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THE IMPACT OF THE AMOUNT OF BINDER AND STARCH CONTENT IN BINDER ON THE AMOUNT OF THE PELLETED FRACTION IN THE PROCESS OF NON-PRESSURE AGGLOMERATION OF NETTLE WASTE

Summary

The article presents the results of tests of the impact of material and process parameters of the process of non-pressure pelleting of post-production nettle waste generated by the Herbapol plant in Białystok. The pelleting process was performed using a mixing-pelleting-dosing system that comprised a system that supplied the plant material to the densifying system of the pelleting and briquetting device. The tests allowed to determine the impact of the amount of binder added to nettle waste (10, 20, 30%) and starch content in aqueous binder solution (0, 10, 20%) on the amount of the pelleted fraction. The tests were carried out at a mass flow rate of the densified raw material of 8 kg·h^{-1}. The obtained results allowed to conclude that increasing the amount of binder from 10 to 30% during non-pressure pelleting causes an increase in the content of the pelleted waste fraction from 13.03 to 35.66%, whereas increasing the amount of potato starch added to aqueous binder solution from 0 to 20% during non-pressure pelleting results in a significant increase in the amount of the pelleted fraction, from 15.57 to 24.37%.
***Key words**: non-pressure pelleting, nettle waste, binder*

WPŁYW ILOŚCI LEPISZCZA ORAZ ZAWARTOŚCI SKROBI W LEPISZCZU NA ILOŚĆ FRAKCJI ZGRANULOWANEJ W PROCESIE GRANULACJI BEZCIŚNIENIOWEJ ODPADÓW POKRZYWY

Streszczenie

W artykule przedstawiono wyniki badań wpływu parametrów materiałowych i procesowych procesu granulowania bezciśnieniowego roślinnych odpadów poprodukcyjnych pokrzywy, generowanych przez zakłady Herbapol w Białymstoku. Proces granulowania przeprowadzono z wykorzystaniem układu mieszająco-granulująco-dozującego stanowiącego układ podający materiał roślinny do układu zagęszczającego urządzenia granulująco-brykietujacego. W badaniach określono wpływ ilości lepiszcza dodawanego do odpadów pokrzywy (10, 20, 30%) oraz wpływu zawartość skrobi w wodnym roztworze lepiszcza (0, 10, 20%) na ilość frakcji zgranulowanej. Badania przeprowadzono przy masowym natężeniu przepływu zagęszczanego surowca 8 kg·h^{-1}. Uzyskane wyniki badań pozwoliły stwierdzić, że zwiększenie ilości lepiszcza od 10 do 30% w trakcie procesu granulacji bezciśnieniowej powoduje wzrost udziału frakcji zgranulowanej odpadów z 13,03 do 35,66%, a zwiększenie ilości skrobi ziemniaczanej dodawanej do wodnego roztworu lepiszcza od 0 do 20% w trakcie procesu granulacji bezciśnieniowej powoduje istotny wzrost ilości frakcji zgranulowanej z 15,57 do 24,37%.
***Słowa kluczowe**: granulowanie bezciśnieniowe, odpady pokrzywy, lepiszcze*

1. Introduction

According to many researchers [9, 15, 19], one of the best methods of agglomeration of very fine particles through non-pressure pelleting that, according to Sobczak [20], makes it possible to obtain dusty particles in small amounts – provided that the binder liquid and the process parameters are appropriately selected – and, in the view of Gluba [6], is economically attractive due to the relative low investment and operational costs. According to Gluba [6], pelleting has found its use in numerous branches of industry, including mineral processing, agricultural products, detergents, pharmaceuticals, food products, and chemical substances of various kinds. Gluba [6] claims that as much as 60% of products in the chemical industry is produced in the powdery or dusty form, while a further 20% uses such forms of additives. Pelleting is a key stage of product manufacturing and processing in these branches.

The course of the non-pressure pelleting process and in consequence the properties of the obtained product depend on the properties of both media involved in the process, as well as on the construction parameters of the device and the process conditions [2, 4, 5, 16]. However, pelleting of powdered materials and the accompanying processes (mixing, shredding, classification) largely depend on physical and rheological properties of these materials [1].

According to Domaradzki et al. [3] susceptibility to non-pressure pelleting may be achieved by milling the material or adding the fine-grained fraction of the same material, other fine-grained materials, or those with good binding properties (peat, clay, bentonite, kaolin) to the dust.

Nettle waste produced in herb processing or pharmaceutical plants is one of the many types of dusty post-production waste generated by herbal companies.

