EFFECT OF THE MOISTURE CONTENT ON ENERGY CONSUMPTION AT GRINDING OF LUPINE SEEDS

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Summary. The paper presents the changes in energy consumption at disintegration of lupine seeds of differentiated moisture content. The seeds of six lupine cultivars (Juno, Amulet, Wat, Bardo, Emir and Sur) were used for the study. Moreover, the temperature and moisture content of the disintegrated material were recorded during the tests. The obtained results showed a distinct correlation between the seed moisture content and energy input during the disintegration of 1 ton lupine seeds. The correlation was described by polynomials of the third order.

Key words: energy of disintegration, lupine seeds, moisture content

INTRODUCTION

Grinding (disintegration) is the process widely applied in the industrial processing of agricultural products, particularly in the industrial feed production, milling and sugar industry, meat, fruit and vegetable processing plants. Disintegration can be applied not only to the raw materials, but also to the half-finished and final products. Disintegration is a high energy consuming process as the energy inputs for the disintegration of solid bodies reach as much as 1/3 of the total generated energy and still show a growing tendency [Opielak 1984, Boss 1986]. Only in the feed production industry above 60% mass of feed components must be disintegrated.

The common application of the disintegration process is connected with the following results:

- an enlarged surface of the ground material particles enables to significantly increase the rate of processes such as solving, drying or mixing,
- grinding makes it possible to reduce the volume of raw materials, thus their easier handling, transportation and further processing,
- owing to the disintegration process, the uniformity of the multi-component mixtures can be more easily obtained,

 disintegration is an important condition to the agglomeration of the mixtures [Opielak 1995].

A detailed description of the grinding process course, i.e. of its optimization and reduction of energy inputs, is very complicated. The difficulties result – among others – from the variability of physical and biological properties of the disintegrated materials. For such a reason the study was undertaken on the effect of moisture content – one of the crucial characteristics of biological materials – on energy inputs in the disintegration process.

MATERIAL AND METHODS

The seeds of three lupine species, commonly cultivated in our country, were selected for the experiments, i.e. the yellow lupine seeds Juno and Amulet cultivars, the white lupine seeds Wat and Bardo cultivars and the blue (angustifoliate) lupine seeds Emir and Sur cultivars. Before grinding, the samples of seeds (of natural moisture content 10.0%) were conditioned to three moisture content levels: 12.0, 14.0, 16.0%. The conditioning consisted in an addition of adequate water amounts calculated according to the just determined formulae. Treated in such a way seed samples were stored for 7 days in air-tight containers at the temperature 5°C, and shaken several times a day. The samples of seeds were removed from the cooling chamber one hour before grinding in order to level out their temperature with the ambient temperature [Andrejko 1995, Grochowicz 1995].

The process of grinding was investigated in a hammer mill at the rotational speed of the working elements 1600 r.p.m.

During disintegration of 10 kg seed samples the following parameters were measured:

- the temperature of seeds before, during and after grinding, with the use of three NiCr-NiAl thermocouples and digital panel meter APAR 592,
- rated turning moment (torque) by means of VF 617 R 544 type frequency converter,
- the moisture content of seeds before and after grinding by oven-drier method according to the Polish Standard PN-86/A 74011,
- moreover, the screen analysis of ground lupine seeds was conducted and the average particle size was calculated by using adequate formulas. Two different sieves were applied to grinding:
- the sieve with round meshes 3.0 mm diameter of the total active surface $90 \times \cdot 200 \text{ mm}^2$, and clearance index 0.28,
- the sieve with round meshes 2.0 mm diameter of the total active surface $90 \times \cdot 200 \text{ mm}^2$, and clearance index 0.29.

All measurements were taken in three replications.

EXPERIMENT RESULTS

Characteristics parameters of lupine seeds of six cultivars (Juno, Amulet, Wat, Bardo, Emir, Sur) in a hammer mill is shown on the Fig. 1–3. It was found that the grinding process was the reason of the decrease in the seed moisture content, particularly apparent in white and blue cultivars, disintegrated at an application of the sieve with meshes diameter $\varphi = 2.0$ mm.



