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THE INFLUENCE OF MOISTURE CONTENT OF BARLEY ON THE FLAKING PROCESS

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ABSTRACT

The paper presents the study, which aimed at determining how moisture content of barley grain and the size of the grain crusher working gap affect changes on the embodied energy during the flaking process and properties of the obtained flakes. Thus, the barley grains of Barke variety were moisturized up to the level of 14, 18, 22 and 26%. Then grains were subjected to flaking, and at the same time the embodied energy was measured. The next step was to evaluate the physical properties of the product such as: angle of repose, chute angle, bulk and shaken density. Also a mesh analysis was applied. Moreover, the absorption coefficient of water has been evaluated for each series of products. As stated, the size of grain crusher working gap significantly affects changes of the embodied energy during the process. The lowest values were registered for 2.0 mm wide gap. As observed, the moisture content of grains affects the physical properties of the product. It should also be noted, that during the flaking process of grain with moisture content of 14%, the significant amount of flour is obtained.

Introduction

Cereal grains are the basic food raw material in the production of food and feed. They have many favourable food properties and contain small amount of water which gives a possibility of easy transport and processing. Due to these properties they are the most popular plant product in the international turnover. Approximately 10% of the global cultivation area of cereals is covered by barley (68-71 mln. ha) (Borek, 2008). This plant has been used by a man for ten thousand years. Barley grain is used mainly for production of groats, flakes, coffee substitute, as a raw material in brewing for production of beer and feed. The most important method of using barley in the food industry is production of malt (Baik and Ullrich, 2008)

The basic structural component of barley grain are carbohydrates (at the average 66% of dry mass of grain), mainly starch. Additionally, plants are rich in proteins. They may amount from 9 to even 15% of dry mass of grain. The content of fats in the barley grain is at the average of 4% but in the naked forms this value may be higher (Dziki and Laskowski, 2004). Moreover, grain is rich in minerals (2.7-3.2%). Spelt forms of barley include more ash than the naked ones. Products from barley are a precious source of vitamins from group B and a vitamin E. A chemical composition of cereal grains is varied. Moreover, particular components are distributed irregularly in a grain, thus the manner of seed processing has a decisive impact on the chemical composition of grain products (Jurga, 1997, Panasiewicz et al., 2005). External layers of a grain are the richest in vitamins and fibre, thus products made of the whole grain e.g. wholemeal flour and bread, groats and cereal flakes have a high nutritive value (Pijanowski, 1996).

Presently, when healthy lifestyle is fashionable, "Fit" products are bought more eagerly. These are, inter alia, cereal flakes including oat and barley flakes. The fact that digestibility of barley starch is considerably lower than other cereals is crucial (Czarnowska-Misztal et al., 2007). Furthermore, in the recent years, a special attention has been paid to consumption of fibre (Nawrolnik, 2013). Cereal grains, in particular barley grains, is very rich in this component (Michalak et al., 2003). High-fibre products with high content of soluble fraction, such as flakes of the wholemeal grain recommended by dietitians may be obtained only from raw material which is high in fibre, such as oat and barley (Muir et al., 2004, Rzedzicki and Wirkijowska, 2008).

Therefore, the objective of the research was to determine how the moisture of barley grain and a range of the working slot of a grain crusher affect the changes of energy consumption of the flaking process and the quality of the obtained flakes. The scope of the research included repeated moistening of grain, then flaking of grain and assessment of the physical properties of products.

Research methodology

Barke variety of spring barley was used in the research. Before moistening the grain moisture was determined (acc. to the standard PN-ISO 712:20002), which was 14%. Then, the raw material was moistened to the moisture content of 18, 22 and 26%. The assumed moisture of grain was obtained by adding to the sample an appropriate amount of distilled water. The amount of water necessary for moistening was calculated from the formula:

$$M_W = \frac{w_2 - w_1}{100 - w_2} \cdot M_N \tag{1}$$

where:

M_W – amount of water required for moistening, (g)
M_N – mass of the moistened cereal, (g)
w_1 – initial moisture, (g)
w_2 – required moisture, (%)

After moistening of grain, samples of the mass of 500 g were closed in hermetic vessels and placed in a cooling chamber in temperature of 4±°C for 24 hours. In order to obtain regular moisture in the whole material, samples were shaken several times during the process of their seasoning. Two hours before flaking, samples were taken out of the cooling chamber in order to obtain the temperature of the surrounding.

