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TESTS OF THE PROCESS OF POST-PRODUCTION ONION WASTE PELLETING

Summary

The aim of the research was to analyse the process of onion waste pelleting in terms of its use as a fodder additive. The paper assesses the influence of the moisture content of shredded onion waste on the energy consumption of the pelleting system and the density and kinetic durability of the obtained pellets. The tests of the pelleting process were carried out on an SS-4 stand, whose main component was the P-300 pellet mill with a flat rotating die with an opening diameter of 8 mm and an opening length of 28 mm, working with a set of two densification rolls. In the course of the tests, the influence of the moisture content of shredded onion waste (17.1%, 19.1% and 24.0%) on the energy consumption of the power mill, the temperature of the working system during pelleting, and the kinetic durability of the obtained pellets were tested. The tests of the pelleting process were carried out at a mass flow rate of shredded onion waste of $Q=20$ kg⊙h^{-1}, a rotational speed of the set of densification rolls of $n_r=170$ rpm^{-1} and a gap between the rolls and the die of $h_r=0.4$ mm. On the basis of the performed tests, it was concluded that as the moisture content of the onion waste increases from 17.1 to 24.0%, the energy consumption of the power mill decreases by 22.6%, along with a decrease in density of approx. 15%, at a minimum reduction in kinetic durability of pellets of approx. 0.5%.
***Key words**: pelleting, potato waste, density, kinetic durability*

BADANIA PROCESU PELETOWANIA POPRODUKCYJNYCH ODPADÓW CEBULI

Streszczenie

Celem badań była ocena procesu peletowania (granulowania) odpadów cebuli w aspekcie jego wykorzystania jako dodatku do pasz. W pracy oceniono wpływ wilgotności rozdrobnionych odpadów cebuli na zapotrzebowanie na moc układu granulującego oraz na gęstość i wytrzymałość kinetyczną otrzymanego granulatu. Badania procesu procesu peletowania (granulowania) przeprowadzono na stanowisku SS-4, którego głównym elementem jest granulator P-300 z wykorzystaniem płaskiej obrotowej matrycy o średnicy otworów 8 mm i długości otworów 28 mm, współpracującej z układem dwóch rolek zagęszczających. W trakcie badań określono wpływ wilgotności rozdrobnionych odpadów cebuli (17,1, 19,1 i 24,0%) na zapotrzebowanie granulatora na moc, temperaturę układu roboczego w trakcie procesu granulowania oraz na gęstość i wytrzymałość kinetyczną otrzymanego granulatu. Badania procesu granulowania przeprowadzono przy masowym natężeniu przepływu rozdrobnionych odpadów cebuli $Q=20$ 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. Na podstawie przeprowadzonych badań stwierdzono, że wraz ze zwiększeniem wilgotności odpadów cebuli od 17,1 do 24,0% następuje spadek zapotrzebowania na moc granulatora o 22,6% oraz spadek gęstości o ok. 15% przy minimalnym spadku wytrzymałości kinetycznej granulatu o ok. 0,5%.
***Słowa kluczowe**: peletowanie, odpady cebuli, gęstość, wytrzymałość kinetyczna*

1. Introduction

During Poland's gradual integration with the European Union, numerous legal waste management standards were introduced [6].

According to Dach and Niżewski [6], in the case of the agro-food industry, this resulted in new restrictions, as it turned out that materials that are theoretically a good fertilizer (e.g. decoctions, or vegetable, mushroom or herbal production waste) must be treated as waste and subject to the proper procedures of storage, disposal, processing and use.

According to Kumider [14], the amount of waste produced during fruit and vegetable processing is within 10-35% of the mass of the processed raw material.

Post-production onion waste in the form of onion skins and outer layers is one of the types of waste produced in fruit and vegetable processing plants.

According to Eurostat [9], during its production, onion is processed into the form of: dried, whole, sliced or broken onions, with a total volume of 3.5×104 tons, which generates a considerable amount of waste, including skins, on the EU Scale.

This is corroborated by Moure et al. [15], according to whom over 450,000 tons of onion solid waste (OSW) is produced in Europe each year.

According to the Law on waste of April 27, 2001 [8], onion skins are included in group 02 (waste from agriculture, horticulture, aquaculture, fishing, hunting and food processing), with code 02 03 80 attributed to it (pomace, sediment and other plant processing waste).