Fig. 1. Effect of grinding process on the drop of the moisture content of lupine seeds; cultivars: a – Juno, b – Amulet, c – Wat, d – Bardo, e – Emir, f – Sur



Fig. 2. Effect of grinding process on the temperature rise of lupine seeds, cultivars: a – Juno, b – Amulet, c – Wat, d – Bardo, e – Emir, f – Sur

b)



2.0 mm; $E_r = -2.4 \cdot w^3 + 96.3 \cdot w^2 - 1220.9 \cdot w + 5065.9$ $3.0 \text{ mm}; \text{E}_{r} = -0.3 \cdot \text{w}^{3} + 13.3 \cdot \text{w}^{2} - 173.6 \cdot \text{w} + 735.9$ 240 🍳 2.0 mm 200 🔍 3.0 mm Energy input for grinding [kWh/t] 160 120 80 40 0 - 9 10 11 12 13 14 15 16 17 moisture content [%]

c)

2.0 mm; $E_r = 0.7 \cdot w^3 - 27.6 \cdot w^2 + 377.7 \cdot w - 1537.5$ 3.0 mm; $E_r = -0.9 \cdot w^3 + 38.5 \cdot w^2 - 484.8 \cdot w + 1988.3$







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e)

2.0 mm; $E_r = 2.6 \cdot w^3 - 106.7 \cdot w^2 + 1493.1 \cdot w - 6698.2$ 3.0 mm; $E_r = -2.0 \cdot w^3 + 79.8 \cdot w^2 - 995.1 \cdot w + 4048.2$



Fig. 3. Trend curves of the changes in energy inputs for grinding of lupine seeds depending on their moisture content; cultivars: a - Juno, b - Amulet, c - Wat, d - Bardo, e - Emir, f - Sur

A substantial temperature rise in the ground seeds was also observed during the disintegration process. The recorded data (Fig. 2) showed that the temperature increase was similar for all lupine cultivars, ranging from 10.5 to 29°C. However, no clear effect of the seed moisture content, seed cultivar or sieve mesh diameter on the temperature rise was stated.

Measurement results of energy consumption at the grinding of lupine seeds were also given in Fig. 3. The energy consumption at the grinding process was significantly dependent on the moisture content of seeds and the diameter of sieve meshes.

It was evidently stated that a rise in the moisture content of lupine seeds within the range of 10.0-16.0% increased energy inputs for grinding. However, an enlargement of the diameter of sieve meshes resulted in reduced energy consumption for the grinding of all the lupine seed cultivars. The lowest energy inputs were necessary for the grinding of 1 ton of yellow lupine seeds, whereas the disintegration of 1 ton white and blue lupine seeds consumed much more energy.

The change in energy inputs for grinding, subsequent to differentiated moisture contents of lupine seeds, were described by polynomials of the third order and the trends of these changes are presented in Fig. 3. In all the cases the high values of determination coefficients R^2 (near to 1) indicate that the mathematical descriptions fit the experimental data adequately enough.

CONCLUSIONS

On the basis of the obtained investigation results the following conclusions were formulated:

1. The disintegration process of lupine seeds resulted in a reduction of their moisture content, particularly visible in white and blue cultivars, ground in a hammer mill equipped with the sieves of 2.0 mm mesh diameter.

2. The grinding of lupine seeds increased the temperature of the ground material within the range from 10.5 up to 29°C. However, no evident effect of seed moisture content, cultivar or sieve mesh diameter on the temperature rise was observed.

3. Increasing the diameter of sieve meshes reduced energy inputs for the grinding of the seeds of all the tested lupine cultivars.

4. An increase of the moisture content of lupine seeds from 10.0 to about 16.0% resulted in a rise of energy inputs for the disintegration of seeds. The changes in energy consumption for grinding connected with different moisture contents of lupine seeds may be described by polynomials of the third order.

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