Barley grain was flaked with the use of a grain crusher H–750 by MAGROTEX (Poand) company. The device was connected to a computer, the task of which was to register energy required to flake the sample. The flaking process was carried out at the working gap size of a grain crusher which was s_1=0.5 mm; s_2=1.0 mm and s_3=2 mm. Samples with 500 g mass were flaked.

Measurement of physical properties of so prepared flakes was carried out according to the applicable Polish Standards, i.e. angle of repose – PN-74/Z-04002/07, chute angle – PN-74/Z-04002/08, bulk density – PN-ISO 7871-2:1998, shaken density – PN-80/C-04532. Measurement of physical properties was carried out in seven repeats and an arithmetic average was accepted as a result.

Moreover, a screen analysis of flakes was carried out. A laboratory vibrating screen AS 200 by Retsh company (Germany) was used. 100 g of flakes was screened using the vibrations amplitude of 2 mm, the measurement time was 4 minutes and the interval was 20 s. A wire screen with the following dimensions of meshes was used. 0.01; 0.02; 0.05; 0.1; 0.2 and 0.315 mm. Based on the obtained results, an average dimension of particles was calculated using the following relation (2):

$$s = \frac{\frac{l_1 + l_2}{2} \cdot m_1 + \frac{l_2 + l_3}{2} \cdot m_2 + \cdots + \frac{l_n + l_{n+1}}{2} \cdot m_n}{100} \qquad (2)$$

where:

s – average dimension of particles, (mm)
l – dimension of screen meshes, (mm)
m – mass of a fraction on the screen, (%)

The last stage of research consisted in determination of the flakes ability to absorb water. The measurement consisted in a cyclic immersing (10 immersions per a minute) of containers filled in with 5 g of flakes in a container with water of 8°C temperature and then placing them on rotational arms of a device. For all samples the measurement time was 5 minutes. Then, containers along with a material were placed in a dryer. After the process, the samples were weighed and the loss of mass of the tested flakes was calculated. Comparing the mass of a sample before immersing in water and afterwards, the amount of water absorbed by flakes was calculated.

The obtained results were statistically anlysed with the use of Statistica 6.0 programme. In order to determine the mathematical relations between the tested parameters and the size of the grain crusher gap and the moisture of the raw material, the analysis of variance and Tukey's test were carried out at the level of significance of α=0.05.

Research results and their analysis

Figures 1-7 present changes of energy consumption of the flaking process and properties of the obtained flakes in relation to the size of the working gap of a grain crusher and the determined moisture of a grain. Various letters presented in plots prove occurrence of statistically significant differences between average sizes.

Figure 1 presents the impact of the grain moisture and the size of the working gap on the flaking energy. It should be stated clearly that the increase of the working gap from 0.5 to 1.0 and 2.0 mm resulted with the decrease of energy inputs necessary for the flaking of grain, independently from the moisture of grain. Moreover, moisture influenced the energy consumption of the process. It was found out that the raw material moisture significantly affects the flaking energy. The highest values of energy were reported at the grain moisture of 18%, whereas the least energy was necessary for flaking of raw material with 26% moisture at the use of a working gap of a grian crusher which is 2 mm.

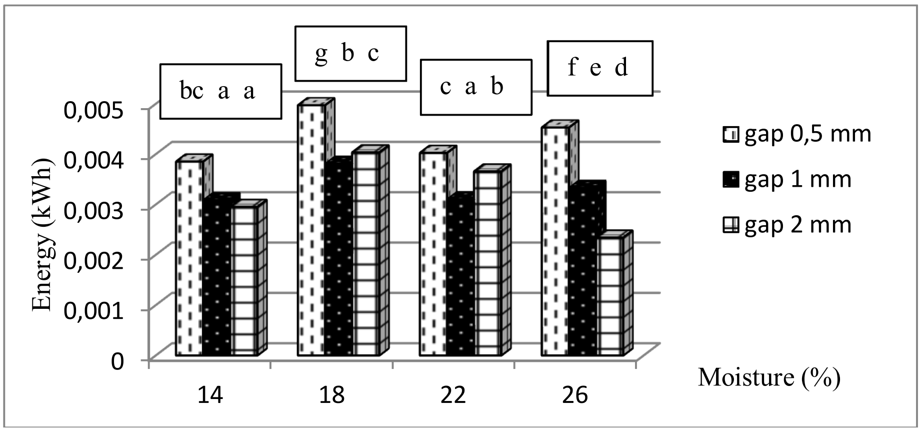

Figure 1. Influence of moisture content of grain and size of the working gap on the flaking energy

Figure 2 presents the impact of the grain moisture and the size of the grain crusher working gap on the angle of repose of flakes. It was assessed that the highest values of the angle of repose of flakes were reported for grain with 26% moisture independently from the used grain crusher working gap.