Herbapol Białystok S.A. generates 30 tons of nettle waste annually, which is usually sold cheaply or given away for a refund of the price of transport [18]. This is confirmed by Kobus et al. [14], according to whom some herbs are ground into fractions with very small particle dimensions during harvest and the processes of drying, transport, and storage. The industry treats all these fractions as waste.

Post-production herbal waste is a very small-particle material, which poses a significant problem as far as its use as a raw material for pressure agglomeration is concerned. These issues result in such materials usually being subjected to the process of non-pressure agglomeration.

The most common method of utilization of herbal waste is using it as a fodder additive [7, 8].

2. The aim of the research

The aim of the study is to determine the impact of material and process parameters of non-pressure pelleting of fine-rained and dusty nettle waste on the amount of the pelleted fraction and the density of the obtained pellets.

3. Research methodology

The raw material subjected to non-pressure pelleting was fine-grained nettle waste obtained from Herbapol in Białystok, generated when the plants are being processed in the facilities, during final sorting before drying, and when dried herbs are being sorted and packaged.

Tests of non-pressure pelleting were performed on a test stand using a mixing-pelleting-dosing system which is an element of a pelleting and briquetting device (Fig. 1) described in papers [11-13].

According to Hejft and Obidziński [11] constructing the system enables simultaneous performance of operations of both mixing and non-pressure pelleting of the dusty fractions of the material.

The mixing-pelleting-dosing system presented in Fig. 1 is equipped with a rotating cylinder which, in its front side, has openings through which the material is fed to its interior (Fig. 1a). On the internal side of the moving internal cylinder there are two replaceable plates (Fig. 1c), mounted to the cylinder with screws (arranged in a helix along its length) with adjustable angle of their position.

The internal cylinder is driven by an electric motor that powers a hollow driving shaft connected with a shield, to which the cylinder is fixed.

The design of the shaft as hollow makes it possible to supply the internal cylinder, through the hole in the shaft, with a liquid that could be used as binder, another liquid additive, or steam (according to the needs).

The rotating internal cylinder is shielded by an immobile external cylinder (Fig. 1b). Particles of material fed to the rotating internal cylinder (through charge openings and conical rails (Fig. 1a) mounted on the shield driving the cylinder), pour along the surface of the rotating internal cylinder between the mounted blades (Fig. 1c) and move towards the discharge as a result of the helical arrangement of the blades inside the cylinder. Supplying binder to the internal cylinder, through the hole in the shaft, results in partial pelleting (non-pressure) of dusty fraction particles contained in the material when it is poured in between the blades. The system's design makes it possible to adjust the tilt angle between the device and the working system of the pellet mill by changing the position of the fixing arm of the mixing-pelleting-dosing system.

In the course of the tests, the impacts of the amount of binder added to nettle waste was determined (10, 20, 30%) and of starch content in aqueous binder solution on the amount of the pelleted fraction produced through non-pressure pelleting of fine-grained post-production nettle waste.

Determination of the impact of the amount of binder (10, 20, 30%) added to nettle waste was performed at a rotational speed of the internal cylinder of the mixing-pelleting-dosing system of 40 rpm^{-1} and at a starch content in aqueous binder solution of 10%.

a)

b)

c)

Source: own work / Źródło: opracowanie własne

Fig. 1. View of components of the mixing-pelleting-dosing system [own photos]: a) from the charge, b) from the discharge, c) internal

Rys. 1. Widok zespołów układu mieszająco-granulująco-dozującego: a) od strony zasypu, b) od wewnątrz

Determination of the impact of starch content in aqueous binder solution (0, 10, 20%) was performed at a rotational speed of the internal cylinder of the mixing-pelleting-dosing system of 40 rpm^{-1} and at a 20% binder content in nettle waste.

All tests were carried out at a mass flow rate of the densified raw material through the working system of 8 kg·h^{-1}.

During agglomeration, binder was supplied to the inside of the cylinder by means of a spraying nozzle. After agglomeration the obtained product was placed in a separate vessel and subjected to drying in a temperature of approx. 23ºC for 48 hours, after which sieve analysis was performed for each of the samples in order to determine the mass fraction and the granulometric distribution of the pelleted fraction. Particles larger than 0.5 mm were considered as the pelleted fraction.

