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Short Communication

Utilization of Post-Production Waste of Potato Pulp and Buckwheat Hulls in the Form of Pellets

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Abstract

The purpose of this research was to determine 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 $kg \cdot h^{-1}$) on the following parameters: the density and kinetic durability of the obtained pellets, their heat of combustion, calorific value, and water activity. Increasing the pulp content in a mixture with buckwheat hulls from 15 to 25% and increasing the mass flow rate of the flow of the mixture from 50 to 100 $kg \cdot h^{-1}$ caused a reduction of the density and kinetic durability of the obtained pellets and a significant increase of the water activity and moisture content of the pellets. Increasing the pulp content in the mixture from 0 to 25% caused a slight reduction of the heat of combustion, from 19.44 to 19.09 $MJ \cdot kg^{-1}$, and calorific value (for dry matter of buckwheat hulls, and pellets from a mixture of buckwheat hulls and potato pulp).

Keywords: potato pulp, buckwheat hulls, pellet quality

Introduction

Due to the requirement addressing the reduction of carbon dioxide emissions into the atmosphere, universally respected in 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 industries, has become more and more common. Pieńkowski [1] claims that solid biomass and biofuels are the biggest reservoir of renewable energy.

According to Mediavilla et al. [2], most of the raw materials processed by pellet production plants in Europe are sawdust and shavings obtained from sawmills and wood-processing industries. However, due to the increase in prices and the increasingly limited accessibility of wood sawdust on the European market [3], there is a growing interest in the use of other natural raw materials for the production of pelletized biofuels and many other types of post-production waste: dusty agricultural-food waste [4], industrial tomato post-production waste [5], olive pomace waste obtained in the process of olive oil production [6], and mixtures of grape waste and coffee husks [7], including those from the agriculture and food industries [8-13].

One of the types of plant waste obtained from processing buckwheat into groats are by-products such as buckwheat hulls. They have multiple uses: as pillow filler material for therapeutic pillows, quilts or mattresses [14, 15], as a fodder additive [14], and owing to the high content of phenols, they can serve as a source for obtaining these compounds [14, 15], as a material for creating composts and substrata for horticulture; as bedding for domestic animals; and as filler for packing fruit and fragile goods [14, 16].

In addition, unshredded buckwheat hulls are a material characterized by low susceptibility to densification, which is confirmed by the author's own research as well as the experiments of Ekofrisa [17], a company that produces pellets from buckwheat hulls, allowed to conclude that the production of pellets from buckwheat hulls is more complicat-

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ed than the production of typical sawdust pellets, because buckwheat hulls have no binding material.

In the majority of cases, introducing 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 pelletization process [11, 13, 18-20].

The purpose of this research was to determine the influence of potato pulp content in a mixture with buckwheat hulls and the variable mass flow rate of the mixture on the quality of the obtained pellets (density and kinetic durability of the pellets, their heat of combustion, and calorific value). In the course of the research, the influence of the pelletization process on changes in the water activity of the densified mixture and the obtained pellets in the aspect of their use as fodder or heating fuel also was determined.

Experimental Procedures

This paper presents the results of a research study on the process of pelletization of a mixture of post-production waste: buckwheat hulls, which were post-production waste created during the production of buckwheat groats in PZZ 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 and the prepared mixtures of buckwheat hulls and pulp) 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 [21].

The tests of the pelletization process of the mixture of buckwheat hulls with potato pulp were carried out on an SS-4 test stand, whose main component was a P-300 pellet mill with a "flat matrix – densification rolls" working system [21]. In the course of the tests carried out on 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 (Q_m=50, 75, and 100 kg·h^{-1}), the density and kinetic durability of the obtained pellets were determined. The tests 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 was d_o=8 mm and their length was l_o=28 mm.

The kinetic durability of the obtained pellets was determined 24 hours after the pelletization process, pursuant to PN-R-64834:1998 and the recommendations given in [22] using Holmen's test.

The density of pellets was determined 24 hours after the process. In the course of measurements, the length and diameter of 15 randomly chosen pellets were measured by means of a calliope with an accuracy of ±0.02 mm, while their mass was determined by means of a WPS 360 laboratory balance with an accuracy of ±0.001 g. Before the measurements of the length of pellets, surfaces of pellets were leveled by means of abrasive paper. The density of the pellets was calculated as the ratio of the mass of the pellets to their volume.

The determination of the heat of combustion and the calorific value were performed pursuant to PN-73/T06500/09 and PN-73/G-04513 and according the recommendations given in paper [11] using a KL-12Mn calorimeter. The tests were determined for buckwheat hulls and for a buckwheat hulls mixture at 20% pulp content. The tests were carried out for the moisture content of buckwheat hulls of 6.2% (immediately before the tests) and for the moisture content of a buckwheat hulls mixture at a 20% pulp content of 9.08%.