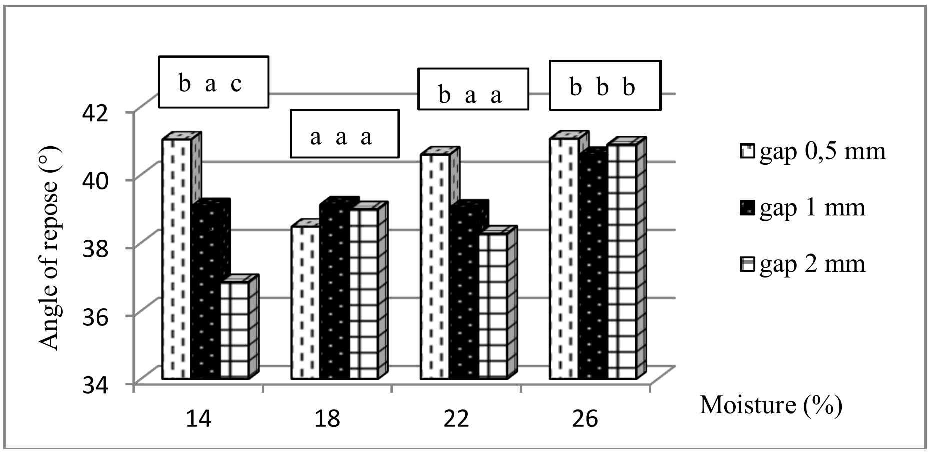

Figure 2. Influence of moisture content of grain and size of the working gap on the angle of repose of barley flakes

Figure 3 presents the impact of the grain moisture and the size of the working gap on the chute angle of flakes. It was reported that at the use of particular working gaps, the value of the chute angle of flakes increased along with the increase of grain moisture. The analysis of the results of Tukey's test of significance of differences presented in figure 3 at the level of significance of α=0.05 allowed determination of the significant impact on the increase of the value of the chute angle of flakes, when grains were moistened from 22% to 26%.

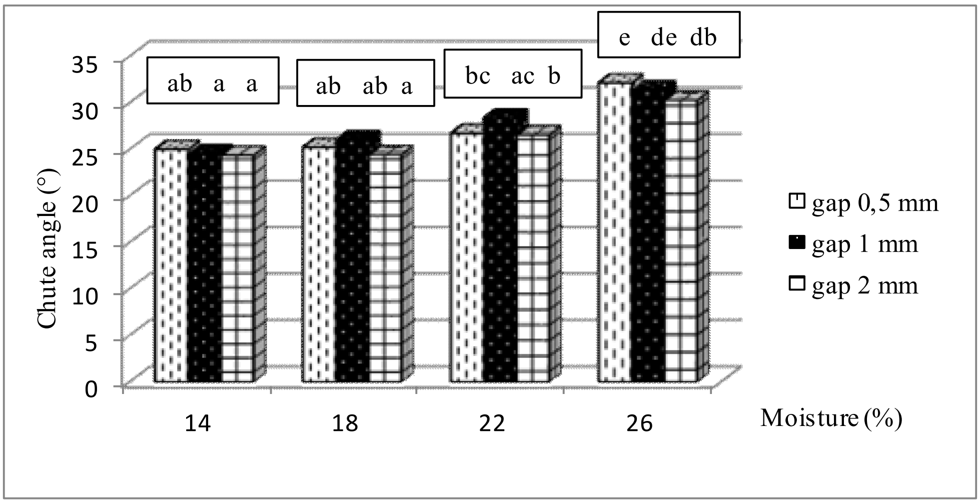

Figure 3. Influence of moisture content of grain and size of the working gap on the chute angle of barley flakes

Figure 4 presents the impact of the moisture content of grains and the size of the working gap on the shaken density of flakes. It was reported that the increase of the barley grains moisture and the increase of the working gaps of the grain crusher directly affect the shaken density of flakes. The lowest values of the shaken density of flakes were reported for a grain with moisture of 14% whereas the highest for moisture of 26%.

