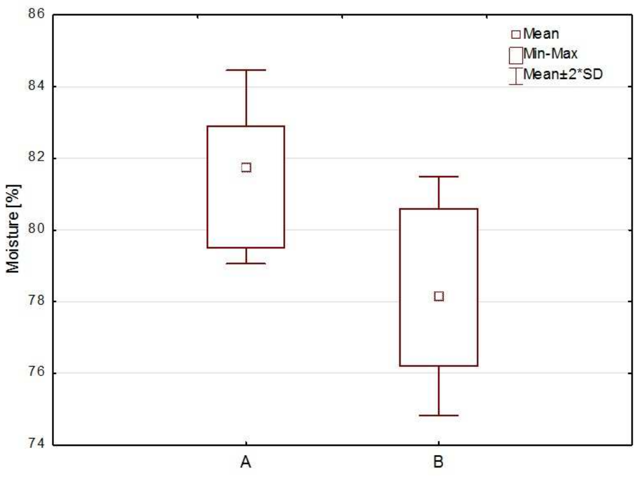
Based on the results of the study, it was found that the particular value of selected physicochemical parameters in fruit pomace from two different plants (A and B) differed from each other (Table 2). It could have been influenced by different kinds of species and varieties of apples used for production, as well as various habitat conditions for the cultivation of used apples.

Table 2. Selected physical and chemical properties of apple pomace from two sources (A I B)
Tab. 2. Wybrane właściwości fizyko-chemiczne wytłoków jabłkowych z dwóch źródeł (A i B)

		A	B
Moisture	[%]	81,8	78,2
Na		0,0014	0,002
K		0,13	0,32
Ca		0,03	0,01
Mg		0,02	0,05
P		0,09	0,06
C		10,8	6,0
N		0,5	1,2

Source: own elaboration / Źródło: opracowanie własne

The moisture content of the analyzed pomace was higher in the case of samples from plant A (Fig. 1). However, values in both cases range from 70 to 90%, which are given in the literature [20, 25]. The high moisture of the analyzed material indicates microbiological instability but also indicates its suitability for composting purposes. Humidity of composted material between 50% and 70% is the most suitable for the composting process and should be maintained throughout the duration of the activity of microorganisms [23].



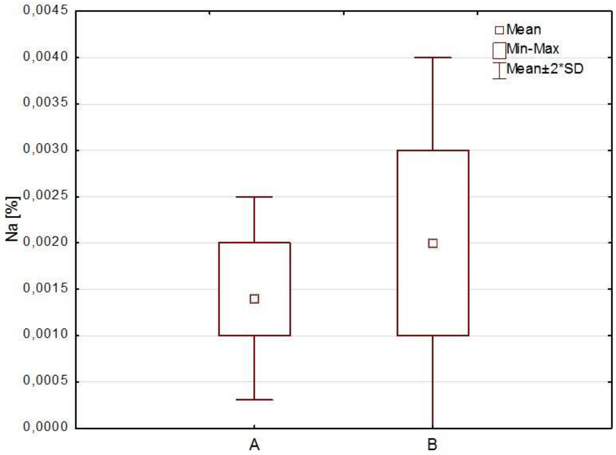
Source: own elaboration / Źródło: opracowanie własne

Fig. 1. The dynamics of moisture (%) in apple pomace from plants A and B
Rys. 1. Dynamika wilgotności (%) wytłoków jabłkowych z dwóch zakładów (A i B)

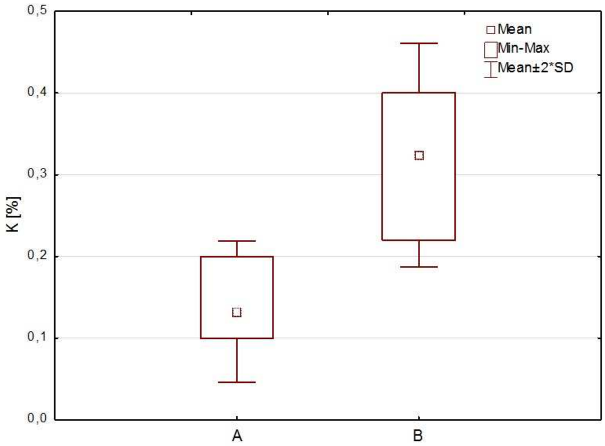
The content of sodium cations (Na^{+}) in apple pomace from plant A and B was slightly different. The potassium content (K^{+}) in the pomace from plant B was more than twice as high (Fig. 2). However, the concentration of these ions in comparison to the literature data was very low [5, 7]. According to the commentary on Annex I to