The water activity of the densified mixture and the obtained pellets were determined using an AquaLab apparatus. In the course of the determination, samples with a mass of approx. 0.5 g were placed in a special test container in the measuring chamber of the apparatus. The mean of the obtained values was adopted as the end result of the determination of water activity. The water activity was determined before and immediately after the process.

Research Results and Discussion

Table 1 shows the results of the tests according to the experiment plan.

On the basis of the performed tests (Table 1 and Fig. 1), increasing the pulp content in a mixture with buckwheat hulls from 15 to 25% and increasing the mass flow rate of the flow of the mixture from 50 to 100 kg·h^{-1} caused a reduction of the density and kinetic durability of the obtained pellets.

For example, increasing the pulp content from 15 to 25% caused a reduction of the density by approx. 19.5% (from 1185.96 to 954.88 kg·m^{-3}), and kinetic durability reduction by approx. 6% (from 98.85 to 93.22%) at a mass flow rate of the flow of the mixture of 50 kg·h^{-1}. The recorded reduction of the density and the kinetic durability was caused by an increase of the moisture content of the mixture (from 18.63 to 26.23%), which caused a reduction of the resistance to forcing through the openings and an expansion of the pellets being produced due to the evaporation of the excess water contained in the pellets after they left the openings. This results in a reduction of the density and kinetic durability of the pellets (especially at a 25% pulp addition to buckwheat hulls). The moisture content of the buckwheat hulls mixture increased from 18.63% (at a 15% pulp content in the densified mixture) to 22.43% (at a 20% pulp content in the densified mixture) and to 26.23% (at a 25% pulp content in the densified mixture). Moisture content values in the range of 15 to 20% allowed obtaining pellets with a satisfactory quality. The obtained pellets from buckwheat hulls with a potato pulp content of up to 15% fully meet the requirements of the norms pertaining to wood pellets in European countries [23], as well as the requirements of EN 14961 [24, 25]. Pellets with a potato pulp content of up to 20%, on the other hand, fully meet the requirements of EN 14961-6 [24, 26], for non-woody pellets for non-industrial uses.

Table 1. Results of the tests of the densification process of a mixture of buckwheat hulls and potato pulp.

N x_i	Independent variables		Dependent variables (determined)			
	x_1=z_w [%]	x_2=Q_m [mm]	Pellets density ρ [kg/m^3]	Kinetic durability of pellets P_{dx} [%]	Water activity of pellets a_w [-]	Moisture of pellets w [%]
1	15	50	1185.95	98.85	0.909	16.83
2	20	50	1094.09	95.52	0.935	22.10
3	25	50	954.88	93.22	0.959	23.53
4	15	75	1134.42	96.09	0.901	16.01
5	20	75	1008.57	92.34	0.914	21.67
6	25	75	902.49	90.74	0.959	22.30
7	15	100	1005.85	93.58	0.855	15.60
8	20	100	998.96	85.38	0.941	22.03
9	25	100	813.73	83.22	0.947	24.47

The performed tests confirmed that potato pulp content is an important additive (admixture) to buckwheat hulls. Unshredded buckwheat hulls are a material characterized by low susceptibility to pelletizing (in order to obtain high-quality pellets, high densifying pressures are needed). The addition of potato pulp causes a reduction of densifying pressures necessary to obtain high-quality pellets from a mixture of buckwheat hulls and potato pulp. The addition of potato pulp also causes a 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. Increasing the pulp content in the densified mixture resulted in obtaining greater and greater amounts of binder (in the form of a sticky liquid produced from starch and moisture) during the pelletization 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 a reduction of the resistance to forcing through the openings. This, in turn, caused a reduction of the power consumption of the pellet mill and led to obtaining more durable pellets.

On the basis of the performed tests (Fig. 2) it can be concluded that increasing the pulp content in a mixture with buckwheat hulls from 15 to 25% caused a significant increase of water activity of the pellets and an increase of its moisture content, determined immediately after the densification process. Increasing the mass flow rate of the flow of the mixture through the working system of the pellet mill from 50 to 100 kg·h^{-1} caused a slight reduction of both the activity and the moisture content of the pellets. The slight reduction of both the water activity and the moisture content is probably a result of the fact that pellets of a lower density but with increasing mass flow rate of the flow of the mixture were obtained. In the time period between the