Figure 5 presents the impact of the grain moisture content and the size of the grain crusher working gap on the chute angle of flakes. The highest values of the bulk density were reported in the case of flakes obtained from a grain of 22% moisture. Moreover, the increase of the bulk density of flakes along with the increase of the working gap between shafts was visible. After the analysis of the results of Tukey's test of significance of differences, presented in figure 5, at the level of significance α=0.05, it was found out that the moistening grain with the use of a working gap of a grain crusher with 1 and 2 mm width significantly influences the bulk density of flakes.

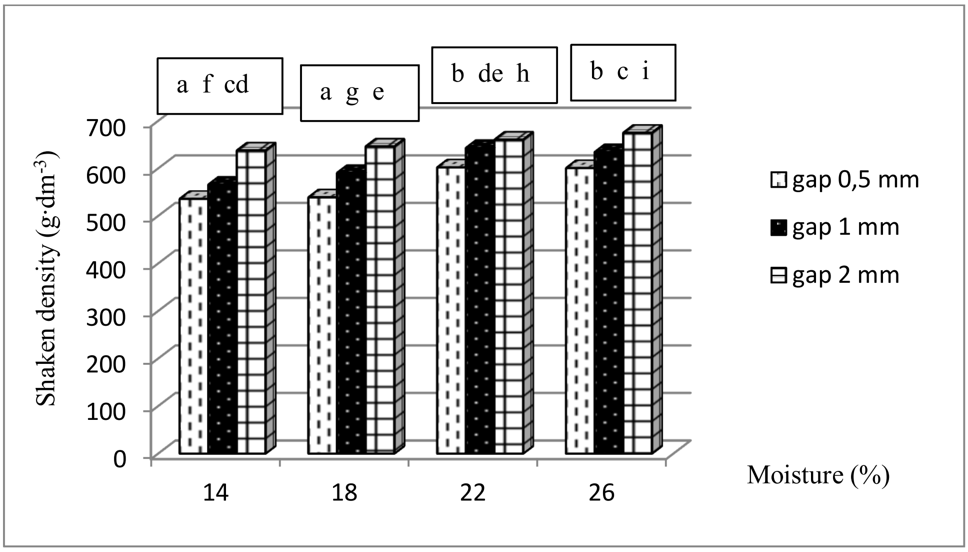

Figure 4. Influence of moisture content of grain and size of the working gap on the shaken density of barley flakes

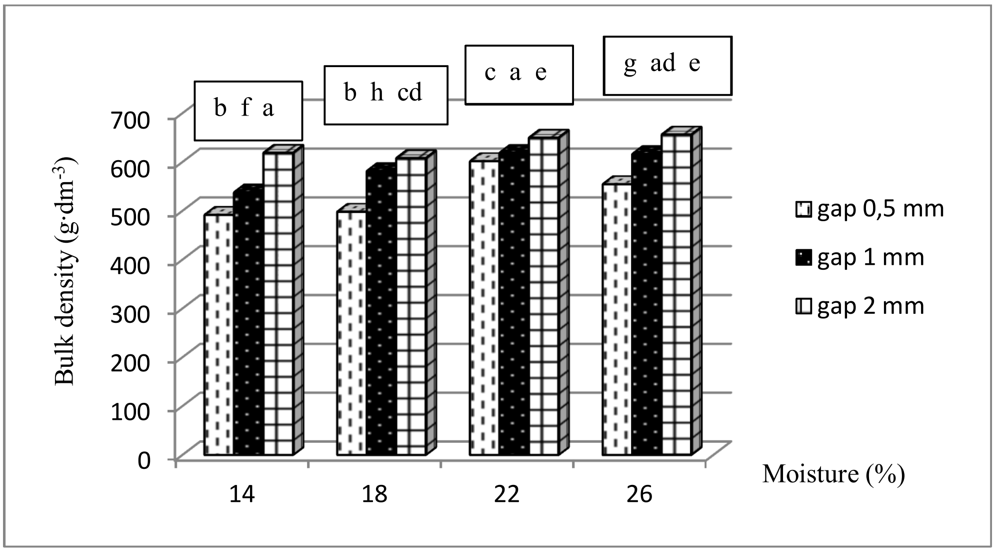

Figure 5. Influence of moisture content of grain and size of the working gap on the bulk density of barley flakes

Table 1 presents the impact of moisture of grains on the participation of fraction of flakes obtained on particular screens. For moisture of grains which was 18%, 22% and 26%, the highest mass of fraction was obtained on a screen with 0.315 mm diameter of meshes. In the case of grain with moisture of 18, 22 and 26% an insignificant (up to 2%) amount of floury fraction was reported, flakes were uniform. Whereas, flakes obtained from seeds with moisture of 14% characterized with a considerable difference of dimensions and the highest content of floury fraction.

