

ENERGY CONSUMPTION OF MAIZE GRAIN CRUSHING DEPENDING ON MOISTURE CONTENT

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Summary. Energy consumption in disintegration process is one of the most important components influencing the final cost, after the raw material's price and the labour costs. Feed industry is trying to specify its production by looking for new methods of disintegration at optimal parameters aiming at costs reduction and improvement of technology, in order to reach appropriate and acceptable product for the farmers. The study was conducted on the modified crushing mill produced by SIPMA at the following working gaps: 2 mm, 1,5 mm, 1 mm, 0,5 mm, 0,2 mm. Moisture content of grain was at the level of 12%, 20%, 30%. Moisture content of grain and size of the working gap between rolls influences energy consumption of the crushing process. The moisture content increase from 12% to 30% causes an average size particle rise by 100% for all the levels of working gaps between rolls.

Key words: crushing process, energy consumption, maize grain.

INTRODUCTION

Grain disintegration process relies on grain division into small parts. It is done in a mechanical way through the cohesion force breaking and the result is particle size reduction and the surface area rise. There are the following disintegration machines used in the agricultural engineering [Austin 2004; Kowalik and others 2002; Laskowski and others 1997; Niemiec and others 2003; Niemiec and others 2005; Wiercioch and others 2006; Zawislak 2002]:

- hammer mill,
- roller mill,
- crushing mill.

Energy consumption in disintegration process is one of the most important components influencing the final cost after the raw material's price and the labour costs. Feed industry is trying to specify its production by looking for new methods of disintegration at optimal parameters aiming at costs reduction and improvement of technology, in order to reach appropriate and acceptable product for the farmers [Grochowicz 1993; Korpysz and others 1994; Tavares 2004; Zawislak and others 2002]. Research on the disintegration process and particularly on the crushing process leads to an improvement of the feed quality. The granulometric distribution is very profitable because of a small quantity of dust fraction (which causes diarrhea and gastritis in animals) after grinding on roller mill and crushing mill. But energy consumption is 50% less in crushing mill then grinding on roller mill [Królikowski 2002; Łukaszuk 2001; Obidziński and others 2000; Romański 1998; Woźniak and others 1996; Woźniak and others 2006; Zawislak 2005].

Efficiency of crushing mill is estimated by quantity of product passing through the gap between rollers in the time unit. It depends on the following parameters:

- working gap width,
- working gap length,
- roller speed,
- properties of disintegrated material,
- filling degree of working gap volume [Romański 1998; Romański and others 1999; Woźniak 2005].

Crushing capacity can be calculated for the smooth couple rollers at identity speed by the following formula [Kowalik and others 2002; Romański and others 1999]:

$$Q = 3600 \cdot b_1 \cdot L \cdot v \cdot \gamma \cdot k, \quad [\text{t} \cdot \text{h}^{-1}], \quad (1)$$

where:

b_1 – working gap width, [m],

L – rollers length,

v – rollers speed,

γ – bulk density of the material [t/m^3],

k – filling degree coefficient of working gap.

METHODS

The following physical properties of grain and grind were defined:

- bulk density according to the norm PN ISO 7971-2,
- shaken density according to the norm PN ISO 8460,
- chuck angle according to the norm BN/9135-11,
- beginning moisture content by drying method according to the norm PN-76/R-64752,
- sieve analysis on screenings: 6,4 mm, 4 mm, 3,15 mm, 2 mm, 1 mm, according to the norm PN-89-R-64768.

CRUSHING PROCESS STUDY

The study was conducted on the modified crushing mill produced by SIPMA.

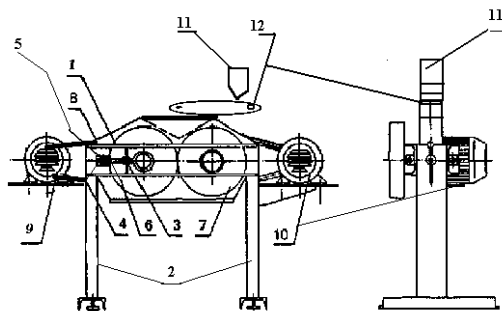


Fig. 1. Scheme of modified grain crusher (1,2 – frame; 3,4,5 – gap regulation system; 6,7 – driving cylinders; 8 – cover; 9,10 – driving system; 11 – feeder; 12 – band supplier)

The study was conducted at the following working gaps: 2 mm, 1,5 mm, 1 mm, 0,5 mm, 0,2 mm. Moisture content of grain was at the level of 12%, 20%, 30%. The rollers speed was 400 rpm. The unit energy consumption was measured by a system including: converter Lumel PP83, PCL 711B card and computer PC. It gives a possibility to receive the results in the form of electric base and measured instantaneous power.

Grain was wetted to three levels of moisture content: 12%, 20%, 30%. Moisture content was checked by drying method according to the norm PN 76/R-64752. Quantity of water added to watering of maize grain was calculated according to the formula:

$$M_w = \frac{X_2 - X_1}{100 - X_2} \cdot M_z, \quad (2)$$

where:

M_w – water added,

M_z – mass of maize,

X_1 – beginning moisture content,

X_2 – demand moisture content.

