TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2013, Vol. 13, No. 2, 73–78

The evaluation of the power consumption of the pellets production process from the plant materials

Sławomir Obidziński

Department of Agricultural and Food Techniques, Faculty of Mechanical Engineering, Bialystok University of Technology, 45C Wiejska Street, 15-351 Bialystok, Poland,
tel. +48 0857469282, fax: +48 0857469210, e-mail: obislaw@pb.edu.pl

Received April 5.2013; accepted June 28.2013

Summary. In the paper presents the results of a research on the influence of potato pulp content (15, 20 and 25%) in a mixture with buckwheat hulls and the variable mass flow rate of the mixture (50, 75 and 100 kg·h^{-1}) on the energy consumption of the pelletisation process and on the moisture content of the obtained pellets. On the basis of the research results it was established that the addition of potato pulp to pelletised buckwheat hulls caused a significant reduction in the power consumption of the pellet mill at each of the tested mass flow rates of the flow of the mixture through the working system of the pellet mill and increase of the moisture content of the densified mixture and the pellets produced from this mixture.

Key words: potato pulp, buckwheat hulls, energy consumption, moisture content of pellets.

1. INTRODUCTION

Due to the requirement addressing the reduction of carbon dioxide emission into the atmosphere, universally respected in the recent years, the use of biomass as a raw material in the production of electric energy and heat, including waste biomass from the agriculture and food industry, has become more and more common. Due to the increase in prices and the increasingly more limited accessibility of wood sawdust on the market, as reported by Stolarski, Kwiatkowski [23], there is an growing interest in the use of other natural raw materials for the production of pelletised biofuels, e.g. sunflower, coffee, oats, and many other types of post-production waste [21, 22], including those from the agriculture and food industry [3, 24, 14].

One of the types of waste raw materials obtained from processing buckwheat into groats are by-products such as contaminants, hulls, or shredded buckwheat grains, mixed with particles of broken hulls, commonly known as buckwheat bran. Buckwheat hulls have multiple uses: due to their therapeutic properties they are sold as pillow filler material for therapeutic pillows, quilts or mattresses [23]. Despite the low nutritional value, and owing to the high content of phenols of strong antioxidant properties, they can serve as a source for obtaining these compounds [23]. They can be used as a fodder additive, which allows it to be stored for longer periods of time [2]. They are also used as a raw material for creating composts and substrata for horticulture; as bedding for domestic animals; and as filler for packing fruit and fragile goods [23]. In practice, however, as claimed by Stolarski and Kwiatkowski [23], buckwheat hulls are most commonly treated a waste material, and buckwheat processing plants are seeking realistic possibilities of their utilization.

Stolarski, Kwiatkowski [23] claims that the calorific value of by-products of buckwheat processing, as well as the pellets produced from them, is similar to the calorific value of pellets from pine sawdust or pellets from the common osier. The content of sulphur in buckwheat hulls is very small, therefore, combustion of fuels produced from them causes only a negligible pollution to the environment, which is obviously a significant aspect as far as environmental protection is concerned. According to Borkowska and Robaszewska [1], the advantages of briquettes obtained from buckwheat hulls are similar to those of wood briquettes, and their calorific value is higher than the calorific value of firewood.

An undeniable drawback of buckwheat hulls, however, is their small bulk mass, which makes transport difficult; hence, processing the hulls in the plant where they are produced is the most beneficial solution. In addition, unshredded buckwheat hulls are a material characterized by a low susceptibility to densification, which is confirmed by the author's own research as well as the experiments of Ekofrisa [6], a company that produces pellets from buckwheat hulls. The research allowed to conclude that the production of pellets from buckwheat hulls is more complicated than the production from typical biomass material e.g. sawdust, because buckwheat hulls have no binding material. Therefore, hulls are ground into dust and compressed with steam. Due to this, in order to increase the susceptibility of buckwheat hulls to densification and improve the conditions for carrying out the process, a binder material needs to be added to them during the pelletisation process. Potato pulp, which mainly consists of raw fiber, starch remnants and mineral compounds, and is a post-production waste material created during the production of potato starch, can serve as such a material.

