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RESEARCH INTO THE HARDNESS OF PELLET FROM WHEAT STRAW WITH AN ADDITION OF GROUND WHEAT

Summary

The results of research into the hardness of pellet made from a mixture of wheat straw with ground wheat are presented in the paper. The share of ground wheat in the pellets was 0; 4.2 and 8.1%. The measurement of the hardness of pellet was performed with the Kahl method. An influence was found of the content of ground wheat on the increase in the hardness of pellet.
Key words: *biomass, ground wheat, mechanical strength*

BADANIA TWARDOŚCI PELETU ZE SŁOMY PSZENNEJ Z DODATKIEM ŚRUTY Z ZIARNA PSZENICY

Streszczenie

W pracy przedstawiono wyniki badań twardości peletu wykonanego z mieszaniny słomy pszennej ze śrutą z ziarna pszenicy. Udział śruty pszenicznej w granulacie wynosił 0; 4,2 i 8,1%. Pomiar twardości peletu wykonano metodą Kahla. Stwierdzono wpływ zawartości śruty pszenicznej na wzrost twardości peletu.
Słowa kluczowe*: biomasa, śruta pszeniczna, wytrzymałość mechaniczna*

1. Introduction

Durability is an important feature of the quality of granulated feed and pellets to be used for energy and fodder purposes. This is defined as an ability to maintain a permanent form in specific unfavourable conditions of the activity of external mechanical factors. A high value of durability means that the pellet is more durable and granules do not undergo any damage [9, 10]. The measurement of the durability of pellet can be performed as:

- a measurement of its kinetic durability through an assessment of the level of its abrasion and crushing as a result of movement and mutual impact in a closed turning container,
- a measurement of its hardness by determining the crushing force which is able to destroy (split) the individual granules [5, 8, 11].

The measurement of the force causing a decomposition of pellet may come down to the determination of destructive stresses through the determination of the relation of force to the cross section of pellet [4]. Formula 1 describes this dependence in a generalized form:

$$\tau = P \cdot F^{1} \text{ [Pa]} \quad (1)$$

where:
τ – destructive stresses [Pa],
P – force destroying granule [N],
F – field of granule cross section [m^2].

In the case of comparing pellet with a circular section with the same size of the diameter, one may perform only a measurement of the destructive force value.

One of the basic criteria for the assessment of the quality of pellet refers to its feeding properties taking into consideration the requirements of animal consumption [2, 8]. Pellet from plant materials is also currently used as energy material for combustion in heating boilers, so the requirements concerning the physical parameters of fodder and energy pellet do not have to be the same. For example, the hardness of pellet produced from biomass used to feed animals can be limited by the possibility of its cracking or by its nutritious properties [1]. Pellet from biomass to be used only for energy purposes may not be suitable for consumption by animals due to elements included in it [3]. Additions of materials that are rich in sugars, proteins, fibre and fats to energy pellet are to improve its durability and improve its energy value as well as to limit the emissions of harmful substances to the environment during combustion. The purpose of additions used in the production of fodder pellet is to have an influence on the durability of pellet but also on its nutritious properties. Apart from its composition, the humidity of the raw material and the cooling or seasoning method also have an influence on an improvement of the durability of both fodder and energy pellet [11, 12, 13]. In the case of the pelletisation of straw for the needs of farms, considering its universal application, additions should be selected so that pellet produced could be used both as feed and litter for animals but also as energy material [14].

The purpose of research was to assess the strength of pellet made from wheat straw with an addition of wheat grain meal and a determination of the influence of the dampness of raw material and the content of wheat grain meal on the hardness of the mixed pellet produced.

2. Material and methods

Chopped wheat was used to prepare the material for the pellet. Straw was chopped in a “Bąk” universal shredder. The ground wheat included in the mixture was obtained from wheat grain that was milled in a SR farming stone grinding mill, with the slit width set to 0.7 mm. The chopping size of the meal was the result of the spacing set of the disc – stones.

The relative humidity of chopped wheat straw and ground wheat was determined with the use of the dry oven test. The samples were dried in the temperature of 105°C, in compliance with the PN-EN ISO 18134-1:2015-11 Standard [6]. The relative humidity of the material was as follows:

- chopped wheat straw: 2.99 %,
- ground wheat: 14.43 %.

