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PRODUCTION OF HEATING PELLETS WITH APPLE POMACE CONTENT

Summary

The paper presents the results of tests of pelleting of materials of plant origin: oat bran and apple pomace. The tests were performed on a prototype pelleting and briquetting device with the use of a flat matrix with 8 mm (diameter) x 28 mm (length) openings, working with a system of three densification rolls. In the course of the tests the influence of apple pomace content (10%, 15%, and 20%) in a mixture with oat bran was determined, and the influence of pomace type (the pomace used was obtained during the pressing of cold clarified, hot clarified, and cloudy juices) on the device's power consumption and kinetic durability of the obtained pellets. The tests of pelleting process were carried out at a mass flow of raw material of 150 kg·h^{-1}, rotational speed of the system of densification rolls of n_r=170 rpm^{-1} and at a gap between the rolls and the matrix of h_r=0.4 mm. 24 hours after pellets had left the working system, their kinetic durability was determined using the Holmen tester. On the basis of the performed tests, it was concluded that with the increase of percentage content of apple pomace in a mixture with oat bran, moisture content of the densified material increased, which had a considerable impact on the course of the pelleting process and the quality of the obtained pellets. The type of apple pomace added to oat bran has a significant influence on power consumption of the pellet mill and kinetic durability of the obtained pellets.
***Key words**: pelleting, oat bran, apple pomace, kinetic durability*

WYTWARZANIE GRANULATU OPAŁOWEGO Z UDZIAŁEM WYTŁOKÓW JABŁKOWYCH

Streszczenie

W pracy przedstawiono wyniki badań procesu granulowania odpadów pochodzenia roślinnego: otrębów owsianych oraz wytłoków jabłkowych. Badania przeprowadzono na prototypowym urządzeniu granulująco-brykietującym z wykorzystaniem matrycy płaskiej o średnicy otworów 8 mm i długości otworów 28 mm, współpracującej z układem trzech rolek zagęszczających. W trakcie badań określano wpływu zawartości wytłoków jabłkowych (10, 15 i 20%) w mieszaninie z otrębami owsianymi oraz wpływ rodzaju wytłoków (zastosowano wytłoki powstałe przy wytłaczaniu soków klarowanych na zimno, klarowanych na ciepło i soków mętnych) na zapotrzebowanie urządzenia na moc oraz na wytrzymałość kinetyczną otrzymanego granulatu. Badania procesu granulowania przeprowadzono przy masowym natężeniu przepływu surowca 150 kg·h^{-1}, przy prędkości obrotowej układu rolek zagęszczających n_r=170 obr.min^{-1} oraz przy szczelinie między rolkami a matrycą h_r=0,4 mm. Po 24 godzinach od momentu opuszczenia układu roboczego przez granulat oznaczono jego wytrzymałość kinetyczną z wykorzystaniem testera Holmena. Na podstawie przeprowadzonych badań stwierdzono, że wraz ze wzrostem zawartości procentowej wytłoków jabłkowych w mieszance z otrębami owsianymi wzrastała wilgotność zagęszczanego materiału, co miało istotny wpływ na przebieg procesu granulowania i jakość otrzymanego granulatu. Rodzaj wytłoków jabłkowych dodawany do otrębów owsianych ma istotny wpływ na zapotrzebowanie granulatora na moc oraz na wytrzymałość kinetyczną otrzymanego granulatu.
***Słowa kluczowe**: granulowanie, otręby owsiane, wytłoki jabłkowe, wytrzymałość kinetyczna*

1. Introduction

Among the most common waste generated by agriculture and various branches of the food industry there are, among others, potato pulp obtained during potato starch production, buckwheat hulls obtained during groats production in cereal plants, rapeseed cake obtained during the production of rapeseed oil, herbal waste obtained during drying, packing and selection of herbs, etc. Such types of waste are often utilized only to a small extent and constitute a huge problem for the plant.

Pomace is a type of waste produced in fruit and vegetable processing plants, which amounts to 20-25% of processed raw material [23]; whereas according to Kumider [7], the amount of waste obtained from fruit and vegetable processing constitutes 10-35% of the mass of processed raw material.

