

EFFECT OF BINDER ADDITIVE ON MECHANICAL PROPERTIES OF STRAW PELLET

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Abstract: Research was carried out into the impact of the content of wheat flour in a mixture with chopped wheat straw and the humidity of this material on the hardness of the pellet obtained from this raw material. The maximum content of wheat flour was 9.6% of the dry matter of the raw material, and the humidity of the raw material was 11.6, 25.7 and 36.0%. An increase of wheat flour content in the whole range examined considerably increased the pellet hardness, while an increase of humidity content in the raw material had an impact on increased hardness up to 25.7% only.

Keywords: biomass, pellet, binder

1. INTRODUCTION

The most common processing method of plant biomass for energy purposes is its pressure densification: pelletisation or briquetting [1,2]. The strength of pellet from biomass depends on the humidity of the raw material and of the components included in the raw material because the pellet is produced from dry fragmented biomass under a high pressure, and in an increased temperature. The research demonstrated that the humidity of biomass has a huge impact on its mechanical properties. When humidity increases, plant biomass becomes more resistant to tear, breaking and pelletisation [3]. There exists an optimal humidity content for fibrous material which is subject to pressure agglomeration, one that is significantly smaller than that for starch and protein used as raw materials for granulation [4].

Plant biomass includes cellulose, hemicellulose, protein, lignin, crude fibre and ash. From among these chemical components, some of them may be natural binders. Lignin has its melting point at ca. 140°C. When biomass is heated, lignin becomes tender, sometimes it melts, and it demonstrates thermosetting properties, which strengthens the granules. Cellulose and hemicellulose, which constitute a fraction of plant cell walls and agricultural residues: straw from wheat, rape, maize, readily bond with lignin during the process of concentration [5]. Materials with greater contents of starch and protein form granules that are more durable than biomass with a greater quantity of cellulose material. The binder in the process of concentration increases the density, hardness and the shear strength of pellet [6].

Furthermore, fats in the form of oil or rape meal [7] can be used as additives that bind biomass during pelletisation. Lignin sulfonate of sodium, which also

improves the calorific value of the mixture, can also be used as a natural binder [8,9]. Molasses, starch and flour as well as corn grain meal can also act as a binder that improves the strength of granular biomass [10,11,12,13]. Apart from the content of binders that are the result of the composition of the raw material, fragmentation of the raw material, a selection of matrices as well as the method and time of granulate conditioning also have an impact on the quality of pellet [14].

The purpose of the research conducted was to designate the impact of the content of binder in the form of wheat flour added and mixed with the chopped wheat straw and the impact of the humidity of the mixture obtained on the hardness of the granulate produced from this mixture.

2. MATERIALS AND METHODS

Chopped wheat straw with an addition of wheat flour was used to produce the pellet. The moisture content of the samples of flour and chopped wheat straw was determined in accordance with the EN ISO 18134-3:2015-11 Standard. The determination of moisture for the examined groups of pellets was conducted using the dry oven test. The research was carried out in accordance with the PN-Z-15008/02 Standard that is identical to PN-G-04511. An electric laboratory dryer was used in the tests. The samples were dried in the temperature of 105°C.

The relative humidity determined of chopped wheat straw was 11.8%, and the humidity of wheat flour was 6.8%. Nine samples each with 500g of chopped straw were prepared for the tests, to which wheat flour was added in the amounts of 0.0, 25.0 and 50.0g; then, to each of the prepared raw material groups, distilled water was added in the amounts of 0.0, 100.0 and 200.0ml. The share determined of the dry matter of flour in relation to the dry matter of the mixture of flour and chopped straw was as follows: 0.0%; 5.0%; 9.6%.

The moisture content in the raw material formed for the production of pellet was calculated based on the determined humidity content in the flour and the humidity content in chopped wheat straw taking into consideration their percentages of dry matter and the addition of water. The average moisture contents for the individual groups of chopped wheat straw and wheat flour are to be found in Table 1.

A plate granulator with a rotary matrix and an immovable shaft with rollers press the raw material into matrix holes was used for the densification of the material and in the pellet production. The diameters of the holes in the matrix that form the pellet were 6mm. After the completion of the production, the pellet was dried in the temperature of 105°C until humidity had been totally removed. Then, the pellet hardness of was measured with the use of a Kahl's hardness tester by

measuring the force causing its crumpling. The force measurement according to Kahl was repeated 31 times for each type of the pellet obtained from 9 raw material samples prepared.

Tab. 1. Indexes of the mixture of chopped wheat straw and wheat flour

Wheat straw	Flour	Wheat straw (m.d.)	Flour (m.d.)	Water addition	Average moisture content
gr	gr	%	%	ml	%
500	0	100.0	0.0	0	11.6± 0.2
500	25	95.0	5.0	0	
500	50	90.4	9.6	0	
500	0	100.0	0.0	100	25.7± 0.7
500	25	95.0	5.0	100	
500	50	90.4	9.6	100	
500	0	100.0	0.0	200	36.0± 1.0
500	25	95.0	5.0	200	
500	50	90.4	9.6	200	

3. RESULTS AND DISCUSSION

The results obtained of the pellet hardness measurements were subject to a variance analysis to determine the significance of the influence of the factors examined on the pellet hardness with the statistical significance of $p \leq 0.05$. The calculated smallest acceptable difference in the hardness of the pellet groups was $NUR = 16.7$ (least significant differences - LSD). The impact of the share of wheat flour in the mixture and the impact of the humidity content in the mixture on the pellet hardness are presented in Figs. 1 and 2.