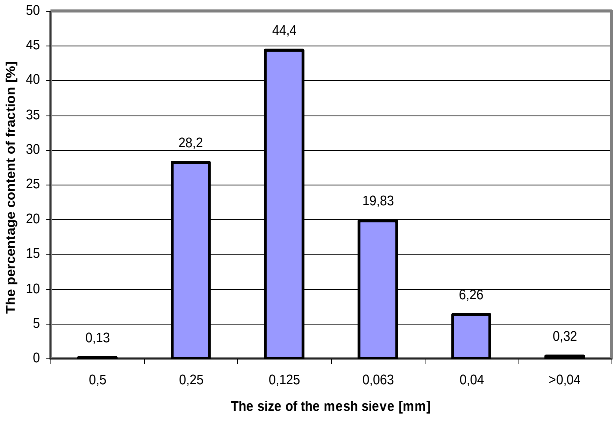
Determination of the granulometric composition of fine-grained nettle waste and separation of the pelleted and non-pelleted fractions were performed using an LPz-2e shaker by Multiserw Morek, pursuant to PN-EN 932-1. During the determination process, a previously weighed 50 g nettle waste sample was poured onto the upper sieve of the sieve analysis set. A set of 5 sieves with the following side sizes of the square mesh was used: 0.5 mm, 0.25 mm, 0.125 mm, 0.063 mm, and 0.040 mm. Shaker operation time was 5 minutes, at an assumed vibration amplitude of 80%. After finishing the sieving process, each of the fractions was weighed and the obtained result constituted the percentage content of a given fraction

Determination of the amount of pelleted waste was performed 48 hours after it had been produced, after drying. Mixed pelleted and bulk fractions were subjected to sieving with the use of a set of 6 sieves with the following side sizes of the square mesh: 0.5 mm, 1.0 mm, 2.0 mm, 4.0 mm, 6.0 mm, and 8.0 mm. Separation of the pelleted fraction was performed by sieving it for 30 seconds. Measurement results were processed in Microsoft Excel.

One-way ANOVA test (One-Sample Kolmogorov-Smirnov test) at a significance level of P = 0.05 was used to determine the significance of differences between the values of contents of the pelleted fraction produced at increasing values of the tested independent variables.

4. Results of tests

Fig. 2 shows the granulometric distribution of sieve - analysed nettle waste.



Source: own work / Źródło: opracowanie własne

Fig. 2. Granulometric distribution of sieve-analysed nettle waste
Rys. 2. Rozkład granulometryczny cząstek odpadów pokrzywy poddanych analizie sitowej

The sieve analysis allowed to conclude that the 0.5 mm fraction comprised the smallest percentage content (0.13%) in the tested nettle waste. The 0.125 mm fraction represents the highest percentage content (44.4%), the 0.25 mm fraction comprising 28.2%. The waste, however, contains a considerable amount of the 0.063 mm (19.83%) and the 0.040 mm (6.26%) fractions.

According to Hejft and Obidziński [13], the granulometric distribution of this kind, i.e. with high contents of the dusty fraction, poses significant problems and results in increased power consumption of pressure pelleting devices, which is why it would be advisable to mix this kind of waste, before densification, with waste with larger particles or subject it to non-pressure agglomeration before performing pressure agglomeration.

Figure 3 shows the relationship between the amount of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste and the amount of binder added to nettle waste.

On the basis of the obtained results it was concluded that increasing the amount of binder from 10 to 30% during non-pressure pelleting results in a significant increase of the amount of the pelleted fraction from 13.03% to 35.66%.

The one-way ANOVA test (One-Sample Kolmogorov-Smirnov test) at a significance level of P = 0.05 revealed significant differences in the amounts of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste at consecutive (10, 20, 30%) amounts of binder added to nettle waste.

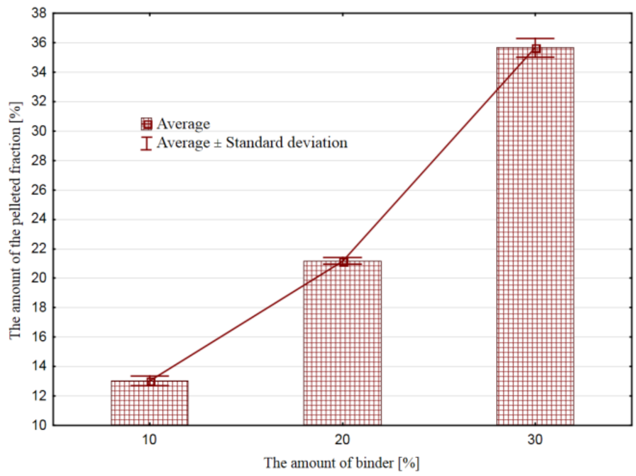


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Fig. 3. The relationship between the amount of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste and the amount of binder added to nettle waste
Rys. 3. Zależność ilości frakcji zgranulowanej otrzymanej w procesie granulowania bezciśnieniowego drobnoziarnistych poprodukcyjnych odpadów pokrzywy od ilości lepiszcza dodawanego do odpadów pokrzywy

