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ENERGY REQUIREMENTS FOR PELLETING OF CHOSEN FEED MATERIALS WITH RELATION TO THE MATERIAL COARSENESS

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Summary. This paper presents the results of a study investigating the effect of particle size of ground barley and lupine (in the range of 0.25 to 2.5 mm) on energy consumption during the pelleting process. The study was performed on a test stand equipped with a microprocessor-supported system for measuring steam, heat and electric energy consumption. It was found that the mean values of unit thermal energy consumption ranged from 97.21 to 130.33 kJ*kg^{-1} for lupine and from 111.35 to 145.49 kJ*kg^{-1} for barley. Mean unit pressing energy expenditure values were determined in the range from 77.71 to 98.65 kJ*kg^{-1} for lupine and from 97.54 to 125.11 kJ*kg^{-1} for barley.

Key words: steam and heat consumption, pressing energy, pelleting, conditioning, particle size of ground feed raw materials.

Nomenclature:
E_c – unit thermal energy expenditures, [kJ*kg^{-1}],
E_p – unit pressing energy expenditures, [kJ*kg^{-1}],
p – calculated significance level,
r – Pearson's correlation coefficient,
R^2 – coefficient of determination,
T_k – conditioning temperature, [^{o}C],
Z_p – unit steam consumption, [kg*t^{-1}],
α_i – assumed significance level,
$d_{śr}$ – average size of ground particles [mm].

INTRODUCTION

A determination of an influence of the size of ground material particles on feed pelleting is an important consideration as it affects the effectiveness of the pelleting process. Feed raw materials have to be ground both for processing reasons which affect the course of the pelleting process as well as the nutritional requirements of various animal species and age groups [3, 7]. Particle size affects the feed digestibility coefficient [4, 10, 14, 15] which is of key significance with regard to mixed feeds for pigs.

The structure of the ground material should comprise limited quantities of both powdery and excessively large particles, as discussed in detail by Payne [11]. Thomas et al. [13] argue that energy consumption during pelleting increases and pellet quality deteriorates when the above requirement is not met. According to those authors, the vast differentiation in the size of feed particles could lead to their separation during conditioning, thus preventing the conditioning process from being adequately carried out. Several researchers claim that the best processing results are achieved during the pelleting of medium- and fine-sized feed particles from 0.4 to 2 mm [1, 8, 9, 12]. The above observations are due to the fact that fine particles are marked by larger surface area which absorbs heat and moisture more readily during conditioning. Fine-sized particles also have a larger number of contact points which support the formation of bonds between raw material particles and reduce resistance during passage through the matrix [2].

Selected literary sources indicate that most of the relevant research studies investigated the effect of the size of ground feed particles on pellet quality. There are no published sources discussing the impact of the above factor on energy consumption of the pelleting process, in particular the consumption of steam and heat. In view of the above, the objective of this study was to determine the effect of the size of ground barley and lupine particles and the relevant hydrothermal processing conditions on unit energy consumption during pelleting.

MATERIALS AND METHODS

The experimental material comprised barley cv. Edgar and lupine cv. Emir. The raw materials were ground in a H 950 hammer mill equipped with a 3 to 9 mm sieve. Five fractions with a various degree of grinding were separated from the processed material with the use of a set of sieves with the following mesh size: 0.5, 1.0, 1.6, 2.0 and 3.0 mm. The mean size of the produced fractions was 0.25, 0.75, 1.3, 1.8 and 2.5 mm, respectively. After grinding, the material was brought to a constant moisture content of 12%.

The experiment was performed on a test stand equipped with an LW 69 steam generator, a blade conditioner, a Kahl L-175 pellet mill (matrix with 4 mm mesh size, 20 mm in thickness) and computer systems for the measurement of steam, heat and electric energy consumption. A detailed description of the test stand and the methods applied to determine steam, heat and electric energy consumption is presented in the referenced materials [5] and [6]. The pelleting process involved steam conditioning. Prior to pressing, the studied material was brought to five temperature levels: 50, 60, 70, 80 and 90ºC by treatment with steam under a pressure of 400 kPa.

The analysis of dependencies between the size of ground particles, hydrothermal processing conditions and unit pelleting energy expenditures was carried out with the application of statistical procedures in STATISTICA application at a significance level of $\alpha_i = 0.05$. The form of equation was selected with the application of backward step regression. The significance of regression equation coefficients was analysed with Student's t-test. Model adequacy was verified with Fisher's test.

RESULTS

The mean steam consumption values subject to the average size of ground grain particles are shown in Fig. 1. The obtained results indicate that unit steam consumption grows with an increase in the size of grain particles after grinding. The produced results show a broad variation from 37.38 to 57.22 kg*Mg^{-1}. The lowest unit steam consumption was reported for ground lupin with average particle size of 0.25 mm. Similar changes were also noted with respect to unit thermal energy expenditures (Fig. 2) where the relevant values ranged from 97.21 to 145.49 kJ*kg^{-1}.