The dependence of the pellet hardness from the share of flour with different humidity contents in the raw material is presented in Fig. 3.

On the basis of the statistical analysis carried out, the significance of the impact of the flour content on the pellet hardness was found.

It is evident from the diagram in Fig. 3 that an increase of the hardness of pellet made from wheat straw occurred also with an increased moisture content in the raw material, with a null flour content.

The largest impact of the flour content in the raw material on the pellet hardness occurred with the humidity content of 25.7% in the raw material. A significant impact both of the flour content in the raw material and the humidity of the raw material on the hardness of the pellet produced from it occurs with the flour content in the range from 0.0 to 5.0% and humidity up to 25.7%.

The work of the plate granulator with a powered matrix that was used in the tests could also contribute to the decreased pellet hardness with an increased humidity content in the raw material. It was observed that there is an increased slip between biomass resting on the spinning matrix and the rollers that press the raw material into the matrix holes with an increased humidity of the raw material.

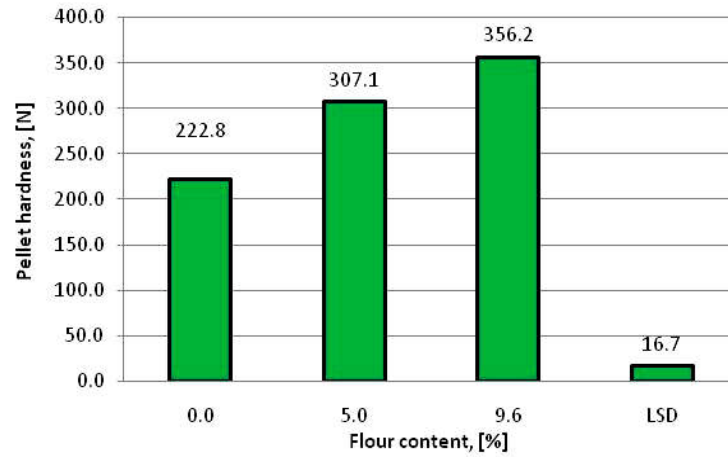


Fig. 1. Impact of the share of flour in the mixture with chopped wheat straw on the hardness of pellet obtained from this raw material

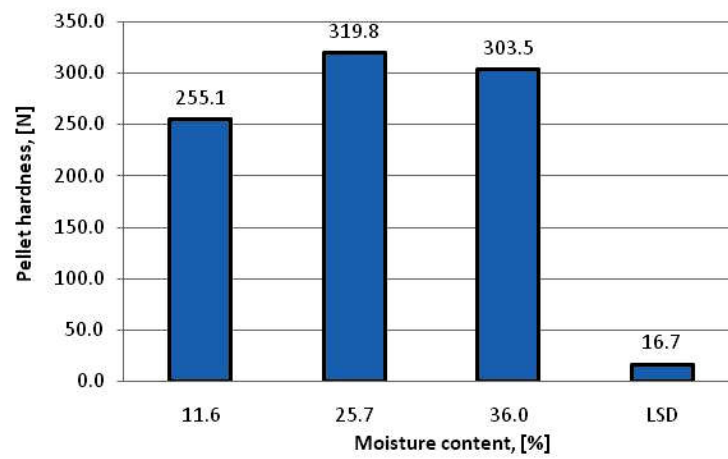


Fig. 2. Impact of the moisture content of the mixture from chopped wheat straw and wheat flour on the hardness of pellet

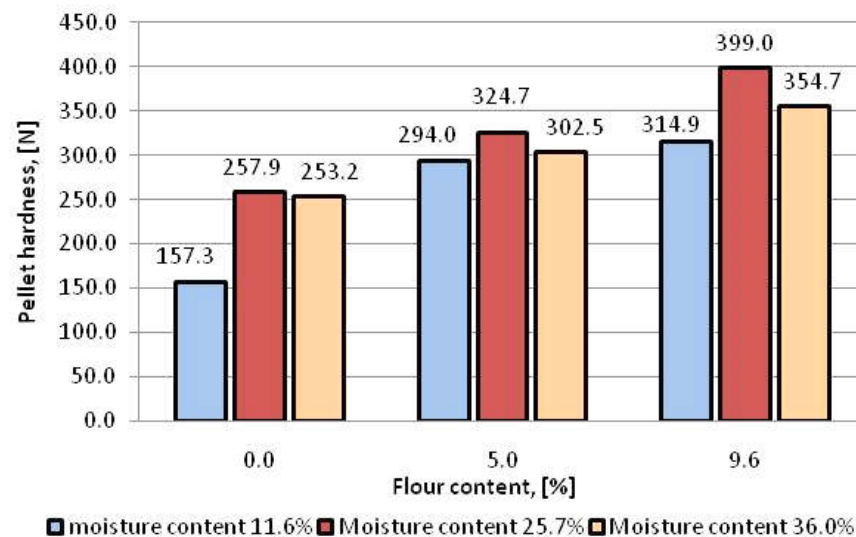


Fig. 3. Impact of the share of flour and the humidity of the mixture from chopped wheat straw and wheat flour on the pellet hardness

4. CONCLUSIONS

The following conclusions were formulated based on the research conducted and the results obtained:

An increase of the addition of wheat flour to chopped wheat straw has a considerable impact on an increase of the hardness of the pellet obtained from this raw material.

It was found that both the humidity of the raw material and the percentage value of the share of flour in the raw material from fragmented straw as a binder have an essential impact on the granulate hardness.

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Biographical notes

The authors didn't provide biographical notes before the publication of this issue.