According to Kumider [7], pomace is a perishable and unstable material, while the high water content (up to as much as 73% in the case of apple pomace) may lead to a rapid increase of microbiological contamination at the plant's premises in its surroundings, especially that, as reported by Zawirska [23], a proportion of pomace is land filled, causing environmental and economic damage.

According to Fronc and Nawirska [4], despite the problems connected with microbiological instability, pomace is a rich source of many valuable ingredients, e.g. saccharides, proteins, mineral compounds, pectins, fibre, organic acids, vitamins, aldehydes, alcohols, colouring and aromatic matters. Owing to this, it should be treated as an intermediate product for further processing.

On a small scale, apple pomace is used as a substrate for biogas production [6], as a raw material for ethanol production [3], as a material for obtaining fibre [2, 20], as an additive that positively influences breadmaking [19], as a possible source of pro-health polyphenols and anthocyanins [14, 23], as additives during compost production [14, 23] and as an ingredient used in fodder production [18, 14, 23].

On a larger scale, however, pomace is not commonly used and apple processing plants seek a method for its widespread utilization.

One of such methods may consist in its use as an ingredient (component) in the production of heating pellets, e.g. in a mixture with oat bran.

In previous research [9] it was discovered that non-shredded oat bran with a moisture content of 5.09% is a material characterized by low susceptibility to densification. Other research studies into densification of oat bran [8, 9] showed that in order to increase its susceptibility to densification, it needs to be shredded, which would reduce its tendency to slide on the surface of matrix openings, increase its moisture content before the pelleting process; alternatively, a binder additive needs to be used in the form of, for example, potato pulp [10, 11] or apple pomace [1].

2. The aim of the research

The aim of the research was to assess the influence of apple pomace addition to oat bran, and the influence of the type of apple pomace on power consumption of a prototype pelleting and briquetting device and kinetic durability of the obtained pellets.

3. Research methodology

Tests of the process of pressure agglomeration (pelleting) were performed on a prototype pelleting and briquetting device (fig. 1) with the use of a flat matrix with 8 mm (diameter) x 28 mm (length) openings, working with a system of three densification rolls, described in papers [5, 13].

The test materials subjected to the pelleting process were waste of plant origin: non-shredded oat bran (post-production grain waste from Podlaskie Zakłady Zbożowe S.A. in Białystok) and apple pomace (post-production waste from fruit processing). Apple pomace from the Sawa (SA) apple variety (obtained from ecological orchards run by Institute of Horticulture in Skierniewice) was used for the tests. The pomace was obtained during the production process (pressing) of three types of juice: cloudy (marked as ME), cold clarified (KZ), and hot clarified (KC). The process of juice pressing was performed in Institute of Horticulture in Skierniewice. After pressing, pomace was frozen and kept in tightly sealed bags in a temperature of -10˚C.

Before commencing the tests of the pelleting process, apple pomace was frozen. 24 hours after it was removed from the freezer, mixtures of pomace and oat bran were prepared and left for 24 hours in tightly sealed plastic bags, in order to obtain an even distribution of moisture throughout the whole volume of mixtures.

The stand was equipped with universal meter for power consumption measurement 17, torque and force indicator 16, and recorder 18 coupled with computer 19. Signals from power consumption meter 17 and torque and force indicator 16 were supplied to recorder 18 in the form of binary files, which were further processed with the use of Microsoft Excel and Statistica 10.0PL software.