Commission Regulation (EC) No 889/2008, the average potassium content in apple pomace is from 0.40 to 0.80%, whereas in grape marc the amount is from 1.80 to 2.0% [6].

a)



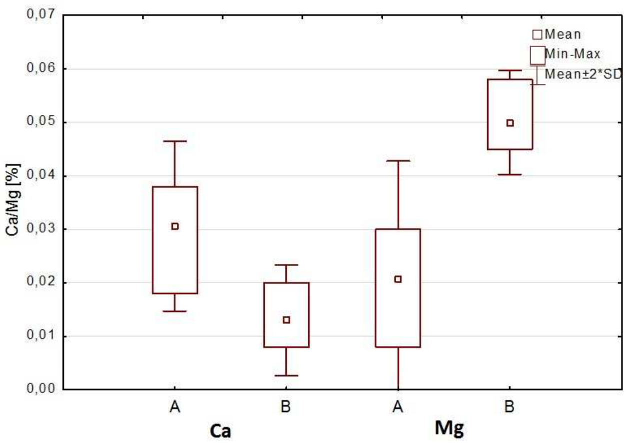
b)



Source: own elaboration / Źródło: opracowanie własne

Fig. 2. The dynamics of: a) Na (%); b) K (%) content in apple pomace from plants A and B
Rys. 2. Dynamika zawartości a) Na (%); b) K (%) wytłoków jabłkowych z dwóch zakładów (A i B)

The concentration of magnesium (Mg) and calcium (Ca) in fruit marc samples varied (Fig. 3).

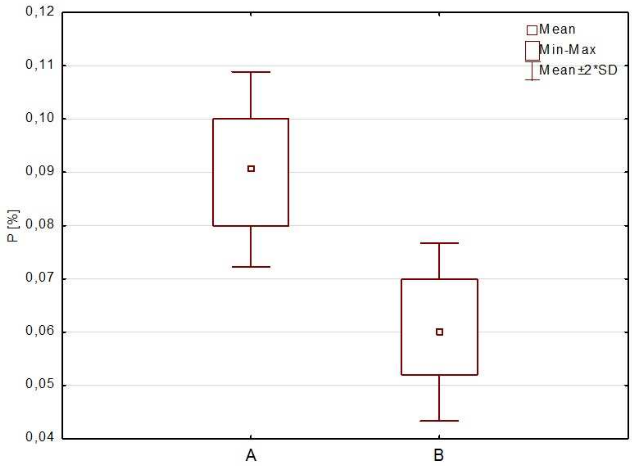


Source: own elaboration / Źródło: opracowanie własne
Fig. 3. The dynamics of Ca (%) and Mg (%) content in apple pomace from plants A and B
Rys. 3. Dynamika zawartości Ca (%) i Mg (%) wytłoków jabłkowych z dwóch zakładów (A i B)

In pomace from plant A, the average calcium content was higher than from plant B, while magnesium was lower. Literature data indicate that the content of Ca in apple pomace may be from 0.1 to 0.2%. However, in the analyzed samples of calcium it was as much as 10 times less. According to the research of other authors Mg content ranged from 0.05-0.1% [4, 6, 7].

Magnesium (Mg), as an essential nutrient of plants and the main component in various life functions of plants, is surprisingly often a neglected element in optimally conducted plant production systems. However, it plays key role in many plant functions and has a huge impact on the production of high quality crops. Magnesium deficiency becomes a big problem on soils that are fertilized only with N, P, K. Low calcium content may indicate a poor quality of raw materials (apples).

The content of phosphorus (P) in apple pomace is small and can range from 0.06 to 0.1% [6]. In the samples analyzed, the average P content is exactly in this range (Fig. 4). Analyzing the content of phosphorus, it should be emphasized that in addition to nitrogen (N) and potassium (K), it is an element of great importance for the development of plants [4].