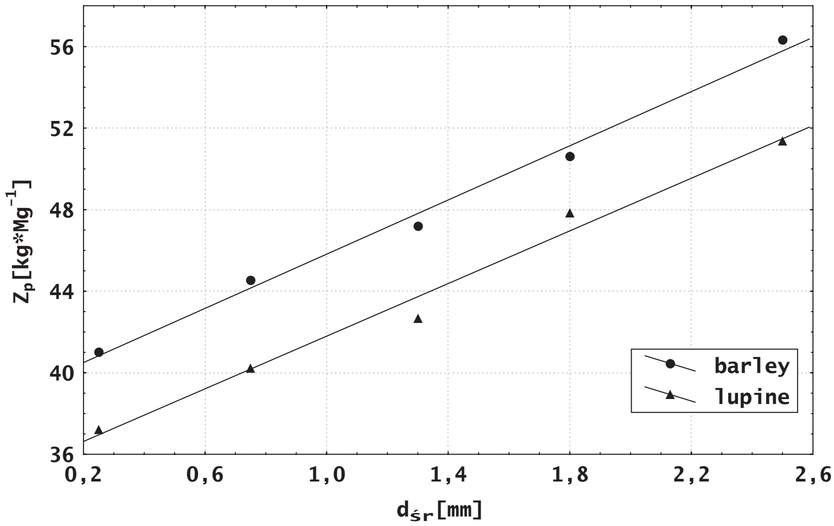

Fig. 1. Dependency between steam consumption (Z_p) and the average size of ground particles ($d_{śr}$) – mean values for 5 material temperatures after conditioning (T_k)

The performed statistical analysis based on the obtained results showed a very high positive correlation between both steam consumption (r=0.94; p<0.022), heat consumption (r=0.96; p<0.023) and the average size of ground particles.

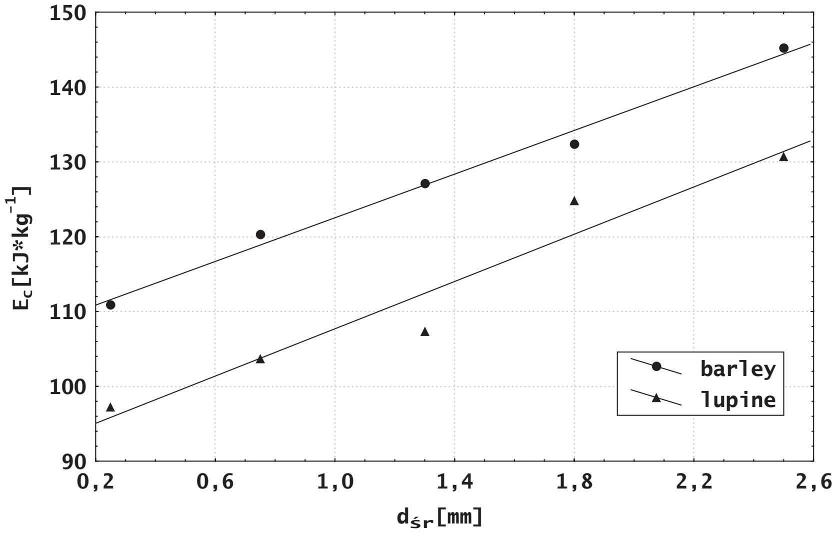

Fig. 2. Dependency between unit thermal energy expenditures (E_c) and the average size of ground particles ($d_{śr}$) – mean values for 5 material temperatures after conditioning (T_k)

The above dependencies can be illustrated by multiple linear regression models:

for ground barley

Z_p=9.16$d_{śr}$+1.43T_k-59.42; R^2=0.96, (1)

E_c = 11.27$d_{śr}$ + 3.7T_k –148.05; R^2 = 0.95, (2)

for ground lupine

Z_p=4.74$d_{śr}$+1.26T_k-56.68; R^2=0.94, (3)

E_c = 22.43$d_{śr}$ + 3.67T_k –172.33; R^2 = 0.94. (4)

Unit pressing energy expenditures obtained during the pelleting of raw materials with various particle size are presented in Fig. 3. As shown by the results, the average values of the analysed parameter fall within the range of 77.71 to more than 125 kJ*kg^{-1}. The highest values were reported in respect of barley with the largest average size of ground particles (2.5 mm). As regards both materials, the average size of ground particles was also directly proportional to unit pressing energy expenditures.

