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ENERGY REQUIREMENTS FOR THE PELLETING OF BROILER PREMIUM GROWER DIETS WITH A DIFFERENT SOYBEAN OIL CONTENT

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Abstract. The paper presents the results of a study investigating the effect of the soybean oil content (0 to 6%) of Broiler Premium Grower diets 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 135.41 to 161.23 kJ·kg^{-1}. Mean unit pressing energy expenditure values were determined in the range from 88.11 to 129.44 kJ·kg^{-1}.

Key words: thermal energy, pressing energy, pelleting, conditioning, fines, Broiler Premium Grower, soybean oil.

Nomenclature:
C_r – content of fines in pellets [%],
E_c – thermal energy consumption [kJ·kg^{-1}],
E_p – electrical (pressing) energy consumption [kJ·kg^{-1}],
E_g – total energy consumption [kJ·kg^{-1}],
m_o – weight of the pelleted product after sifting fines [g],
m_p - weight of the pelleted product before sifting fines [g],
p – calculated significance level,
r – Pearson correlation coefficient,
R^2 – coefficient of determination,
Z_o - content of soybean oil in BPG diets,
α_i – assumed significance level.

INTRODUCTION

High-energy components such as animal fats and vegetable oils are often added to commercially mixed feeds. The technological process of fat addition should account for the widely varied fat inclusion levels (3-20%) in feeds [10, 11, 12]. If the supplemental fat source is added prior to pelleting, the fat content of the diet should not exceed 3-5% [9, 19].

Adding supplemental fat to feeds before pelleting makes it difficult to produce hard cohesive pellets due to limited penetration of water and steam [1, 2, 16, 17, 18]. However, as demonstrated by Kulig and Laskowski [8], an increase in fat concentration in feed material from 2 to 5.5% reduces

energy consumption during pelleting by 30%, on average. Supplemental fat can be used to decrease dustiness and prevent disintegration of feed pellets [3, 20].

Today broiler chickens are often fed fat-supplemented pelleted diets [15]. Soybean oil is widely used as an ingredient of such diets. Many authors [4, 13, 14] share the opinion that soybean oil contributes to an increase in body weight, a decrease in feed intake per unit of weight gain and shortening of the fattening period, thus exerting a beneficial influence on overall production results. According to Cutlip et al. [5], feed costs account for 60-65% of total broiler production costs. Pellet production costs are largely determined by the price of raw materials and the energy consumption of the process, in which approximately 60% of energy is used for pelleting [9].

In view of the above, the objective of this study was to determine an effect of the soybean oil content of Broiler Premium Grower diets on energy consumption during the pelleting process.

MATERIALS AND METHODS

The experimental material comprised standard Broiler Premium Grower (BPG) diets with a soybean oil content of 0 to 6% (changed every 1.5%). The raw materials were ground in a H 950 hammer mill equipped with a 3 to 9 mm sieve. 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 vapour generator, a blade conditioner, an Amandus Kahl L-175 pellet mill (die with 6 mm mesh size, 30 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 can be found in [6] and [7]. The pelleting process involved steam conditioning. Prior to pressing, the studied material was brought to a temperature of 80ºC by treatment with water vapour under a pressure of 400 kPa.

The energy requirements of the pelleting process were estimated based on pellet mill capacity (determined after passing through the die) and pelleting line capacity which is lower, compared to the former, by the value corresponding to the amount of fines (separated from pellets during sifting). In order to determine the content of fines in pellets, a 500 g sample of dried and cooled pellets was passed through a sieve with a mesh size 1 mm smaller than pellet diameter. The separated pellets were weighed on a WPE 300 scale accurate to 10^{-1}g, and the percentage content of fines in the pelleted product was calculated using the following formula:

$$C_r = \frac{m_p - m_o}{m_p} \cdot 100 \ [\%]. \tag{1}$$

The analysis of dependencies between the soybean oil content of diets and the energy parameters of the pelleting process was carried out with the application of STATISTICA procedures at a significance level of $\alpha_i = 0.05$. Figure 5 presents the results of an analysis of the significance of differences between mean values of the studied parameter relative to soybean oil content for instantaneous and final capacity (Tukey's test, $\alpha_i = 0.05$). Soybean oil concentrations that differ significantly with respect to the mean value of a given parameter are denoted by different letters.

RESULTS

At the first stage of the study, the content of fines in pellets was determined after passing through the die, in order to estimate capacity loss for the pelleting line resulting from the need to

press these particles again. Based on the above, the actual energy consumption during the process could be calculated.