Table 1
Percentage of the fraction of the flakes obtained on individual screens

Moisture (%)	Grain crusher gap (mm)	Dimensions of meshes, (mm)						
		0.315	0.2	0.1	0.05	0.02	0.01	bottom
14	0.5	31.070	41.932	21.960	3.395	1.254	0.306	0.083
18		88.520	9.561	1.555	0.158	0.133	0.070	0.003
22		93.430	6.489	0.033	0.005	0.043	0	0
26		92.400	7.537	0.025	0.013	0.025	0	0
14	1.0	40.990	43.030	14.61	0.930	0.315	0.125	0
18		89.230	10.317	0.395	0.035	0.023	0	0
22		88.670	11.302	0.015	0.013	0	0	0
26		89.590	10.405	0.005	0	0	0	0
14	2.0	57.820	38.303	3.759	0.050	0.068	0	0
18		84.117	15.475	0.380	0.028	0	0	0
22		86.085	13.900	0.015	0	0	0	0
26		98.852	0	1.148	0	0	0	0

Figure 6 presents the impact of the grain moisture and the size of the grain crusher working gap on the average dimension of flakes particles. The analysis of the results of Tukey's test of significance of differences presented in figure 6 at the level of significance of $\alpha=0.05$ allowed determination of the significant impact of the grain moistening of grains from 14% to 18% on the increase of flakes particles dimensions. However, no further increase of the grain moisture on the average dimension of flakes particles was reported. The smallest dimension of particles was obtained from grain with 14% moisture at the 0.5 mm gap, whereas the highest for the grain with 26% moisture at the working gap of 2.0 mm and it was at the level of 0.255 mm.

Figure 7 presents the impact of the grain moisture and the size of a working gap on the flakes ability to absorb water. It was assessed that flakes with 14% moisture absorbed more water than flakes with a higher moisture content. Furthermore, the working gap has an impact on the amount of the absorbed water. The highest values were reported for flakes obtained in the 2.0 mm working gap whereas the lowest for flakes obtained in the 0.5 mm working gap.

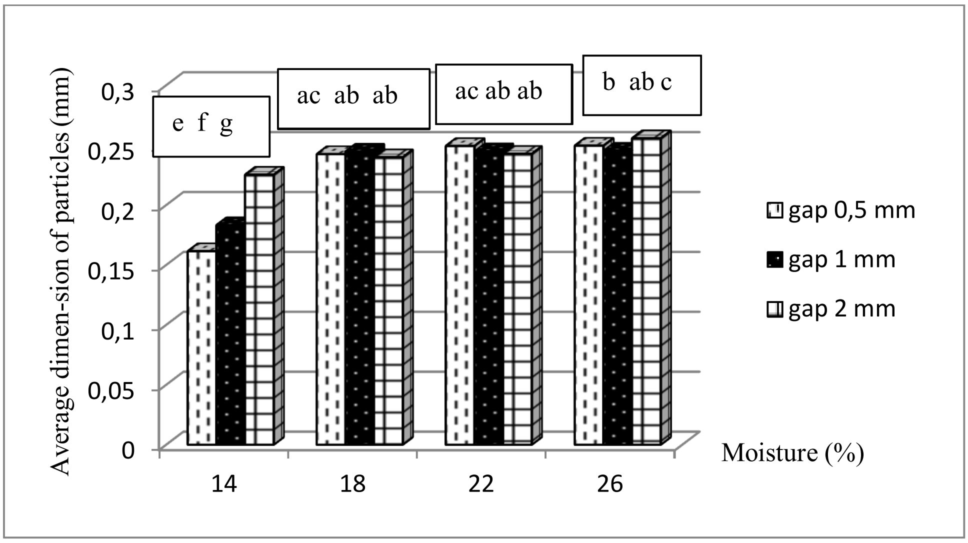

Figure 6. Influence of moisture content of grain and size of the working gap on the medium average size of flakes