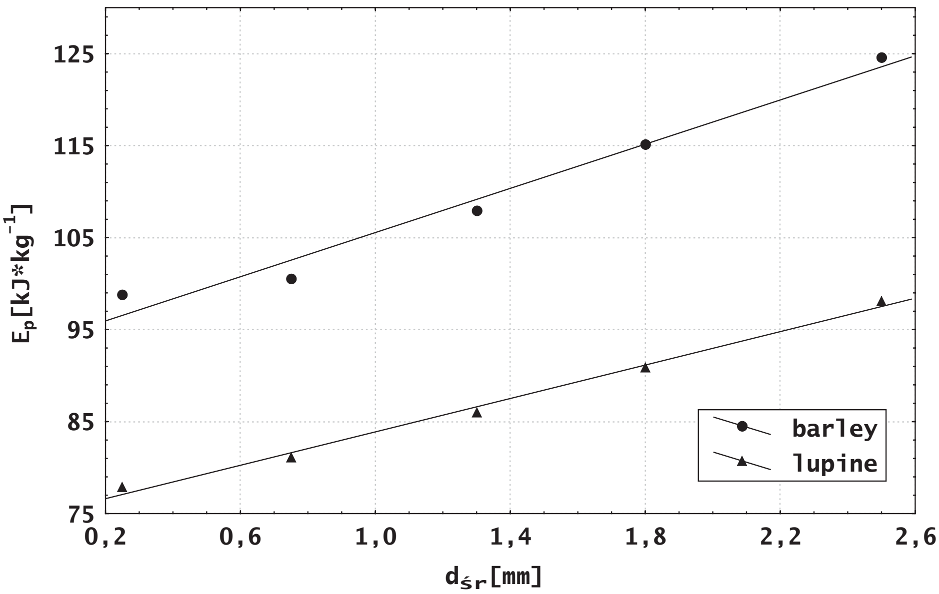

Fig. 3. Dependency between unit pressing energy expenditures (E_p) and the average size of ground particles ($d_{śr}$) – mean values for 5 material temperatures after conditioning (T_k)

A qualitative evaluation of the analysed dependencies can be presented in the form of the following equations:

for barley

E_p = 12.01 $d_{śr}$ – 1.21 T_k + 171.98; R^2=0.96, (5)

for lupine

E_p = 9.08 $d_{śr}$ – 1.06 T_k + 148.65; R^2=0.95. (6)

The total pelleting energy demand (the total sum of pressing electric energy and thermal energy demand in the form of steam) is shown in Fig. 4. The values of the analysed parameter ranged from 175.22 to 264.54 kJ*kg^{-1}. As regards all the analysed sizes of ground particles, the differences in energy consumption levels of the pelleting process which result from the physical and chemical properties of the investigated materials remain constant. This observation also applies to the previously analysed energy consumption parameters.

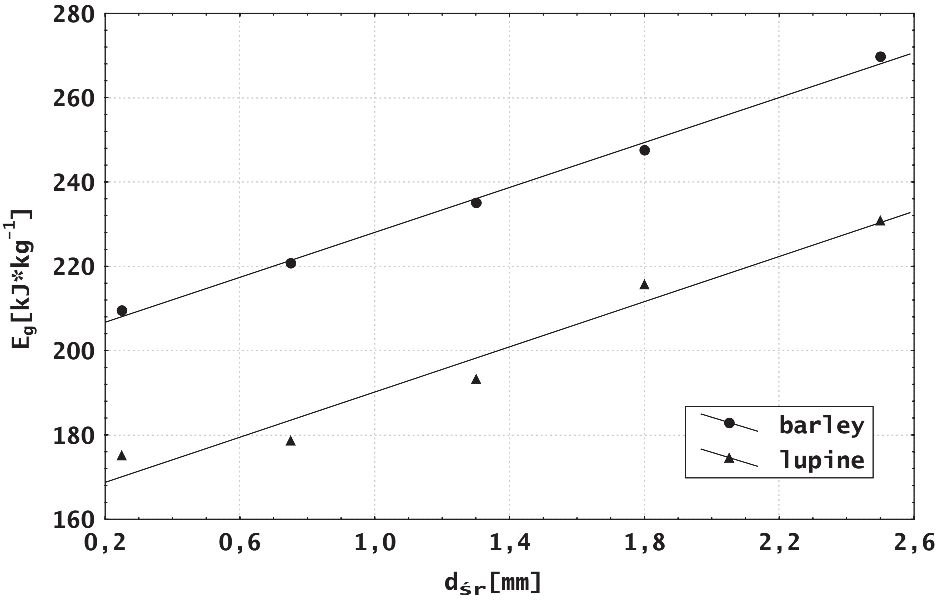

Fig. 4. Dependency between total unit pelleting energy expenditures (E_g) and the average size of ground particles ($d_{śr}$) – mean values for 5 material temperatures after conditioning (T_k)

Multiple regression equations which describe the above dependencies take the following form:

for barley

E_g=31.53$d_{śr}$ + 2.61T_k + 31.53; R^2 = 0.96, (7)

for lupine

E_g=23.28$d_{śr}$ + 2.57T_k + 23.78; R^2 = 0.96. (8)

CONCLUSIONS

The following conclusions can be drawn from the conducted experiment:

1. An increase in steam and heat consumption is directly proportional to an increase in the average size of ground grain particles after conditioning (the average increase in the investigated range of ground particle sizes was approximately 70%, regardless of the analysed material).

2. Unit pressing energy expenditures rise with an increase in the average size of ground particles by around 63% on average. The changes noted due to differences resulting from the specific properties of the investigated materials also remain at a constant, statistically non-significant level.

3. Total energy consumption of pelleting is affected mostly by the chemical composition of the processed raw materials. The degree of material grinding does not level out the differences in energy consumption of the pelleting process resulting from the specific properties of the processed grain.

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