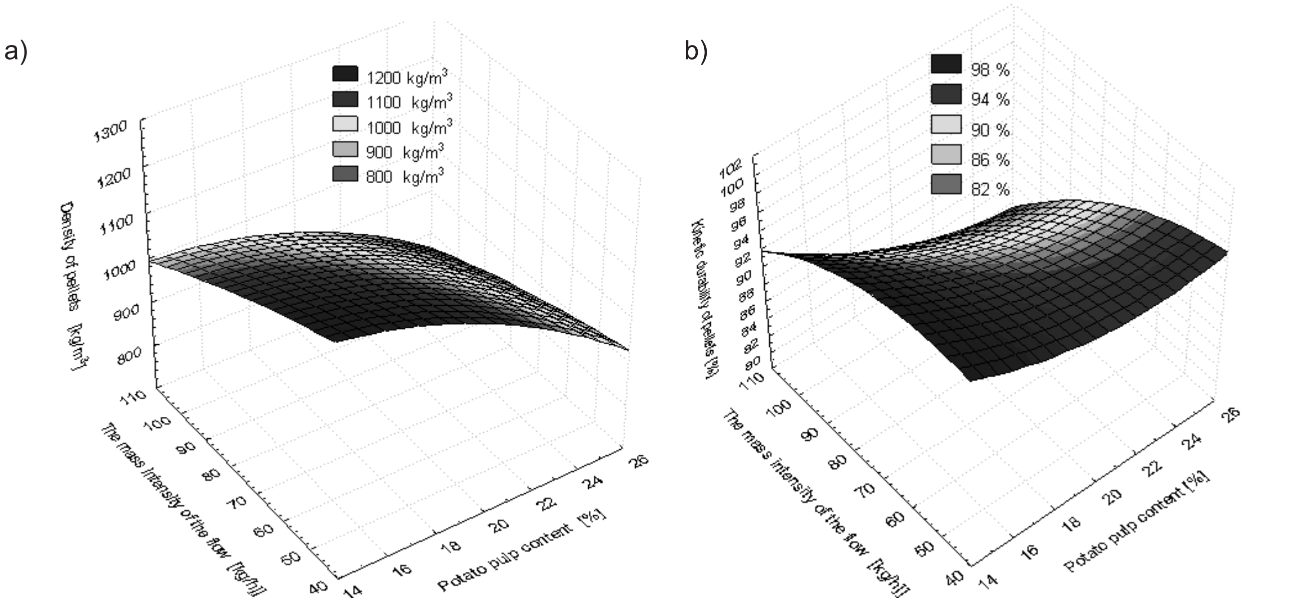

Fig. 1. The influence of potato pulp content in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill on: a) the density of the pellets, b) the kinetic durability of the pellets.

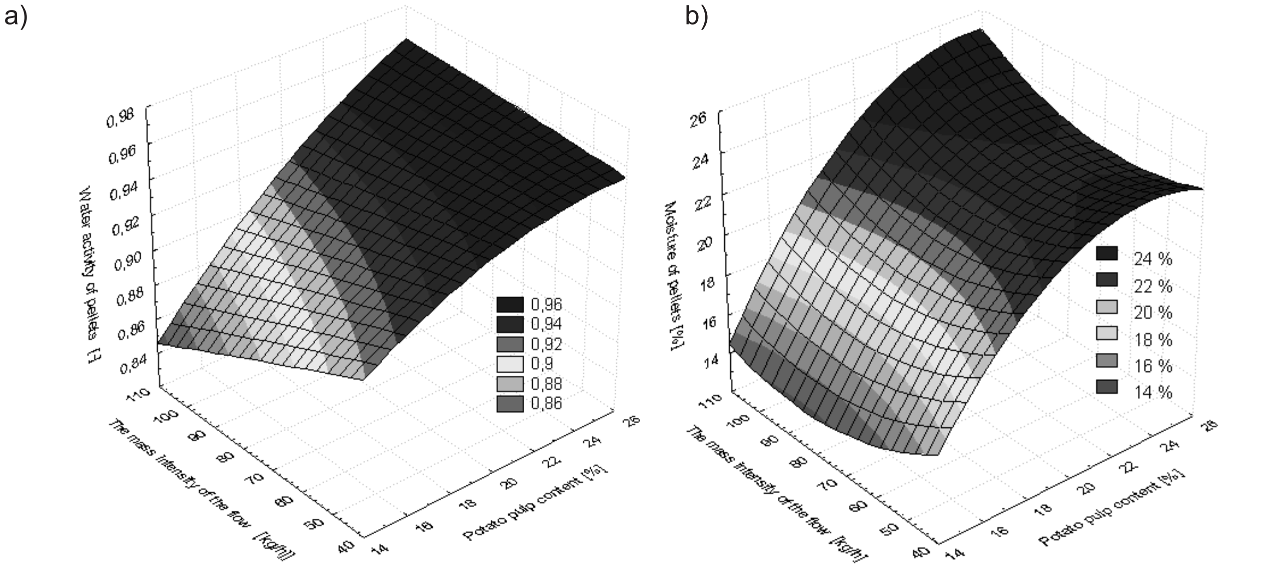

Fig. 2. The influence of potato pulp content in a mixture with buckwheat hulls and the mass flow rate of the flow of the mixture through the working system of the pellet mill on: a) the water activity of the pellets and b) the moisture content of the pellets.