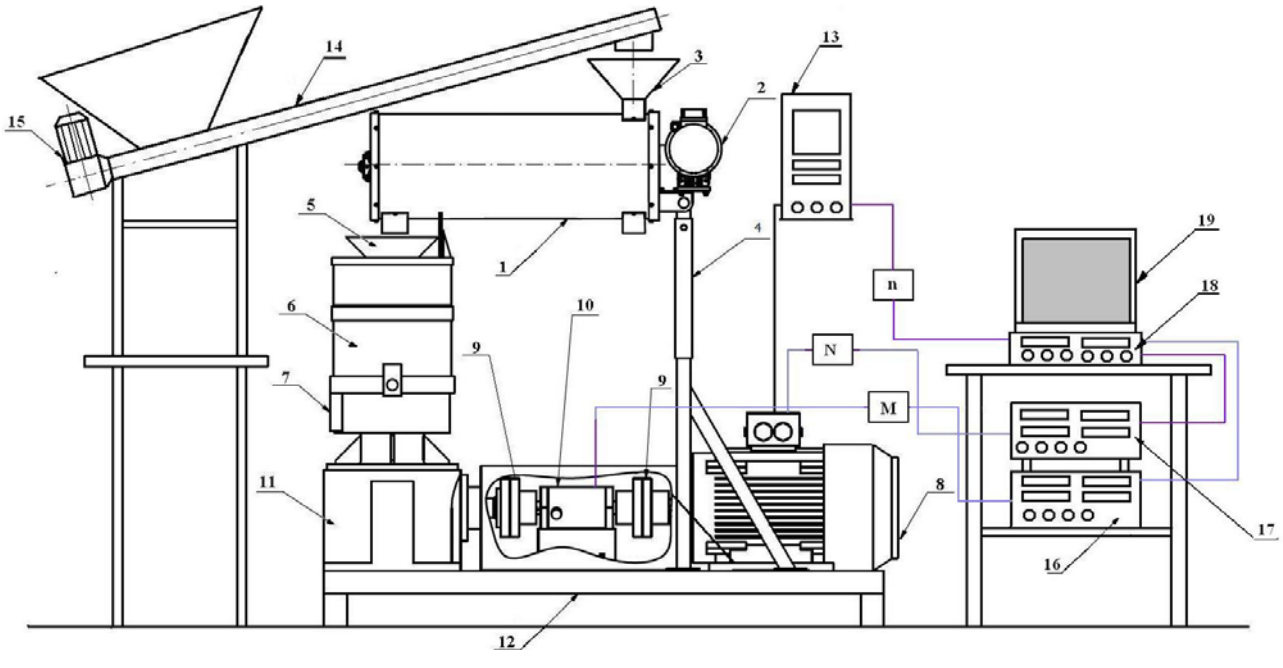
The tests allowed to determine the influence of apple pomace content (10%, 15%, and 20%) in a mixture with oat bran, and the type of the used apple pomace from the Sawa (SA) apple variety obtained during the pressing of: cloudy (ME), cold clarified (KZ), and hot clarified (KC) juice, on power consumption of the device and kinetic durability of the obtained pellets.

Tests of the densification process were performed at a rotational speed of the system of rolls of n_r=170 rpm^{-1}, at a mass rate of flow of raw material through the working system of Q=150 kg·h^{-1}, and a gap between the rolls and the matrix of h_r=0.4 mm.

24 hours after pellets had left the working system, their kinetic durability was determined by means of a Holmen tester. The tests were performed pursuant to PN-R-64834:1998 [15] and PN-EN 15210-1:2010 [17] and recommendations presented in papers [21, 22].

Moisture contents of the tested mixtures of oat bran and apple pomace were determined pursuant to PN-EN 14774-1:2010 [16] by means of a WPE 300S weighting dryer, by each time determining the moisture content of five 5 g samples dried in a temperature of 105°C until a constant mass was achieved.

a)



b)

Fig. 1. Working stand with a new prototype pelleting and briquetting device with a flat immovable matrix [5, 13]: a) scheme of the stand: 1- mixing-pelleting-feeding system, 2- drive of the mixing-pelleting-feeding system (electric motor connected with a reducer), 3- raw material inlet to the mixing-pelleting-feeding system, 4- mounting frame of the mixing-pelleting-feeding system, 5- raw material inlet to the working system of the pellet mill, 6- working system of the pellet mill, 7- outlet of pellets from the working system, 8- drive of the pellet mill (electric motor), 9- clutch, 10-Mi20 torque measuring shaft, 11- spur gear, 12- base, 13-frequency converter, 14- feeder, 15- feeder drive (electric motor connected with a reducer), 16- WT-1 torque and force indicator, 17- METROL KWS 1083 device for active power measurement, 18- Spider 8 recorder, 19- PC computer; b) view of the stand