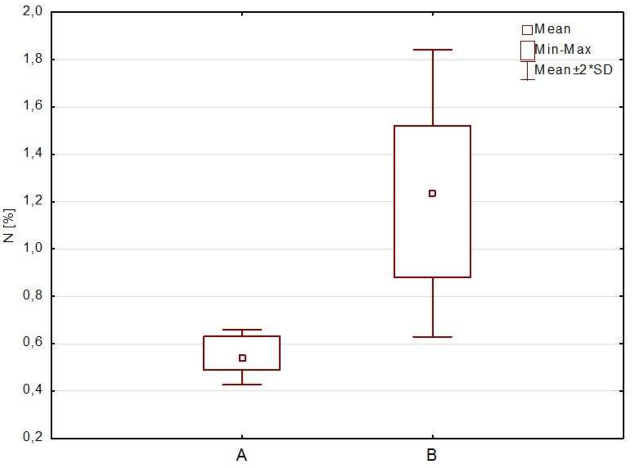
Source: own elaboration / Źródło: opracowanie własne

Fig. 4. The dynamics of P (%) content in apple pomace from plants A and B
Rys. 4. Dynamika zawartości P (%) wytłoków jabłkowych z dwóch zakładów (A i B)

The content of nitrogen (N) in fruit pomace is very variable. The average concentration can range from 0.4 to 0.7% in apple pomace and from 1.8 to 3.5% in grape pomace [6. In the analyzed samples, the average nitrogen content was twice as high in pomace obtained from plant B (Fig. 5). The maximum concentration of N was over 1.5%.

In the case of assessment of fertilizing properties, the carbon content and the ratio of carbon to nitrogen (C:N), which affects the decomposition of organic matter, is significant. The organic substance is degraded by soil organisms that need nitrogen, carbon and other nutrients to carry out this process. In the case of low nitrogen content, the decomposition of organic matter proceeds slowly [13].

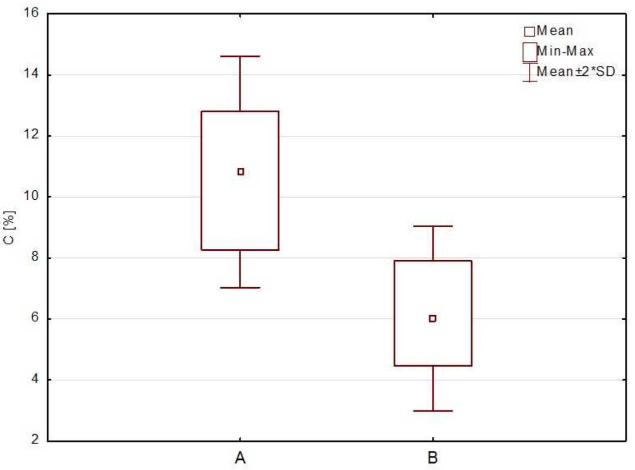
The average carbon content in samples from plant A was 5.5 times higher than plant B (Fig. 6). However, the ratio of carbon to nitrogen in apple pomace was 22:1 (plant A) and 5:1 (plant B). In the case of soil, the C:N ratio is usually 12:1, while the most favorable C:N ratio in the organic substrate used for fertilization is 20:1 or 24:1. In the case when this ratio is higher, microorganisms start to take up absorbing nitrogen from the soil, and then it is not enough for plants. However, when the ratio is lower than 20:1, the mineralization processes start to prevail in the soil [18]. Therefore, to compose fertilizer mixtures, the nitrogen and carbon content of the substrate should be taken into account, and by adding different components, the desired C: N ratio can be obtained.



Source: own elaboration / Źródło: opracowanie własne

Fig. 5. The dynamics of N (%) content in apple pomace from plants A and B

Rys. 5. Dynamika zawartości N (%) wytłoków jabłkowych z dwóch zakładów (A i B)



Source: own elaboration / Źródło: opracowanie własne

Fig. 6. The dynamics of C (%) content in apple pomace from plants A and B

Rys. 6. Dynamika zawartości C (%) wytłoków jabłkowych z dwóch zakładów (A i B)

The subject of fertilizer properties of organic waste is widely discussed in domestic and foreign literature. It was observed that the C:N ratio depending on the substrates used is very variable. Knowledge of physical and chemical properties of materials intended for composting and their relationships are important at every stage of the composting process [8]. Table 3 shows the selected raw materials for the production of organic fertilizer and compost.