For the purpose of the tests, 9 mixtures of chopped straw with a ground wheat addition were prepared. Wheat ground wheat was added to chopped straw by measuring its weight fraction related to chopped straw prepared in the following relations: 0%, 5%, 10%, without taking into account the humidity of the mixed materials. The humidity of the mixture was changed by sputtering and mixing an additional measured water quantity in the prepared mixture of straw and meal. 120, 240 and 360 ml of water were added respectively. The prepared samples were closed in sealed containers and were left for 48 hours for the liquid to penetrate into the structure of the mixture. The indices for the obtained mixture of chopped wheat and ground wheat are presented in Table 1.

The relative humidity of the mixtures was determined based on the calculations of the humidity of the substrates and water added for each mixture individually. Next, a simplification was performed in the calculations that consisted in the determination of average relative humidities with the same addition of water. The percentage shares were calculated as dry mass content of the individual components. The share of the ground wheat dry mass in the dry mixtures of the samples was after conversions as follows: 0%, 4.2%; 8.1%. The prepared material underwent a granulation process in a ZPL disc pelletizer. A matrix with the hole diameter of 6mm was used to produce the pellet.

For the prepared and dried material, its bulk density was determined, and for the produced granulate, once it was dried, its bulk density and volumetric mass density were determined. The results are provided in Table 2. The measurement of the volumetric mass density of the pellet was performed based on the methodology presented in paper [7].

The measurement of the pellet hardness was performed with the use of a Kahl hardness tester. The Kahl hardness tester is presented in Fig. 1. In this device, the sample is positioned between the anvil and the pin, and then the set screw is tightened, the spring is clamped, which causes the pressure of the pin on the sample. In this manner, the force is determined that is required to crush and destroy the granulate. For each granulate produced from the nine prepared samples of the material, the measurement was repeated 45 times of the crushing force with the use of a Kahl hardness tester.

Table 2. Average density of material subject to pelleting and of produced granulate (measurements performed with dry mass)

Tab. 2. Przeciętna gęstość surowca poddanego peletowaniu i otrzymanego granulatu (pomiar wykonany na suchej masie)

Raw material	Pellet	
Bulk density		Volumetric mass density
$kg \cdot m^{-3}$	$kg \cdot m^{-3}$	$kg \cdot m^{-3}$
110	558.4	982.6

Source: own work / Źródło: opracowanie własne

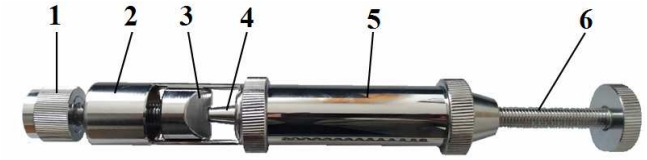

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Fig. 1. Kahl pellet hardness tester: 1 - Fixing screw 2 - Guide piece, 3 - Anvil, 4 - Piston, 5 - Cylinder with scales, 6 - Pressure screw

Rys. 1. Twardościomierz Kahla: 1 - śruba mocująca, 2 - prowadnica, 3 - kowadełko, 4 - trzpień, 5 - cylinder ze skalą, 6 - śruba dociskowa

3. Results and discussion

The results obtained underwent a variance analysis in order to determine the significance of the impact of the agents examined on the granulate hardness. The results of the research related to the impact of the content of ground wheat on the granulate hardness are presented in Fig. 2. It can be stated based on the research conducted that an increase in the percentage share of the ground wheat up to 8.1% resulted in an increase in the granulate hardness by up to 403 N according to Kahl. The least significant difference calculated in the hardness of granulate groups was LDS 18.884. On the significance level of $p < 0.05$, the significance was found of the impact of ground wheat content on the pellet hardness. It was found that there occurs a significant increase in the granulate hardness with an increase in the ground wheat content. This occurred between all of its percentage shares: 0.0; 4.2 and 8.1%.

Fig. 3 presents the results of the tests of the impact of the humidity of the material on the hardness of the pellet produced. It is to be stated based on the tests conducted that 26.6% humidity proved to be optimal. With this humidity, hardness achieved the maximum value, i.e. 416.8 N.

Table 1. Indices of the mixture of chopped wheat straw and wheat grain meal

Tab. 1. Wskaźniki mieszaniny sieczki ze słomy pszennej i śruty ziarna pszenicy

Content				Additional water	Moisture content	Average moisture content
Chopped wheat straw	Ground wheat	Chopped wheat straw (d.m.)	Ground wheat (d.m.)			
g	g	%	%	ml	%	%
700	0	100.0	0.0	120	16.8	16.6
700	35	95.8	4.2	120	16.6	
700	70	91.9	8.1	120	16.4	
700	0	100.0	0.0	240	27.2	26.6
700	35	95.8	4.2	240	26.6	
700	70	91.9	8.1	240	26.0	
700	0	100.0	0.0	360	35.2	34.5
700	35	95.8	4.2	360	34.4	
700	70	91.9	8.1	360	33.7	