In the case of onions, at the peeling methods currently used (by machine or by hand) the losses amount to approx. 20-25%, depending on the size and quality of the raw material.

At a nationwide scale of onion production amounting to 577,983 tons (data for 2009) [29], the amount of waste that needs to be disposed of is approx. 144,496 tons a year. Hence, this is a considerable amount of waste that can be changed into a full-value fuel or fodder.

Onion skins are used for various purposes. According to Dach and Niżewski [6], onion waste is an organic material which – appropriately processed and used as fertilizer – may significantly improve soil yields. However, according to Dach and Niżewski [6], it cannot be directly used as fertilizer as far as onion production is concerned, due to the risk of infection of plantations with fungal diseases, particularly *Fusarium*.

According to Barbar et al. [3], onion skins can be used as a new raw material for enzymatic production of pectic oligosaccharides with a directed degree of polarization.

According to Barbar et al. [3], onion skins were used for the production of paper for typing of duplicates in a typewriter. Moreover, they are also used as a raw material for the acquisition of carpet and cotton fabric dyeing pigments [5]. Currently, they are used as a raw material for the acquisition of compounds used as antioxidants with a strong antioxidant activity – mostly polyphenols (such as quercetin and other flavonoids with medicinal properties) [1, 7].
They are also a raw material that is a rich source of pectin [3].

Onion waste is also used [24, 25, 26]:
- as a substrate for biogas production,
- as a raw material in ethanol production,
- in nutrition, as a raw material in dietary fibre production,
- as a source of acquisition of sulphur compounds,
- as a source of dietary fibre.

Numerous scientific and application papers [1, 10, 11, 16, 17, 18, 19, 20] confirm that pelleting or briquetting various kinds of plant waste materials into the form of a solid fuel (pellets, briquettes) is one of the most common methods of their management.

2. Aim of the research

The aim of the research is to analyse the process of post-production onion waste pelleting in terms of its use as a heating fuel or a fodder additive. In the paper, the influence of the moisture content of shredded onion waste on the energy consumption of the pelleting system and the density and kinetic durability of the obtained pellets were assessed.

3. Research methods

Shredded onion waste was the research material subject to pelleting (Fig. 1) obtained from a plant located in Mełno, which peels onions for the needs of the P.P.H.U. Eldom Grudziądz cold storage facility.

Source: own work / Źródło: opracowanie własne

Fig. 1. View of the tested onion waste (after drying and shredding)

Rys. 1. Widok badanych odpadów cebuli (po wysuszeniu i rozdrobnieniu)

The obtained raw material was very moist and unshredded. The drying process took place in natural conditions. Then, pre-dried waste material was shredded by means of a "Bąk" H-111/1 flail shredder into fractions of approx. 5 mm and smaller.

Tests of the pelleting process were carried out on an SS-4 stand, presented in papers [20, 21].

The main component of the SS-4 stand included a P-300 pellet mill with a "flat die-densification rolls" working system. The SS-4 stand was equipped with a universal meter for the measurement of the device's energy consumption and a recorder (Spider 8) coupled with a computer.

In the course of the tests, the influence of the moisture content of shredded onion waste (17.1, 19.1 and 24.0%) on the energy consumption of the pellet mill, the temperature of the working system during the pelleting process, and the density and kinetic durability of the obtained pellets were determined.

The tests were carried out with the use of a flat rotating die with an opening diameter of 8 mm and an opening length of 28 mm, working with a set of two densification rolls.

The tests of the pelleting process were carried out at a mass flow rate of the shredded onion waste of $Q=20\ kg\cdot h^{-1}$, at a rotational speed of the set of densification rolls of $n_r=170\ rpm^{-1}$ and a gap between the rolls and the die of $h_r=0.4$ mm.

24 hours after pellets had left the working system, their density and kinetic durability were determined with the use of the Holmen tester, pursuant to PN-R-64834:1998, according to the methodology presented in papers [20; 21].

The granulometric distribution of onion waste was determined with the use of a Multiserv Morek LPz-2e laboratory shaker, according to the methodology presented in paper [20], among others, using a set of 7 sieves with the following side dimensions of the square mesh: 4 mm, 2 mm; 1 mm; 0.5 mm; 0.25 mm, 0.125 mm and 0.063 mm.