According to many researchers the introduction binder additives or another type of biomass waste causes an increase of the kinetic durability of the obtained pellets and a reduction of the power consumption of the pelletisation process [4, 5, 7, 17, 18, 19, 20].

Mediavilla et al. [9] pelletized different mixtures of vine shoots and cork in a commercial pellet mill, using a 20 mm compression flat die. They discovered that with the addition of industrial cork residue to vine shoots less energy was demanded. Other Mediavilla et al. [10] work show that maize starch or lignosulphonate addition (in dosages of 2.5, 5.0 and 7.0 wt.% (d.b.) of dry additive) increased the process stability and decreased the specific energy demand during the pelletisation process of poplar. Kaliyan and Morey [7] also confirmed that addition of lignosulphonate as a binder during pelletisation process improves pellets physical quality and decreases energy demand. According to Kulig and Laskowski [8], total energy consumption of pelleting is affected mostly by the chemical composition of the processed raw materials. Niedziółka et al. [11] claims that the value of power consumption during the densification process is considerably affected by contents of particular elements in plant mixes used for pelleting. Increase of ground wheat and sawdust in plant mixes results in an increase of power consumption from 14 to 34% compared to the power consumed for mixes with lower contents of these elements. Stahl and Berghel [20] concluded, on the other hand, that as the content of turnip waste obtained in the process of making turnip oil in the densified mixture with sawdust was increasing, the energy consumption of the pelletisation process, as well as the mechanical strength and density of the obtained pellets, were decreasing.

The purpose of the paper was to determine the influence of the addition of potato pulp to buckwheat hulls and the variable mass flow rate of the flow of the mixture through the working system of the pellet mill on the power consumption of the process and on the kinetic durability of the obtained pellets.

2. RESEARCH METHODS

This paper presents the results of a research study on the process of pelletisation of a mixture of post-production waste: buckwheat hulls, which were post-production waste created during the production of buckwheat groats in Podlaskie Zakłady Zbożowe S.A. in Białystok, and potato pulp, which was a remnant of washing out starch from potatoes in PEPEES S.A in Łomża.

The moisture content of the raw materials (buckwheat hulls, potato pulp and the prepared mixtures of buckwheat hulls and pulp) before the densification process was determined pursuant to PN-76/R-64752 using a WPE 300S moisture balance with an accuracy of 0.01%, according to the methods presented in [12, 15]. Each time the moisture content of five samples was determined. For the purpose of the measurements, samples with a mass of 5 g were taken and dried in a temperature of 105°C until the indications of the moisture balance remained unchanged in three consecutive readouts in 15s intervals. The mean of the obtained values was adopted as the end result of the determination of the moisture content.

The tests of the pelletisation process of the mixture of buckwheat hulls with potato pulp were carried out on a SS-4 test stand (fig. 1), whose main component was a P-300 pellet mill with a "flat matrix – densification rolls" working system.