Source: own work / Źródło: opracowanie własne

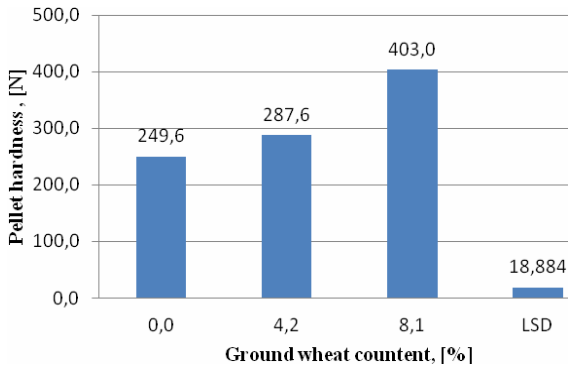

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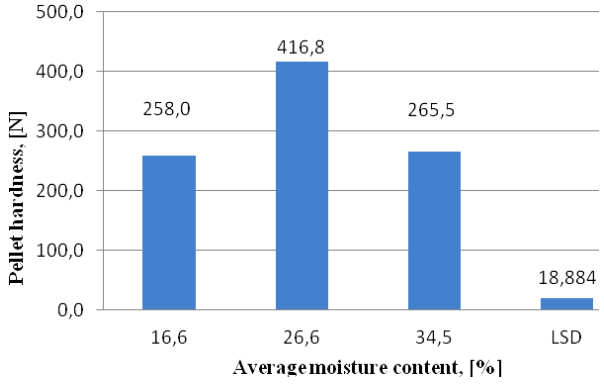
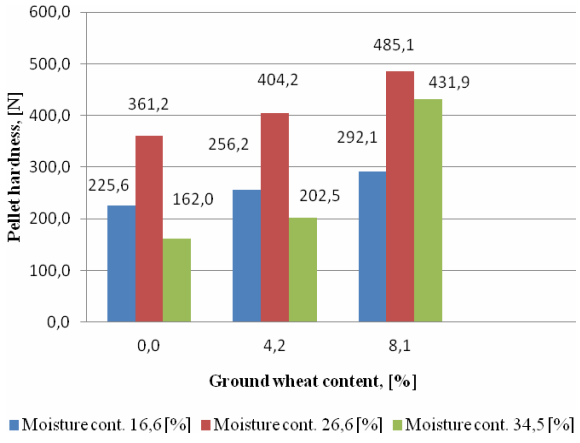
Fig. 2. Impact of ground wheat content on the average hardness of the pellet produced (LSD=18.884)
Rys. 2. Wpływ zawartości śruty z ziarna pszenicy na średnią twardość wytworzonego peletu (NUR=18,884)



Source: own work / Zródło: opracowanie własne

Fig. 3. Impact of the humidity of the mixture of chopped straw with ground wheat on the average hardness of the pellet produced.
Rys. 3. Wpływ wilgotności mieszanki sieczki słomy z śrutą ziarna pszenicy na średnią twardość wytworzonego peletu



Source: own work / Zródło: opracowanie własne

Fig. 4. Impact of ground wheat and humidity on the average hardness of pellet produced (LSD = 32.707)
Rys. 4. Wpływ zawartości śruty z ziarna pszenicy i wilgotności na średnie twardości wytworzonego peletu (NUR = 32,707)

An increase in the humidity of the material up to 35.3% resulted in a decrease in the hardness to 265.5 N. This is a value that comes close to the hardness value of 258 N, one which was obtained with the 16.6% humidity of the material. The LSD value calculated was 18.884. It demonstrates that there is no significant difference between the average pellet hardness with the humidity of 16.6% and 35.3%.

As a result of a detailed analysis based on the chart from figure 4, both of the impact of the ground wheat content and the humidity of the material on the pellet hardness, an increase in the hardness can be observed alongside with an increase in the ground wheat content with any humidity of the material.

No significance of the impact of the ground wheat content on the pellet hardness occurs only between the 0.0% and 4.2% ground wheat content with the humidity of the material of 16.6%.

4. Conclusions

1. In the granulate examined and produced from chopped wheat straw with an addition of ground wheat, a significant influence was found of the content of ground wheat and the humidity of the material on the hardness of the granulate produced.
2. It was established that the hardness of the granulate substantially increases with greater content of ground wheat in the material.
3. It was found that there exists such humidity of the material that is optimal for the pellet hardness, which depends on the share of the individual components (chopped straw and ground wheat).

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