The impact of the increasing amounts of binder added during the process of non-pressure pelleting on the pelleted fraction content is described with the following equation:

$$m_g = 11{,}32 \cdot \boldsymbol{V_l} + 0{,}66 \qquad R^2 = 0{,}975, \qquad (1)$$

where:
m_g – pelleted fraction content [%],
V_l – amount of binder added during the process of non-pressure pelleting [%].

Similar conclusions were drawn by Miastkowski et al. [17] who investigated a non-pressure pelleting of agricultural fertilizers. They concluded that pelleting of fertilizers with 5%, 10%, and 15% clay suspensions has a positive impact on the course of the process and the quality of the produced pellets in comparison with distilled water pelleting. However, according to Miastkowski et. al [17], too high binder concentration may result in worse pelleting conditions and worse properties of the obtained product.

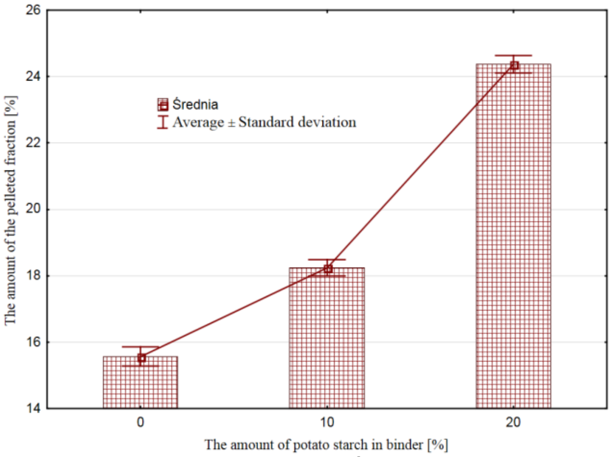

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Fig. 4. The relationship between the amount of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste and the amount of potato starch added to aqueous binder solution during non-pressure pelleting

Rys. 4. Zależność ilości frakcji zgranulowanej otrzymanej w procesie granulowania bezciśnieniowego drobnoziarnistych poprodukcyjnych odpadów pokrzywy od ilości skrobi ziemniaczanej dodawanej do wodnego roztworu lepiszcza

This may be dependent on wettability and hygroscopicity of the raw material which, according to Hejft and Leszczuk [10], determine the effectiveness of action of the liquid and solid phases. Too high hygroscopicity of the raw material often makes pelleting impossible and it becomes necessary to introduce another ingredient to the composition that would result in improved susceptibility to pelleting.

Figure 4 shows the relationship between the amount of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste and the amount of potato starch added to aqueous binder solution during non-pressure pelleting.

On the basis of the obtained results it was concluded that increasing the amount of potato starch added to aqueous binder solution from 0 to 20% during non-pressure pelleting results in a significant increase in the pelleted fraction content, from 15.57% to 24.37%.