The effect of the soybean oil content of BPG diets on the content of fines in pellets is illustrated in Figure. 1. The mean values ranged from 1.09 to 7.36%. A statistical analysis showed a high positive correlation between both studied parameters, which was confirmed by the value of the Pearson coefficient (Fig. 1).

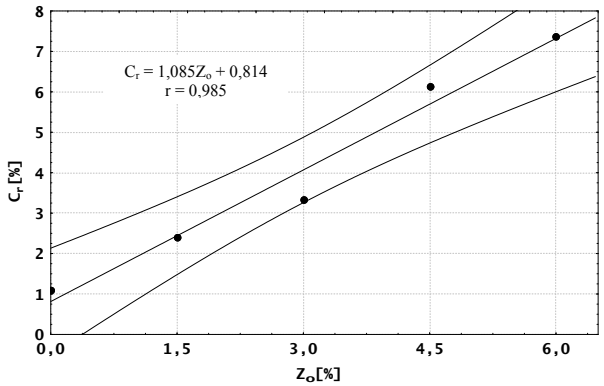

Fig. 1. Dependency between the content of fines in pellets (C_r) and the soybean oil content of BPG diets (Z_o)

When the soybean oil content of diets reached 4.5 and 6%, the content of fines in pellets exceeded 4%. This suggests that dies with a higher degree of compression than that used in the present experiment should be applied to materials with oil concentration above 3%. This, however, would increase the energy consumption of the process.

The mean steam consumption values subject to the soybean oil content of diets are shown in Figure 2.

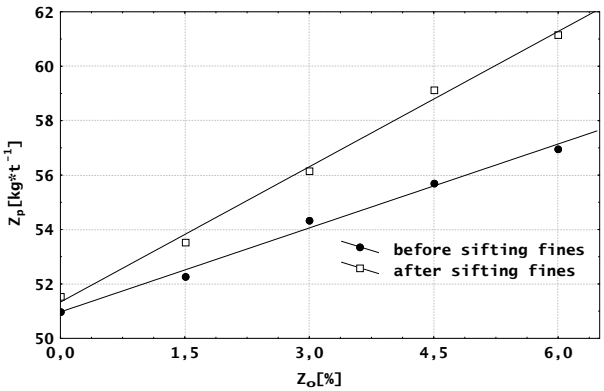

Fig. 2. Dependency between steam consumption (Z_p) and the soybean oil content of BPG diets (Z_o) (mean values with respect to the capacity of the pellet mill and the pelleting line)

The obtained results indicate that unit steam consumption grows with an increase in the soybean oil content of diets, ranging from 50.98 to 61.43 kg·t^{-1}. The lowest unit steam consumption,

with respect to the capacity of both pellet mill and pelleting line, was reported for a diet containing no soybean oil. Similar changes were also noted with respect to unit thermal energy expenditures (Fig. 3), where the relevant values ranged from 135.41 to 161.23 kJ·kg^{-1}.

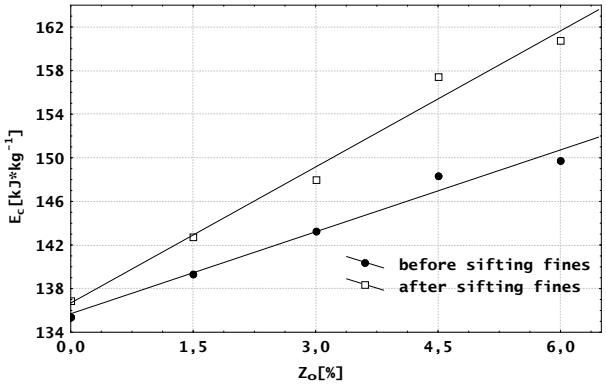

Fig. 3. Dependency between unit thermal energy expenditures (E_c) and the soybean oil content of BPG diets (Z_o) (mean values with respect to the capacity of the pellet mill and the pelleting line)

The above dependencies can be illustrated by multiple linear regression models:
for pellet mill capacity

$$Z_p = 1.028Z_o + 50.97;\ R^2 = 0.993, \quad (2)$$

$$E_c = 2.505Z_o + 135.69;\ R^2 = 0.979, \quad (3)$$

for pelleting line capacity

$$Z_p = 1.657Z_o + 51.33;\ R^2 = 0.997, \quad (4)$$

$$E_c = 4.416Z_o + 136.69;\ R^2 = 0.984. \quad (5)$$

Unit pressing energy expenditures obtained during the pelleting of mixed feed with a different soybean oil content are presented in Figure 4.