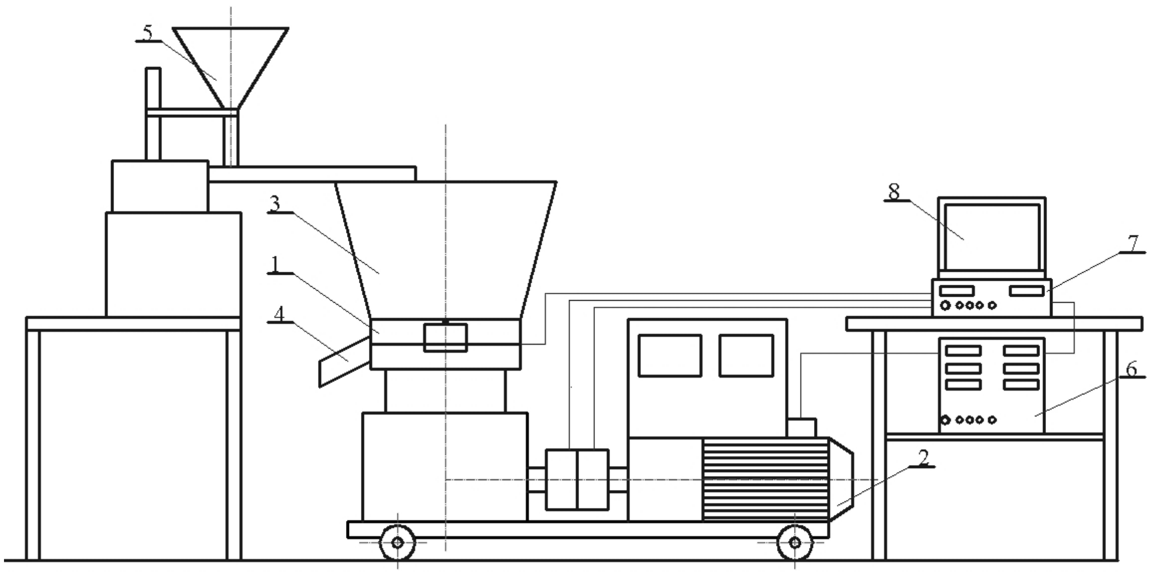
The pellet mill (1) was driven by the electric motor 2, whose torque was transmitted through a bevel gear to the shaft on which a flat rotating matrix was mounted; the matrix worked with a stationary system of two bearing-supported densification rolls that force the densified material through the matrix openings. Feeding the densified raw material evenly to the working system of the pellet mill 1 was possible owing to the vibrating feeder 5, passing the material to the working system of the pellet mill through the inlet 3. The pellets left the working system through the outlet 4. The SS-4 stand was equipped with a universal meter 6 for measuring the electric power demand of the device, and a Spider 8 recorder 7 connected to the computer 8. Signals from the universal meter 6 were transmitted to the Spider 8 recorder 7 in the form of binary files which were further processed using the Microsoft Excel and Statistica 10.0PL software.

In the course of the tests carried out on the SS-4 stand, the influence of potato pulp content (z_w=15 %, 20 % and 25 %) in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill (50, 75 and 100 $kg \cdot h^{-1}$) on the electric power consumption of the engine driving the pellet mill, as well as on the kinetic durability of the obtained pellets were determined.

The tests of the densification of the mixture of buckwheat hulls with potato pulp in the working system of the pellet mill, were conducted for the working gap between the densification roll and the matrix of h_r=0.4 mm and a rotational speed of the matrix of n_m=280 rpm. The diameter of the openings in the matrix used in the tests was d_o=8 mm, while their length was l_o=28 mm.

Designating the humidity of the materials, mixture and obtained pellets was performed pursuant to PN-76/R-64752 with the use of a WPE 300S scale-dryer exact to 0.01%. Each time, the humidity of five samples was determined. In the measurement, samples weighing 5g each were taken and dried at the temperature of 105°C until three consecutive readings of the scale-dryer at intervals of 15s remained unchanged. The mean values obtained as a result of this procedure were adopted as the final result of determining the humidity.

a)



b)

Fig. 1. The SS-4 stand: a) schema of the stand: 1 – working system of the peletizer with the flat matrix, 2 – electric engine driving the peletizer, 3 – cover up the material, 4 – pour out of the pellets, 5 – vibratory feeder, 6 – universal measure to the measurement of the power consumption, 7 – record- keeper Spider 8, 8 – the PC computer, b) the view of the stand

RESEARCH RESULTS

Fig. 2 shows the results of the tests of the influence of the content of potato pulp in a mixture with buckwheat hulls and the influence of the mass flow rate of the flow of the mixture through the working system of the pellet mill on the power consumption of the pellet mill.