Tab. 3. The C:N ratio in selected raw materials and composts

Tab. 3. Stosunek węgla do azotu w wybranych surowcach i kompostach

Raw materials/compost	C:N	Source
Slurry for the production of compost	12.0-25.0	[1]
Compost from sewage sludge	19.6-42.7	[3]
Mixture: sewage sludge, straw, bark, wood chips - before composting	12.6	[7]
Compost: sewage sludge, straw, bark, wood chips	8.7	[7]

Source: own elaboration / Źródło: opracowanie własne

5. Summary

On the basis of the performed tests, the following conclusions have been formulated:

1. The apple pomace is widely used in various industries. Therefore, up to 90% of it are utilized. However, the dispersal of fruit and vegetable processing and the dominance of small and medium enterprises increase the share of undeveloped pomace. Therefore, it is important to designate pomace for agricultural purposes (fodder and fertilizer) and treat it as an intermediate for further processing.
2. Due to its physico-chemical properties, pomace is an appropriate fertilizer material. The production of compost from apple pomace with the addition of other substrates, e.g. with a higher carbon content is the best solution.
3. Due to the fact that fruit marc is characterized by seasonality and variable composition, depending on habitat and climate conditions, detailed research should be conducted to identify factors affecting its physico-chemical properties and to make better use of it.
4. The obtained results confirm that the fertilising properties of apple pomace from two sources may differ significantly from each other.
5. It should be remembered that apple pomace may be rich in metal ions (Mg, Mn, Fe, etc.) and may be contaminated with plant protection products, which may limit its use for further processing [9]. When using marc for agricultural purposes, it is necessary to precisely determine the level of contamination with heavy metals and pesticides so as not to lead to secondary environmental pollution. Therefore, more detailed and extended research should be carried out.

6. References

[1] Banach M., Kowalski Z., Kwaśny J. (2011). Kompost na bazie odpadów z hodowli trzody chlewnej – ocena właściwości nawozowych. Archiwum gospodarki odpadami i ochrony środowiska, vol. 13, 3: 1-20

[2] Białecka B. (2008). Gospodarka odpadami z przemysłu rolno–spożywczego w województwie śląskim. Problemy Ekologii, vol. 1, 28: 2, 1.

[3] Boruszko D. (2011). Badania i ocena wartości nawozowej kompostów i wermikompostów. Rocznik Ochrona Środowiska, 13: 1417–1428.

[4] Bożym M., Dróżdż N., Siemiątkowski G. (2014). Zawartość makroelemnetów i ich form przyswajalnych w kompostach produkowanych z odpadów zielonych. Prace ICiMB, 18: 150–161.

[5] Clark M.S., Horwath W.R., Shennan C., Scow K.M. (1998). Changes in soil chemical properties resulting from organic and low input farming practices. Agronomy Journal, 90: 662-671.

[6] Ciesielska J., Malusà E., Paszt L. (2011). Komentarz do Załącznika I rozporządzenia Komisji (WE) nr 889/2008 ustanawiającego szczegółowe zasady wdrażania rozporządzenia