Pellet density was determined (24 hours after densification) by measuring the height and diameter of pellets with a calliper, with an accuracy of ±0.02 mm, and determining their mass using WPS 360 laboratory scales, with an accuracy of ±0.001 g. Density was calculated as the ratio of the mass of pellets to the sum of their volumes.

Determination of the moisture content of the raw materials (onion waste) before densification was performed pursuant to PN-EN 14774-1:2010 [28] by means of a WPE 300S moisture analyser, with an accuracy of 0.01%, pursuant to the methodology presented in [16, 20].

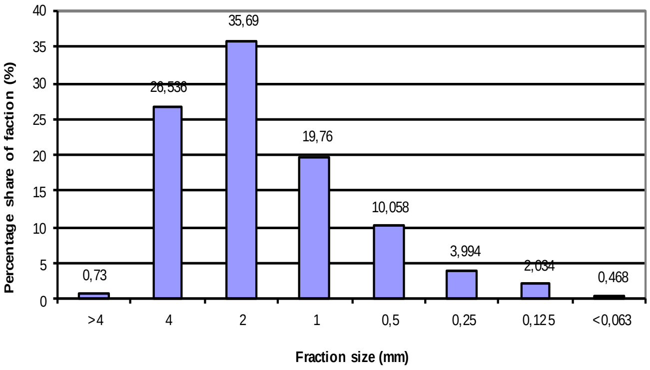
4. Research results

On the basis of initial tests, it was determined that the tested onion waste is characterized by a low bulk density of approx. $171.77\ kg\cdot m^{-3}$.

Fig. 2 shows the results of a sieve analysis of dried and shredded onion waste before pelleting.

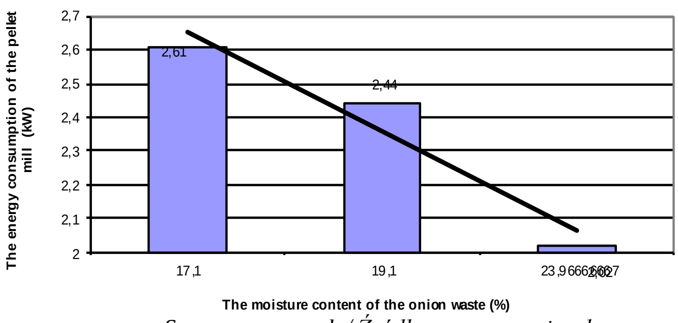
The performed sieve analysis of waste (after shredding) showed that the 2 mm fraction comprised its highest proportion (35.69%), the 4.0 mm fraction comprised 26.54%, while the 1 mm fraction comprised 19.76%. The lowest proportional content was observed for the >4 mm fraction (0.73%) along with the extra-sieve fraction.

Fig. 3 shows the results of tests of the process of densification of onion waste (the relationship between the energy consumption of the pellet mill and the moisture content of the densified onion waste).



Source: own work / Źródło: opracowanie własne

Fig. 2. Granulometric distribution of shredded onion waste (before pelleting)
Rys. 2. Rozkład granulometryczny rozdrobnionych odpadów cebuli (przed procesem ich granulowania)



Source: own work / Źródło: opracowanie własne

Fig. 3. Relationship between the energy consumption of the pellet mill and the moisture content of the densified onion waste
Rys. 3. Zależność zapotrzebowania na moc granulatora od wilgotności zagęszczanych odpadów cebuli

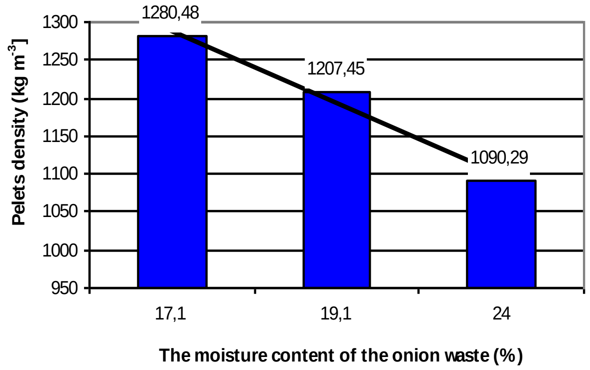
On the basis of the performed tests (Fig. 3), it was concluded that increasing the moisture content of the densified onion waste from 17.1 to 24% results in a decrease in the energy consumption of the motor driving the pellet mill, recorded during the process of pelleting of shredded onion waste, by 22.61% (from 2.61 to 2.02 kW).