The obtained test results (fig. 2) allowed to conclude that increasing the content of potato pulp in a mixture with buckwheat hulls from 15 to 25 % caused a significant reduction of the power consumption of the pellet mill, by approx. 35 % at a mass flow rate of the flow of the mixture through the working system of the pellet mill of 50 kg·h^{-1} (from 2.08 to 1.35 kW); by approx. 35% at a mass flow rate of the mixture of 75 kg·h^{-1} (from 2.73 to 1.78 kW); and by approx. 51 % at a mass flow rate of the mixture of 100 kg·h^{-1} (from 4.26 to 2.07 kW).

The achieved reduction of the power consumption of the pellet mill is caused mainly by the significant increase of the moisture content of the mixture resulting from the increased potato pulp content, from 15 to 25 % (fig. 3).

On the basis of the conducted research of the moisture content of the buckwheat hulls and of a mixture of buckwheat hulls and pulp prior to the pelletisation process it

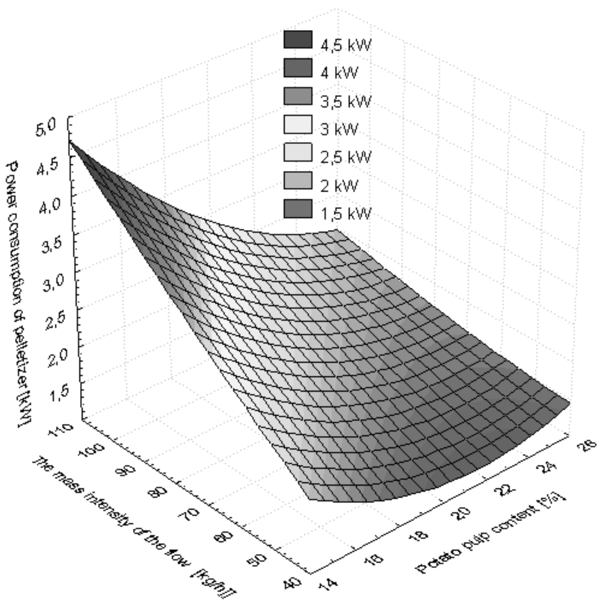


Fig. 2. Correlation between the power consumption of the pellet mill, the content of potato pulp in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill

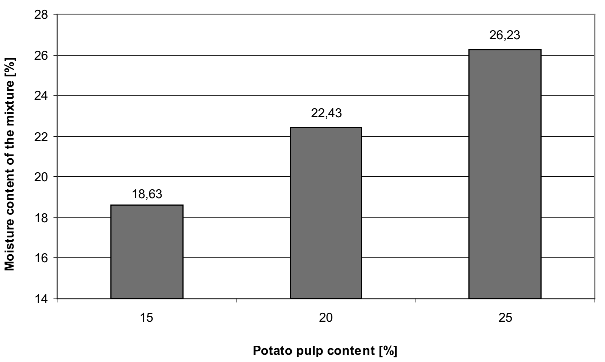


Fig. 3. Correlation between the moisture content of the mixture of buckwheat hulls with potato pulp and the potato pulp content in the mixture

was concluded that the moisture content of the mixture is increasing as the content of pulp in the mixture is increasing.

Buckwheat hulls have a low moisture content of approx. 9.2 %. Pelletisation of hulls of such a low moisture content yields unsatisfactory results. In order to increase their susceptibility to densification and to obtain high density pellets, they need to be shredded, their moisture content needs to be increased prior to the pelletisation process or a binder additive needs to be used. Potato pulp can serve as such an additive, as shown in the author's previous research [12, 13, 15].