Rys. 1. Stanowisko badawcze z nowym prototypowym urządzeniem granulująco-brykietującym z płaską nieruchomą matrycą [5, 13]: a) schemat stanowiska: 1- układ mieszająco-granulująco-dozujący, 2- napęd układ mieszająco-granulująco-dozującego (silnik elektryczny połączony z reduktorem), 3- zasyp surowca do układ mieszająco-granulująco-dozujący, 4- rama mocująca układ mieszająco-granulująco-dozujący, 5- wsyp surowca do układu roboczego granulatora, 6- układ roboczy granulatora, 7- wysyp granulatu z układu roboczego, 8- napęd granulatora (silnik elektryczny), 9- sprzęgło, 10- momentomierz Mi20, 11- przekładnia zębata, 12- podstawa, 13- przemiennik częstotliwości, 14- dozownik, 15- napęd dozownika (silnik elektryczny połączony z reduktorem), 16- wskaźnik momentu obrotowego i siły WT-1, 17- urządzenie do pomiaru mocy czynnej METROL KWS 1083, 18- rejestrator Spider 8, 19- komputer PC; b) widok stanowiska

4. Results of tests

Table 1 shows the results of tests of the densification process of a mixture of oat bran and apple pomace on a new prototype pelleting and briquetting device with a flat immovable matrix.

Tab. 1. Results of tests of the densification process of a mixture of oat bran and apple pomace

Tab. 1. Wyniki badań procesu granulowania mieszaniny otrębów owsianych i wytłoków jabłkowych

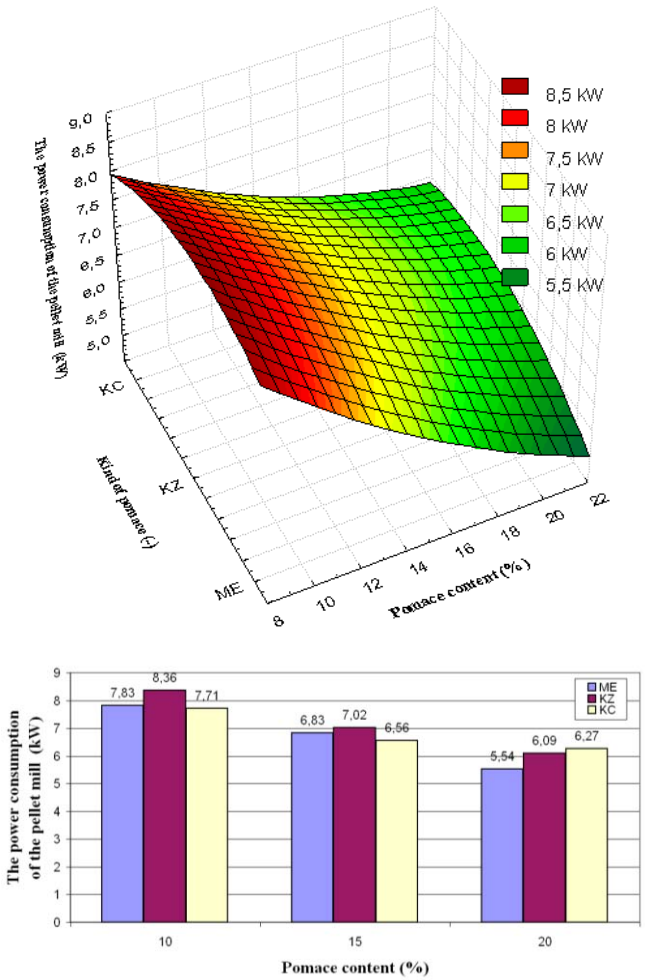
x_i / Meas no.	Independent variables		Dependent variables		
	Pomace content $x_i=z_w$ (%)	Pomace type	Power consumption N_g (kW)	Mixture moisture content w_m(%)	Kinetic durability of pellets P_{dx} (%)
1	10	ME	7.83	10.83	92.25
2	15	ME	6.83	14.70	87.67
3	20	ME	5.54	19.03	82.79
4	10	KZ	8.36	11.97	95.14
5	15	KZ	7.02	15.00	89.15
6	20	KZ	6.09	20.20	79.91
7	10	KC	7.71	12.07	88.42
8	15	KC	6.56	16.03	82.55
9	20	KC	6.27	20.98	72.93