The reduction in the energy consumption of the pellet mill, along with the increased moisture content (caused by the introduction of a binder) of the densified mixture, is also confirmed by results of other research studies [20, 21, 22, 23].

Fig. 4 shows the results of tests of the influence of the moisture content of onion waste on the density of pellets obtained from onion waste in the working system of the pellet mill.

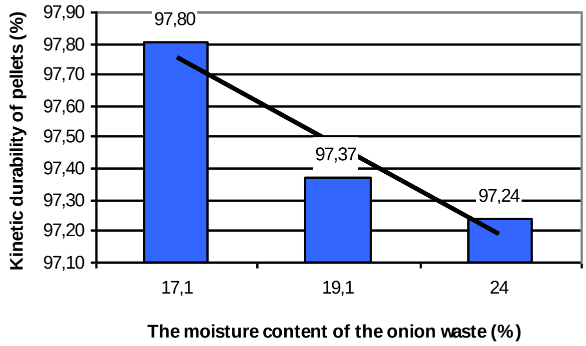
The obtained test results (Fig. 4) show that increasing the moisture content of onion waste from 17.1 to 24% results in a reduced density of pellets obtained from shredded onion waste by 14.85% (from 1280.48 to 1090.29 kg·m^{-3}). Pellets obtained at each of the values of moisture content are characterized by a high density (over 1000 kg·m^{-3}), which indicates their high market value. Such density meets the requirements of ISO 17225 [13].

Fig. 5 shows the results of tests of the influence of the moisture content of onion waste on the kinetic durability of pellets obtained from onion waste in the working system of a pellet mill.



Source: own work / Źródło: opracowanie własne

Fig. 4. Relationship between pellets density and the moisture content of densified onion waste
Rys. 4. Zależność gęstości granulatu od wilgotności zagęszczanych odpadów cebuli



Source: own work / Źródło: opracowanie własne

Fig. 5. Relationship between the kinetic durability of pellets and the moisture content of densified onion waste
Rys. 5. Zależność wytrzymałości kinetycznej granulatu od wilgotności zagęszczanych odpadów cebuli

The obtained test results (Fig. 4) show that increasing the moisture content of the densified onion waste from 17.1 to 24% results in a slight decrease in kinetic durability of pellets obtained from onion waste, by 0.57% (from 97.80 to 97.24%).

Pellets obtained at each of the values of moisture content are characterized by a high kinetic durability, indicating their high quality.

Fig. 6 shows the view of pellets obtained from densified, shredded onion waste with a moisture content of 19.1%.

Source: own work / Źródło: opracowanie własne

Fig. 6. View of pellets from onion skins obtained at a moisture content of 19.1%
Rys. 6. Widok granulatu z łuski cebuli otrzymanego przy wilgotności 19.1%

The pellets shown in Fig. 6 are characterized by a high kinetic durability (97.37%), while their surface is smooth and shiny. Only on some of the pellets sparse cracks can be seen.

The conducted research of the quality of pellets from shredded onion waste shows that they can be successfully used as a full-value solid fuel, at each of the values of moisture content.

5. Conclusions

On the basis of the performed tests, the following conclusions can be formulated:

1. Onion waste is a material characterized by small susceptibility to densification. During pelleting, a high process temperature is required in order to obtain pellets of satisfactory quality parameters.
2. An increased moisture content in the densified onion waste has a significant impact on the course of the pelleting process and the quality of the obtained pellets.
3. Increasing the moisture content of the densified onion waste from 17.1% to 24% resulted in a decreased energy consumption of the pellet mill, by approx. 22.6% (from 2.61 to 2.02 kW), at a simultaneous reduction in pellets density by approx. 14.8% (from 1280.48 to 1090.29 $kg \cdot m^{-3}$) and a slight reduction in kinetic durability of pellets by approx. 0.5% (from 97.80 to 97.24%).

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Badania zostały zrealizowane w ramach pracy nr S/WBiIŚ/2/2015 i sfinansowane ze środków na naukę MNiSW.