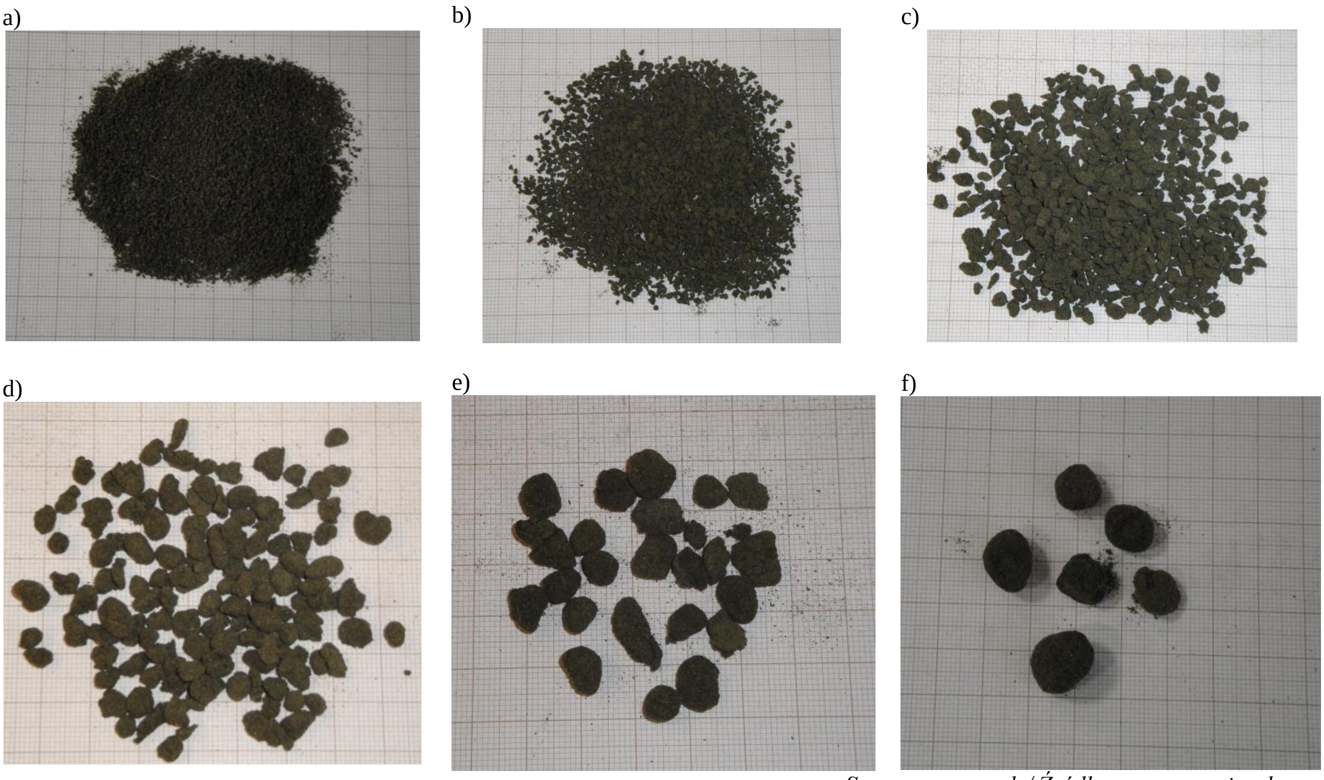
The one-way ANOVA test (One-Sample Kolmogorov-Smirnov test) at a significance level of P = 0.05 revealed significant revealed significant differences in the contents of the pelleted fraction obtained through non-pressure pelleting of fine-grained post-production nettle waste at consecutive amounts of potato starch (0, 10, 20%) added to aqueous binder solution.

The impact of increasing amounts of potato starch added to aqueous binder solution during non-pressure pelleting on the pelleted fraction content is expressed by following equation:

$$m_g = 4{,}40 \cdot \mathbf{z_s} + 10{,}59 \qquad R^2 = 0{,}951 \qquad (2)$$

where:
m_g – pelleted fraction content [%],
z_s – amount of potato starch added to aqueous binder solution [%].

The view of pelleted nettle waste divided into individual fractions in the process of sieve analysis are shown in Fig. 5.



Source: own work / Źródło: opracowanie własne

Fig. 5. View of pelleted nettle waste with fractions sizes: a) 0.5 mm, b) 1 mm, c) 2 mm, d) 4 mm, e) 6 mm, f) 8 mm

Rys. 5. Widok zgranulowanych odpadów z pokrzywy o wielkości frakcji: a) 0,5 mm, b) 1 mm, c) 2 mm, d) 4 mm, e) 6 mm, f) 8 mm

5. Summary

On the basis of the performed tests, the following conclusions were formulated:

- Increasing the amount of binder from 10 to 30% during non-pressure pelleting results in increased content in the pelleted waste fraction from 13.03 to 35.66%.
- Increasing the amount of potato starch added to aqueous binder content from 0 to 20% during non-pressure pelleting results in a significant increase in the content of the pelleted fraction from 15.57 to 24.37%.
- The highest percentage content of the pelleted fraction was obtained at: drum rotational speed of 40 rpm^{-1}, mass flow rate of the raw material through the working system of 8 $kg \cdot h^{-1}$, at a 30% binder content and a 10% starch content in binder.
- The performed one-way ANOVA test revealed significant differences between the values of the pelleted fraction content obtained at increasing binder amounts (from 10 to 30%) during pelleting and at increasing amounts of potato starch added to aqueous binder solution (from 0 to 20%) during non-pressure pelleting of nettle waste.

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