Source: own work / Źródło: opracowanie własne

Figure 2 shows a graphic interpretation of the obtained test results of the influence of apple pomace content in a mixture with oat bran, and the type of apple pomace on power consumption of the pellet mill during pelleting of apple pomace and oat bran.

On the basis of the performed tests (fig. 2 and tab. 1), it was concluded that increasing the content of apple pomace from 10 to 20% causes a reduction of power consumption of the motor that powers the pellet mill, recorded during the process of pelleting of a mixture of oat bran and apple pomace. The reduction of power consumption is to a large extent influenced by the type of used pomace. Increasing the apple pomace content from 10 to 20% causes a reduction of power consumption by 18.62% (from 7.71 to 6.27 kW) when pomace from hot clarified juice is used (KC); a reduction of power consumption by 27.15% (from 8.36 to 6.09 kW) when pomace from cold clarified juice is used (KZ); a reduction by approx. 29.25% (from 7.83 to 5.54 kW) when pomace from cloudy juice is used (ME).

The reduction of power consumption of the power mill with increasing pomace content in the mixture is mainly caused by the significant increase of moisture contents of mixtures of oat bran and apple pomace, from 10 to 20% (fig. 3), resulting from the increased content of pomace in the mixture.



Source: own work / Źródło: opracowanie własne

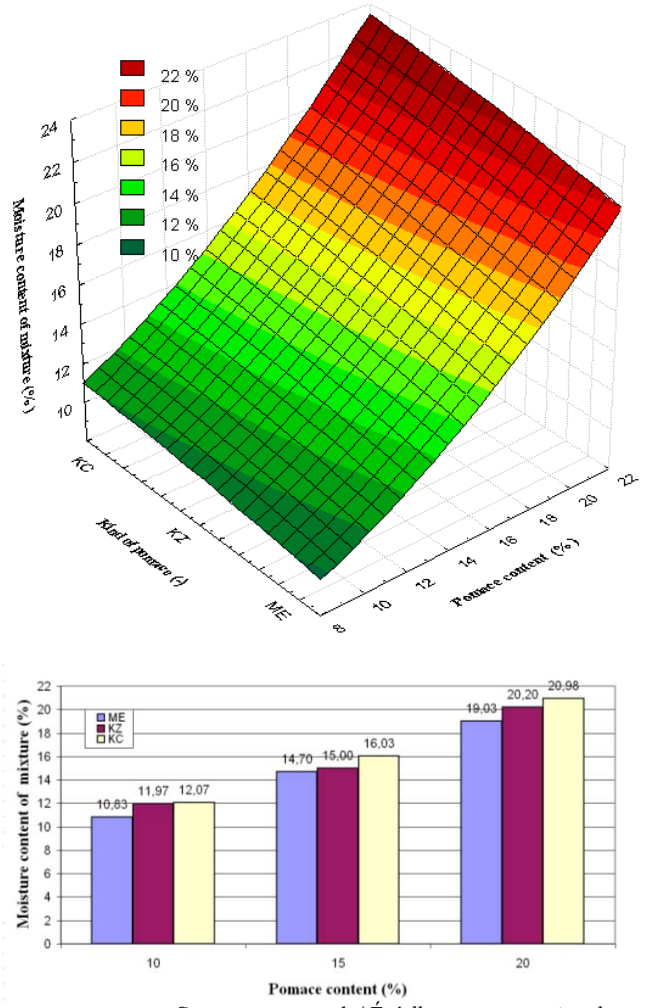
Fig. 2. Influence of apple pomace content in a mixture with oat bran, and the type of apple pomace on power consumption of the pellet mill