The moisture content of the buckwheat hulls mixture increased from 18.63 % (at a 15 % pulp content in the densified mixture) to 26.23 % (at a 25 % pulp content in the densified mixture). Increasing the pulp content in the densified mixture resulted in obtaining bigger and bigger amounts of binder (in the form of a sticky liquid produced from starch and moisture) during the pelletisation process. The increasing content of the produced binder had the effect of "lubrication" of the surface of the openings in the pellet mill matrix, and of reduction of resistance to forcing through the openings. This, in turn, caused a reduction of the power consumption of the pellet mill. This is confirmed by other research of the author, conducted for a mixture of oat bran and potato pulp [16].

The obtained test results (fig. 2) allowed to conclude that increasing the mass flow rate of the flow of the mixture through the working system of the pellet mill from 50 to 100 $kg \cdot h^{-1}$ caused an increase of the power consumption of the pellet mill. At a pulp content in the mixture of 15 %, the increase of the power consumption of the pellet mill was approx. 105% (from 2.08 to 4.26 kW); at a pulp content in the mixture of 20%, the increase of the power consumption of the pellet mill was approx. 49% (from 1.58 to 2.36 kW); whereas at a 25% pulp content in the mixture the increase of the power consumption of the pellet mill was approx. 53% (from 1.35 to 2.07 kW).

The observed increase in the power consumption of the pellet mill at an increasing mass flow rate of the flow of the mixture through the working system of the pellet mill is caused by the fact that as the amount of mixture fed to the working system of the pellet mill is increasing, the amount of material densified in a single densification cycle is also increasing (the thickness of the layer of material pumped into the matrix openings in a single densification cycle is increasing). The increased thickness of the layer in a single densification cycle translates into an increase of the resistance to forcing through the openings and, consequently, an increase of the power consumption of the pellet mill.

The influence of the pulp content z_w in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system Q_s on the power consumption of the pellet mill $\boldsymbol{N_g}$ obtained during the densification of a mixture of buckwheat hulls and potato pulp in a "flat matrix – densification rolls" working system was described by the following equation:

$$\boldsymbol{N_g} = 4.62 - 0.46 z_w + 0.067 \boldsymbol{Q_s} + 0.013 z_w^2 - 0.003\, z_w \boldsymbol{Q_s} + 5.87 \times 10^{-5} \boldsymbol{Q_s}^2 \ [\text{kW}], \tag{1}$$

where:
z_w – pulp content in a mixture with buckwheat hulls [%],
Q_s – mass flow rate of the densified mixture [$kg \cdot h^{-1}$].

Fig. 4 shows the results of the tests of the influence of potato pulp content in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill on changes in moisture content of the obtained pellets.

On the basis of the performed tests (fig. 4), it can be concluded that increasing the pulp content in a mixture with buckwheat hulls from 15 to 25 % caused a significant increase of the moisture content of the pellets, determined immediately after the densification process.

The obtained increase of the water activity and the moisture content of the pellets as the pulp content increased in a mixture with buckwheat hulls was increasing from 15 to 25 % was caused by the moisture content of the mixture increasing as the pulp content in a mixture with buckwheat hulls was increasing (fig. 3).

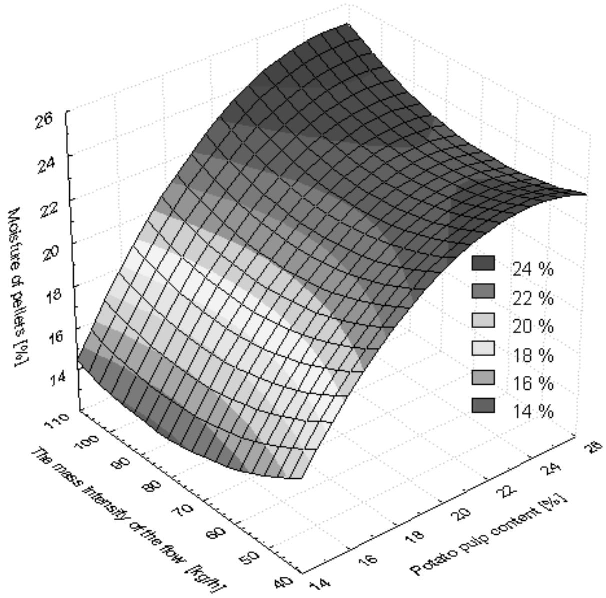


Fig. 4. The influence of potato pulp content in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill on the moisture content of the pellets