Rady (WE) nr 834/2007 w sprawie produkcji ekologicznej i znakowania produktów ekologicznych w odniesieniu do produkcji ekologicznej, znakowania i kontroli.
[7] Czekała J. (2008). Właściwości chemiczne kompostu wytworzonego z komunalnego osadu ściekowego i różnych bioodpadów. Journal of Research and Applications in Agricultural Engineering, vol. 53: 35-41.
[8] Czyżyk F., Strzelczyk M. (2015). Rational utilization of production residues generated in agri-food. Archiwum Gospodarki Odpadami i Ochrony Środowiska vol. 17, 3, 99-106.
[9] Górecka H., Górecki H., (2000). Metale w nawozach organicznych i odpadach stosowanych do celów nawozowych. Przemysł chemiczny, 79/2: 53-55.
[10] Gullón B. (2007). Apple Pomace for Application in Food Industries. Food Technol. Biotechnol., 45 (4): 426–433.
[11] Jara-Samaniego J., PeÂrez-Murcia M.D., Bustamante M.A., Paredes C., PeÂrez-Espinosa A., Gavilanes-TeraÂn I., (2017). Development of organic fertilizers from food market waste and urban gardening by composting. Ecuador. PLoS ONE, 12(7).
[12] Kidoń M., Fogiel J., Walkowiak-Tomczak D. (2016). Radziejewska-Kubzdela E., Biegańska-Marecik R., Młynarczyk K. Zastosowanie suszonych wytłoków jabłkowych jako dodatku do produkcji wafli. Zagospodarowanie ubocznych produktów przemysłu spożywczego (red.) Górecka D., Pośpiecha E. Wyd. UP Poznań.
[13] Klasik M., Alwaeli M., Hybryb W. (2015). Analysis of physicochemical and fertilizing properties of selected group of municipal solid waste and compost for utilization as a base for desert land. Archiwum Gospodarki Odpadami i Ochrony Środowiska, vol. 17, 1: 149-158.
[14] Kołodziejczyk K., Markowski J., Kosmala M., Król B., Płocharski W. (2007). Apple pomace as a potential source of nutraceuticals products. Polish Journal of Food and Nutrition Sciences, 57 (4B): 291-295.
[15] Kovács B. A., Kremper R., Kincses I., Szabó A. (2014). Influences of ammonium-nitrate, food waste compost and bacterial fertilizer on soluble soil nitrogen forms and on the growth of carrot (Daucus Carota L.). Eurasian Journal of Soil Science, 3, 95-100.
[16] Kumider J. (1996). Utylizacja odpadów przemysłu rolno-spożywczego. Wyd. AE, Poznań, 66-70.
[17] Kurcz A., Błażejak S., Kot1 A. M., Bzducha-Wróbel A. (2016). Wykorzystanie odpadów pochodzących z przemysłu rolno-spożywczego do produkcji biomasy drożdży paszowych candida utilis. Post. Mikrobiol., 55, 1: 19–26.
[18] Kwiatkowska J., Maciejewska A. (2008). Wpływ rodzajów substancji organicznej na właściwości fizykochemiczne gleby i zawartość węgla organicznego. Roczniki Gleboznawcze, TOM LIX, 1: 128-133.
[19] Lavelli V., Corti S. (2011). Phloridzin and other phytochemicals in apple pomace: Stability evaluation upon dehydration and storage of dried product. Food Chemistry, 129: 1578-1583.
[20] Malińska K. (2013). Zmiany właściwości fizycznych materiałów podczas kompostowania w warunkach laboratoryjnych. Inżynieria i Ochrona Środowiska 16, nr 4, 523-536.
[21] Okonko I.O., Adeola O.T., Aloysius F.E., Damilola A.O, Adewale O.A. (2008). Utilization of food wastes for sustainable development. Electr. J. Environ., Agric. Food Chem., 8 (4): 263-286.
[22] Sagar N., Pareek S., Sharma S., Elhadi M. Yahia E.M., Gloria Lobo M.(2018). Fruit and Vegetable Waste: Bioactive Compounds, Their Extraction, and Possible Utilization. Comprehensive Reviews in Food Science and Food Safety, vol. 17, 3: 512-531.
[23] Sołowiej P., Neugebauer M., Piechocki J. (2010). Wpływ dodatków i napowietrzania na dynamikę procesu kompostowania Inżynieria Rolnicza 5(123), 259-265.
[24] Sudha M. L., Baskaran V., Leelavathi K., (2007). Apple pomace as a source of dietary fiber and polyphenols and its effect on the rheological characteristics and cake making. Food Chemistry, 104 (2): 686-692.
[25] Tarko T., Duda-Chodak A., Bebak A. (2012). Aktywność biologiczna wybranych wytłoków *owocowych oraz warzywnych.* Żywność. Nauka. Technologia. Jakość, 4 (83): 55-65.

The research has been prepared within the work No. S/WBiIŚ/02/2015 and has been financed from the resources of The Ministry of Science and Higher Education for science.