Rys. 2. Wpływ zawartości wytłoków jabłkowych w mieszaninie z otrębami owsianymi i rodzaju wytłoków jabłkowych na zapotrzebowanie granulatora na moc

Moisture content of the densified mixtures of oat bran and apple pomace obtained during the production of cloudy juice (ME) increased from 10.83% (at a 10% pomace content in the mixture) to 19.03% (at a content of 20%). Moisture content of the mixture containing apple pomace from the production of cold clarified juice (KZ) increased from 11.97% to 20.20%, whereas when apple pomace obtained during the production of hot clarified juice (KC) was used, moisture content increased from 12.07% to 20.98%. Increasing pomace content in the densified mixture caused a greater amount of binder to appear during the pelleting process. The increasing binder content produced the effect of "lubrication" of surfaces of openings in the pellet mill matrix and a reduction of resistance to forcing. This reduction resulted in a reduction of power consumption of the pellet mill.

A similar level of power consumption of the pellet mill is confirmed by results of other research [1] of densification of mixtures of oat bran with a 20% addition of apple pomace from apples of the summer varieties: Piros (PR), James Grieve (JG), and Retina (RE), obtained in the process of production (pressing) of cloudy juice, cold clarified juice, and hot clarified juice. In these tests [1], the highest power consumption (6.18 kW) was observed when mixtures containing the Piros (PR) variety pomace obtained during the production of hot clarified juice (KC) were used, whereas the lowest (5.21 kW) for mixtures containing the James Grieve (JG) variety pomace obtained during the production of hot clarified juice.

A reduction of power consumption of the power mill with increasing binder contents is also confirmed in results of other tests [8, 10, 11, 12].



Source: own work / Źródło: opracowanie własne

Fig. 3. Influence of apple pomace content in a mixture with oat bran, and the type of apple pomace on moisture content of the mixture

Rys. 3. Wpływ zawartości wytłoków jabłkowych w mieszaninie z otrębami owsianymi i rodzaju wytłoków jabłkowych na wilgotność mieszaniny

On the basis of the performed tests (fig. 4 and tab. 1), it was concluded that apple pomace content from 10 to 20% results in a reduction of the kinetic durability of pellets obtained in the course of the densification process of a mixture of oat bran and apple pomace: from 92.25% to 82.79% (when apple pomace obtained during the production of cloudy juice (ME) was used), from 95.14% to 79.91% (when pomace from the production of cold clarified juice (KZ) was used), and from 88.42% to 72.93% (when pomace from the production of hot clarified juice (KC) was used).

The results of the performed tests show that the type of apple pomace added to oat bran is another factor that has a

significant influence on kinetic durability of the obtained pellets (fig. 4). The highest kinetic durability was recorded for pellets containing apple pomace produced during the production of cold clarified juice (KZ) (at 10 and 15% pomace contents), despite the fact that the moisture content of mixtures with pomace of this type was not the lowest (the lowest moisture content at each of the pomace content levels was obtained for mixtures containing apple pomace obtained during the production of cloudy juice (ME) – (fig. 3).