moment the pellets leave the working system and the moment when moisture content and water activity of the pellets are measured, a reduction of moisture content and water activity of the pellets takes place as a result of vaporization of moisture from hot pellets. The lower the density of the obtained pellets, the higher the loss of moisture content and water activity.

For example, increasing the pulp content in a mixture with buckwheat hulls from 15 to 25%, at a mass flow rate of the flow of the mixture through the working system of the pellet mill of 50 $kg \cdot h^{-1}$, caused an increase of water activity of the obtained pellets by approx. 6% (from 0.916 to 0.971).

The pelletization process caused a reduction of the water activity of the obtained pellets (Fig. 2a) and their moisture content (Fig. 2b), in comparison with the moisture content prior to the densification process and the activity prior to the densification process. For example, at 15% pulp content, at a mass flow rate of the flow of the mixture of 50 $kg \cdot h^{-1}$, the water activity of the pellets decreased in comparison with the water activity of the mixture before the densification process by approx. 2% (from 0.936 to 0.916). A similar tendency was also recorded in the case of the reduction of pellet moisture after the densification process.

The value of the reduction of water activity and the moisture content of the pellets decreases as the pulp content in the mixture with buckwheat hulls also decreases. Research by Szlachta and Podawca [27] show that mould grows in fodder whose aw is between 0.60 and 0.75. For this reason, the pellets have to be subjected to cooling or drying after the pelletization process in order to reduce their water activity below 0.6.

On the basis of the tests for buckwheat hulls alone (pulp content of 0%) and for a mixture of buckwheat hulls with 20% pulp content, the influence of pulp content z_w in a mixture on the heat of combustion of mixture Q_s is described by the following equation:

$$Q_s = -0.013z_w + 19.434 \qquad R^2=0.9918 \qquad (1)$$

...while the influence of pulp content z_w on the calorific value Q_i of the mixture, by the equation:

$$Q_i = -0.029z_w + 18.725 \qquad R^2=0.8252 \qquad (2)$$

As the pulp content increases, the heat of combustion and the calorific value of the tested waste materials decrease only slightly. On the basis of the obtained correlations, the heat of combustion and the calorific value of the tested mixtures of buckwheat hulls and potato pulp were determined for other values of pulp content. On the basis of the obtained test results and calculations according to equations (1) and (2), it was concluded that increasing the pulp content from 0 to 25% causes a slight reduction of the heat of combustion from 19.44 to 19.09 $MJ \cdot kg^{-1}$, and of the calorific value from 18.89 to 17.19 $MJ \cdot kg^{-1}$ (for dry matter of the mixture). The values of heat of combustion of the buckwheat hulls obtained in the course of the tests are similar to those obtained by Stolarski and Kwiatkowski [14].

Conclusions

1. The obtained values of density and kinetic durability of the pellets from a mixture of buckwheat hulls with a pulp content of up to 15% fully meet the requirements of EN 14961.
2. The values of density and kinetic durability of the pellets with a pulp content of up to 20% fully meet the requirements of EN 14961-6.
3. Increasing the potato pulp content in a mixture with buckwheat hulls from 15 to 25% and increasing the mass flow rate of the flow of the mixture from 50 to 100 $kg \cdot h^{-1}$ caused a reduction of the density and kinetic durability of the obtained pellets.

4. Increasing the potato pulp content in a mixture with buckwheat hulls from 15 to 25% caused a significant increase of water activity and the moisture content of the densified mixture and the pellets produced from this mixture.
5. The pelletization process caused a reduction of the water activity of the obtained pellets and their moisture content in comparison with the moisture content prior to the densification process and the activity prior to the densification process.
6. Increasing the potato pulp content from 0 to 25 caused a slight reduction of the heat of combustion from 19.44 to 19.09 $MJ \cdot kg^{-1}$, and the calorific value from 18.89 to 17.19$MJ \cdot kg^{-1}$ (for dry matter of the buckwheat hulls and the pellets from a mixture of buckwheat hulls and potato pulp).

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