Watering was conducted in the plastic closed container at capacity of 3 kg maize in cooling condition. The sample of 1000 g was taken to the test with accuracy to 1g. Moisture content of grain was controlled before the crushing process.

RESULTS

The results of the study are shown in Table 1 and Figures 2 – 5.

The results of physical properties from Table 1 have shown characteristics of the material. Rise of moisture content of maize grain is caused by increasing physical properties' value.

Table 1. Physical properties of raw material

Physical properties	Moisture content [%]		
	12	20	30
Bulk density	671 kg·m ⁻³	680 kg·m ⁻³	701 kg·m ⁻³
Shaken density	815 kg·m ⁻³	835 kg·m ⁻³	871 kg·m ⁻³
Chuck angle	19°	24°	31°
Moisture content	12%	19,7%	30,2%

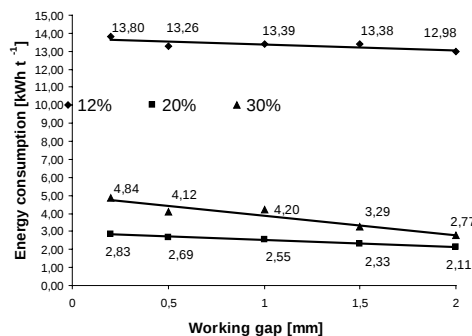


Fig. 2. Dependence of energy consumption on moisture content and working gap

Energy consumption of grain crushing for all the levels of moisture content can be described by the following linear equation:

$$y = ax + b. \quad (3)$$

Table 2. Constants a, b and determination coefficient R²

Moisture content [%]	a	b	R ²
12	-0,315	13,69	0,91
20	-1,0728	4,9592	0,92
30	-0,3914	2,909	0,99

Determination coefficient is between 0,91 to 0,99 for all the levels of moisture content. According to the results the moisture content is strongly connected with energy consumption of the crushing process. Four times less energy is demanded for grain of moisture content of 20% than for grain of moisture content of 12%. This relation is correct for every working gap between the rolls. An increase of moisture content of grain to 30% causes a decrease of energy consumption.

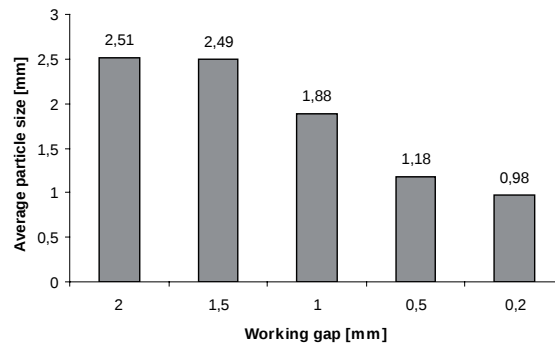


Fig. 3. Average particle size of maize at moisture content of 12% after crushing process in different working gaps

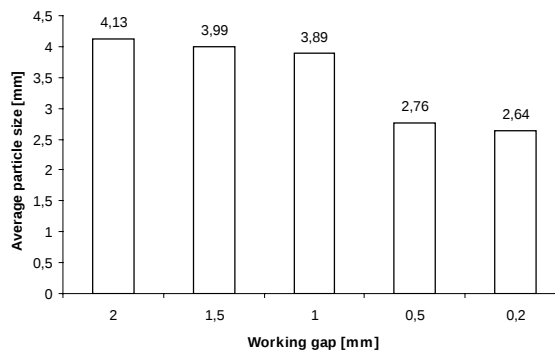


Fig. 4. Average particle size of maize at moisture content of 20% after crushing process in different working gaps

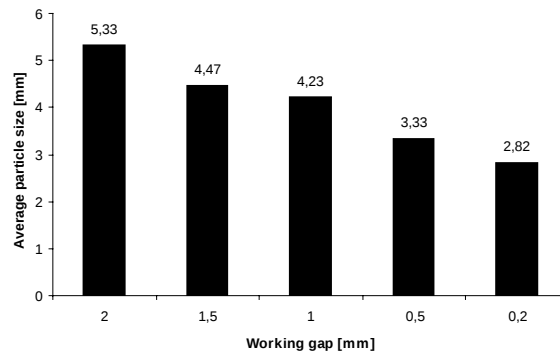


Fig. 5. Average particle size of maize at moisture content of 30% after crushing process in different working gaps

Figures 3, 4, 5 have shown an influence of moisture content of maize grain on average size of a particle after crushing process. According to the results the following relation can be observed: an increase of moisture content results in an average particle size (dg) rise. The moisture content increase from 12% to 30% causes an average size particle rise of 100% for all the levels of working gaps between rolls.

CONCLUSIONS

1. Moisture content of grain and size of working gap between rolls influences energy consumption of the crushing process.
2. Moisture content increase results in energy consumption decrease.
3. Working gap increase results in energy consumption decrease.
4. An increase of raw material's moisture content results in surface area rise of the product.

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