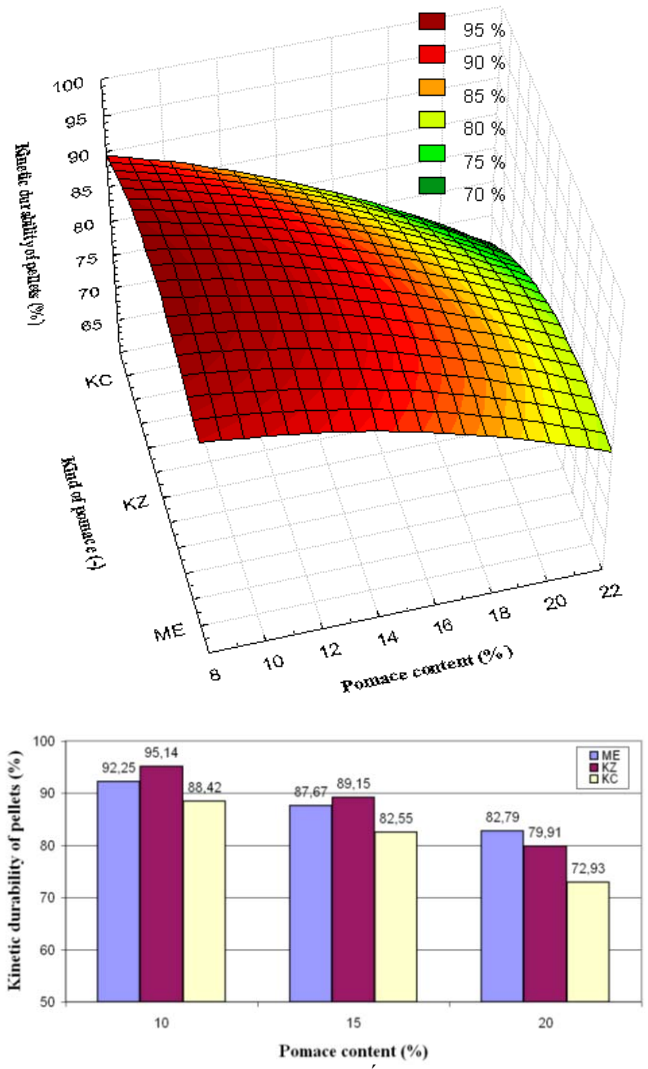


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Fig. 4. Influence of apple pomace content in a mixture with oat bran and the type of apple pomace on kinetic durability
Rys. 4. Wpływ zawartości wytłoków jabłkowych w mieszaninie z otrębami owsianymi i rodzaju wytłoków jabłkowych na wytrzymałość kinetyczną

The lowest kinetic durability, on the other hand, was obtained for pellets produced from a mixture of oat bran containing apple pomace obtained during the production of hot clarified juice (KC). In the case of pomace of this type, moisture content of mixtures was the highest (at each of the levels of pomace contents), which might explain the lowest kinetic durability of the obtained pellets during the densification of a mixture containing this type of pomace.

During the tests of densification of mixtures with a 20% content of oat bran from summer varieties of apples [1] revealed that the obtained pellets were characterized by a kinetic durability of 87.09% (when pomace from the Retina variety produced during hot clarification was used) to 69.96% in the case of pellets containing the Piros variety pomace produced during the pressing of cold clarified juice. During the densification of a mixture of oat bran with a potato pulp content of 15 to 25%, on the other hand, it was concluded that kinetic durability of pellets decreased by approx. 31%, from 95.78% to 65.90% [10].

5. Summary

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

1. As proportional content of apple pomace in a mixture with oat bran increased, moisture content of the densified material also increased, which had a significant influence on the course of the pelleting process and the quality of the obtained pellets.
2. The type of apple pomace added to oat bran has a significant influence on power consumption of the pellet mill and kinetic durability of the obtained pellets.
3. Increasing apple pomace content in a mixture with oat bran from 10% to 20% caused a reduction of power consumption of the pellet mill by approx. 19% (from 7.71 to 6.27 kW) when pomace from hot clarified juice was used; by approx. 27% (from 8.36 to 6.09 kW) when pomace from cold clarified juice was used; and a reduction by approx. 29% (from 7.83 to 5.54 kW) when pomace from cloudy juice was used.
4. Increasing apple pomace content in a mixture with oat bran from 10% to 20% caused a reduction of kinetic durability of pellets by approx. 10% (from 92.25 to 82.79%) when pomace from cloudy juice (ME) was used; by approx. 16% (from 95.14 to 79.91%) when pomace from cold clarified juice (KZ) was used; and by approx. 18% (from 88.42 to 72.93%) when pomace from hot clarified juice (KC) was used.
5. Pellets with the highest kinetic durability were obtained when pomace produced during the pressing of cold clarified juice (KZ) was used. The least beneficial durability properties, on the other hand, were obtained for pellets containing pomace produced during the pressing of hot clarified juice (KC).

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