The obtained test results (fig. 4) also allowed to conclude that increasing the mass flow rate of the flow of the mixture through the working system of the pellet mill from 50 to 100 $kg \cdot h^{-1}$ caused a slight reduction of the moisture content of the obtained pellets. The highest reduction of the moisture content of the obtained pellets as the mass flow rate of the flow of the mixture through the working system of the pellet mill was increasing from 50 to 100 $kg \cdot h^{-1}$ was recorded at a 15 % pulp content in the mixture – a reduction of the moisture content of the obtained pellets by approx. 7%.

The pelletisation process caused a reduction of the moisture content (fig. 4), in comparison with the moisture content prior to the densification process (fig. 3).

CONCLUSIONS

1. Increasing the potato pulp content in a mixture with buckwheat hulls from 15 to 25 % caused a significant reduction in the power consumption of the pellet mill at each of the tested mass flow rates of the flow of the mixture through the working system of the pellet mill.
2. Increasing the mass flow rate of the flow of the mixture through the working system of the pellet mill from 50 to 100 $kg \cdot h^{-1}$ caused a significant increase of the power consumption of the pellet mill, at each of the tested pulp contents in a mixture with buckwheat hulls. The highest increase, by approx. 105 % (from 2.08 to 4.26 kW), was recorded at a pulp content in the mixture of 15 %.
3. The pelletisation process influenced the reduction of the moisture content of the densified mixture. The value of the reduction of the moisture content was decreasing as the pulp content in the densified mixture was increasing.

REFERENCES

1. **Borkowska B., Robaszewska A., 2012**. Use of buckwheat grain in various industry branches. Science Excercises of The Sea Academy in Gdynia, No. 73, 43-55. [in Polish].
2. **Chachułowa J., (editor). 1999**. Fodders. SGGW Publication, Warsaw. [in Polish].
3. **Chou C.S., Lin S.H.,. Lu W.C. 2009**. Preparation and characterization of solid biomass fuel made from rice straw and rice bran. Fuel Processing Technology, 90(2009), 980-987.
4. **Finney K.N., Sharifi V.N., Swithenbank J., 2009**. Fuel pelletisation with a binder: Part I – Identification of a suitable binder for spent mushroom compost – coal tailing pellets, Energy & Fuels 23 (2009) 3195-3202.
5. **Hejft R., 2002.** The pressure agglomeration of vegetable materials. The Library of Exploitation Problems, ITE Radom. [in Polish].
6. **Janušonis V., Erlickyt-Marčiukaitien R., Marčiukaitis M., 2009**. Biomass fuel use in Ekofrisa, Lithuania. EUBIONET III – EE/07/777/SI2.499477.
7. **Kaliyan N., Morey R.V., 2009**. Factors affecting strength and durability of densified biomass products, Biomass Bioenerg. 33 (2009) 337-359.
8. **Kulig R., Laskowski J., 2008**. Energy requirements for pelleting of chosen feed materials with relation to the material coarseness. TEKA Kom. Mot. Energ. Roln., 8, 115-120.
9. **Mediavilla I., Fernández M.J., Esteban L.S., 2009**. Optimization of pelletisation and combustion in a boiler of 17.5 kWth for vine shoots and industrial cork residue, Fuel Processing Technology. 90 (2009) 621-628.
10. **Mediavilla I., Esteban L.S., Fernández M.J., 2012**. Optimisation of pelletisation conditions for poplar energy crop. Fuel Processing Technology 104 (2012), 7-15.
11. **Niedziolka I., Szymanek M., Zuchniarz A., Zawiślak K., 2008**. Characteristics of pellets produced from selected plants mixes. TEKA Kom. Mot. Energ. Roln. – OL PAN, 2008, Vol. 8, 157-162.
12. **Obidzinski S., 2012**. Analysis of usability of potato pulp as solid fuel. Fuel Processing Technology. Fuel Processing Technology 94(2012) 67-74.
13. **Obidzinski S., 2012a**. Fuel and fodder pellets and his production technology. The patents application, P.398399, 12.03.2012r. Polish Patent Office, Warsaw. [in Polish].
14. **Obidzinski S., 2012b** Pelletization process of post-production plant waste. International Agrophisics. Vol. 26(3), 279-284.
15. **Obidzinski S., 2013**. The evaluation of the producing process of the fuel pellets from the oat bran with potato pulp content. Acta Agrophysica, Vol. 20(2), 2013, 389-402. [in Polish].
16. **Obidziński S., Hejft R., 2013**. The pelletting of the plant wastes in the working system of the pelletizer. Journal of Research and Applications in Agricultural Engineering, **Vol. 58**(1), 133-138. [in Polish].