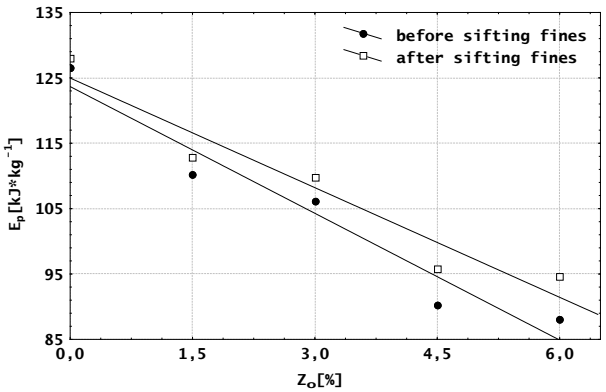

Fig. 4. Dependency between unit pressing energy expenditures (E_p) and the soybean oil content of BPG diets (Z_o) (mean values with respect to the capacity of the pellet mill and the pelleting line)

As shown by the data, the average values of the analyzed parameter fall within the range of 88.11 to 129.44 kJ·kg^{-1}. The lowest values were reported with respect to material with the maximum fat content. As regards both capacities, the soybean oil content of diets was directly negatively proportional to unit pressing energy expenditures.

A quantitative evaluation of the analyzed dependencies can be presented in the form of the following equations:

for pellet mill capacity

$$E_p = -6.467\ Z_o + 123.67;\ R^2=0.944, \quad (6)$$

for pelleting line capacity

$$E_p = -5.589\ Z_o + 124.97;\ R^2=0.932. \quad (7)$$

The total pelleting energy demand (sum of pressing electric energy and thermal energy demand in the form of steam) is shown in Figure 5. The values of the studied parameter ranged from 237.38 to 265.44 kJ·kg^{-1}. It was found that, considering the content of fines in pellets, the total energy consumption of the pelleting process was not significantly ($p>0.05$) affected by the soybean oil content of mixed feed (ranging from 1.5 to 6%).

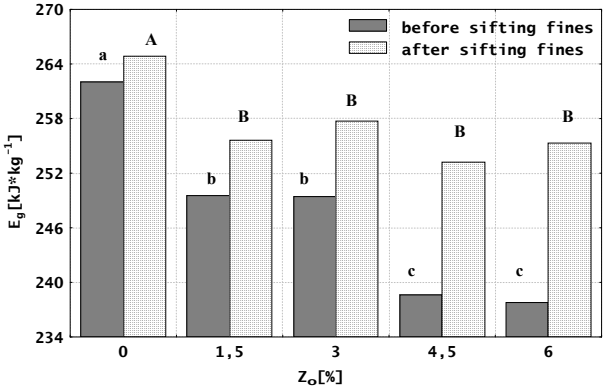

Fig. 5. Dependency between total unit pelleting energy expenditures (E_g) and the soybean oil content of BPG diets (Z_o) (mean values with respect to the capacity of the pellet mill and the pelleting line)

As regards pellet mill capacity, the variability of the analyzed parameter determined for soybean oil content of 1.5-3% and 4.5-6% remained within the range of measurement error.

CONCLUSIONS

The following conclusions can be drawn from the conducted experiment:

1. The increase in steam and heat consumption over the investigated range is directly proportional to the increase in the soybean oil content of BPG diets, reaching on average 12% and 19% with respect to the capacity of the pellet mill and the pelleting line, correspondingly.
2. Unit pressing energy expenditures decrease with an increase in the soybean oil content of feed material. The need to press fines, again, increases energy consumption by 7%, on average.
3. With respect to pelleting line capacity, over the investigated range (excluding the control diet), changes in the total unit energy consumption of pelleting were not significantly affected by the soybean oil content of the mixed feed.

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ENERGOCHŁONNOŚĆ GRANULOWANIA MIESZANEK BROJLER PREMIUM GROWER O RÓŻNEJ ZAWARTOŚCI OLEJU SOJOWEGO

Streszczenie. W pracy przedstawiono wyniki badań wpływu zawartości oleju sojowego w mieszance Brojler Premium Grower (zakres od 0 do 6%) na energochłonność procesu granulowania. Badania przeprowadzono na stanowisku doświadczalnym wyposażonym w mikroprocesorowy układ pomiaru zużycia pary, ciepła i energii elektrycznej. Stwierdzono, iż średnie wartości jednostkowego zużycia energii cieplnej wahały się w przedziale od od 135,41 do 161,23 $kJ \cdot kg^{-1}$. Natomiast średnie nakłady energii prasowania mieściły się w przedziale od 88,11 do 129,44 $kJ \cdot kg^{-1}$.

Słowa kluczowe: energia cieplna, energia prasowania, granulowanie, kondycjonowanie, cząstki rozkruszone, Brojler Premium Grower, olej sojowy.