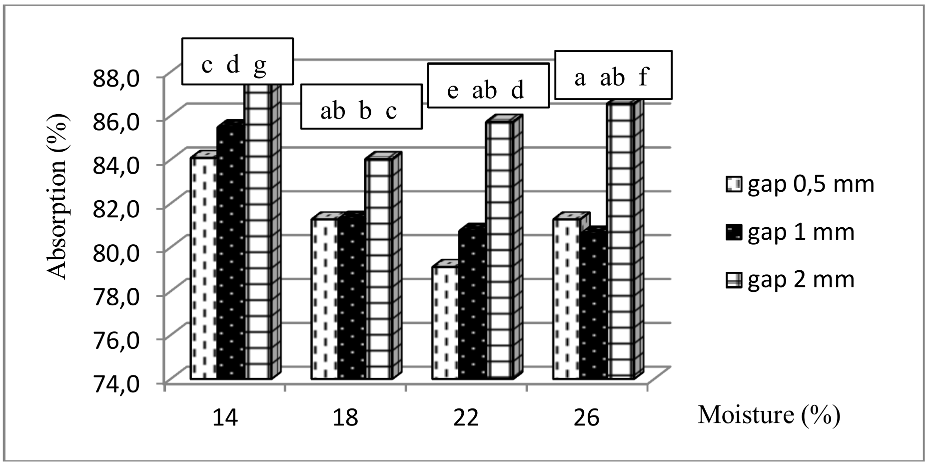

Figure 7. Influence of moisture content of grain and size of the working gap on the ability of flakes to absorb water

The tests, which were carried out, proved that moistening of the barley grain within 14% to 26% caused decrease of energy necessary to flake the raw material. Thus, the tests carried out by other authors, were confirmed. They proved that along with the increase of caryopsis moisture their resistance to mechanical loads decreases (Nadulski et al., 2010). Based on the statistical analysis, it was stated that significant changes of the average size of flakes particles obtained from moistened grain from 14 to 18% took place. However, no impact of barley grain and the working gap on the level of value of the angle of repose and chute angle of flakes was reported. Changes of the shaken density and bulk density of the product depended on the size of the grian crusher working gap; to a lesser extent these values depended on the initial moisture of a grain.

Conclusions

Based on the obtained results of research, the following conclusions were made:

1. The increase of the working gap from 0.5 to 2.0 mm and moistening of grain to the level of 26% significantly causes decrease of energy inputs required for flaking of barley grains.
2. No significant impact of the barley grain moisture and the size of the grain crusher working gap on the angle of repose and chute angle of flakes were reported. The highest values of the mentioned sizes were reported at the highest researched moisture of grain – 26%.
3. Grain moisture and the value of the grain crusher working gap had a significant impact on the granulometric composition of flakes. At the gap of 0.5 mm and the grain moisture of 14% the biggest amount of floury fraction is formed.
4. The amount of water absorbed by flakes depends on the grain moisture and the size of the grain crusher working gap. The biggest amount of water is absorbed by flakes produced from grain with moisture of 14%.

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WPŁYW WILGOTNOŚCI ZIARNA JĘCZMIENIA NA PROCES PŁATKOWANIA

Streszczenie. W pracy zaprezentowano badania, które miały na celu określenie, w jaki sposób wilgotność ziarna jęczmienia oraz wielkość szczeliny roboczej gniotownika wpływają na zmiany energochłonności procesu płatkowania oraz właściwości uzyskanych płatków. W tym celu dowilżono ziarno jęczmienia odmiany Barke do poziomu 14, 18, 22 i 26%. Następnie ziarno poddano procesowi płatkowania, w trakcie którego przeprowadzono pomiar energochłonności. Kolejnym etapem było określenie właściwości fizycznych produktu, takich jak: kąt zsypu, kąt usypu, gęstość usypowa oraz gęstość utrzęsiona. Przeprowadzono również analizę sitową płatków. Dodatkowo określono zdolność płatków do pochłaniania wody. Stwierdzono, że wielkość szczeliny roboczej istotnie wpływała na zmiany energochłonności procesu. Najniższe wartości odnotowano dla szczeliny o szerokości 2,0 mm. Zaobserwowano, że wzrost wilgotności ziarna wpływa na właściwości fizyczne produktu. Należy także stwierdzić, że przy 14% wilgotności ziarna w procesie płatkowania powstaje największa ilość frakcji mączystej (ok. 5%) w porównaniu do płatków z ziaren o wyższej wilgotności.

Słowa kluczowe: jęczmień, proces płatkowania, wilgotność, ziarno