17. Ohman M, Boman C, Hedman H, Eklund R., 2006. Residential combustion performance of pelletized hydrolysis residue from lignocellulosic ethanol production. Energy Fuels 20, 298-304.
18. **Sokhansanj, S., Mani S., Bi X., Zaini P., Tabil L., 2005**. Binderless pelletization of biomass. Presented at the ASAE Annual International Meeting, July 17-20, 2005, Tampa, FL. ASAE Paper No. 056061. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.
19. **Sotannde O.A., Oluyege A.O., Abah G.B., 2010**. Physical and combustion properties of charcoal briquettes from neem wood residues. International Agrophisics, 24, 189-194.
20. **Stahl M., Berghel J., 2011**. Energy efficient pilot-scale production of wood fuel pellets made from a raw material mix including sawdust and rapeseed cake. Biomass and Bioenergy 35 (2011), 4849-4854.
21. **Stolarski M., 2006**. Utilization of the biomass to the pelet production. Clean Energy, 6(56): 28-29. [in Polish].
22. **Stolarski M., Szczukowski S., 2007**. The variety of materials to the pelet production Clean Energy, 6(68), 42-43. [in Polish].
23. **Stolarski M., Kwiatkowski J., 2009**. Remains from processing buckwheat nuts into groats as fuel. Pulawy Diary, Exercise 149, 73-80. Puławy. [in Polish].
24. **Shaw M., 2008**. Feedstock and process variables influencing biomass densification. A Thesis. Department of Agricultural and Bioresource Engineering, University of Saskatchewan. Saskatoon, Saskatchewan, Canada.
25. **Wach E., 2005**. The wood pellets properties. Clean Energy, 6/2005 (44). [in Polish].

OCENA ZAPOTRZEBOWANIA NA MOC W PROCESIE PELLETOWANIA ODPADOWYCH MATERIAŁÓW ROŚLINNYCH

Streszczenie. W pracy przedstawiono wyniki badań wpływu zawartości wycierki ziemniaczanej (15, 20 i 25%) w mieszaninie z łuską gryki oraz warunków prowadzenia procesu granulowania (zmiennego masowego natężenia przepływu mieszanki: 50, 75 i 100 kg•h^{-1}) na energochłonność procesu granulowania oraz na wilgotność otrzymanego granulatu. W wyniku badań stwierdzono, że dodatek wycierki ziemniaczanej spowodował znaczny spadek zapotrzebowania granulatora na moc przy każdym z badanych masowych natężeń przepływu mieszanki przez układ roboczy granulatora oraz istotny wzrost wilgotności zagęszczanych mieszanek oraz pelletu wytworzonego z tych mieszanek.
Słowa kluczowe: wycierka ziemniaczana, łuska gryki, zapotrzebowanie na moc, wilgotność granulatu.

Research carried out within the framework of independent research MNiSzW Nr N N504488239.