POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES

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Pol. J. Food Nutr. Sci.
2007, Vol. 57, No. 2(A), pp. 219-222

INFLUENCE OF ROTATIONAL SPEED OF ROLL IN A ROLLER MILL ON EFFECTS OF MAIZE GRAIN FLAKING

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Key words: maize grain, breaking, crusher

Studies upon breaking the maize grain using a crusher with variable cylinder have been carried out. Grain subjected to the breaking process was of 12, 20, and 30% moisture content. Breaking has been performed applying working gaps of 0.2, 0.5, 1.0, 1.5, and 2.0 mm width as well as cylinder's speed of 400/400, 400/440, and 400/480 rpm (both cylinders rotational speeds, respectively). Experiments revealed that increasing the rotational speed of one of cylinders in a crusher caused the increase of dusty particles in the achieved product. That increase was observed both at moisture contents change and for different widths of a working gap within the crusher.

INTRODUCTION

Breaking fodder raw materials is a very complex process due to different properties of particular components used. The amount of energy required for breaking is directly proportional to the surface area of newly achieved particles as well as to the durability of material being broken. The description of breaking the plant-origin materials as well as optimization and decrease of energy-consumption are very complicated. It results, among others, from variability of properties of broken materials and diversity of devices applied in that process [Grochowicz, 1996; Opielak, 1997; Romański, 1998; Zawiślak, 1997].

The breaking process can be described using Bond's theory that can be defined as the energy for breaking the weight unit of a given material from infinitely large dimensions to 100 μm, which is presented by following formula:

$$E_{BO} = 10W_i[\frac{1}{\sqrt{d}} - \frac{1}{\sqrt{D}}]$$

where: D – linear dimensions of a body before breaking (mm); d – linear dimensions of a particle after breaking (mm); and W_i – breaking work index ($kWh{\cdot}Mg^{-1}$).

Fodder industry tries to adapt to farmer's and breeder's needs by searching for new opportunities to decrease price for their products through performing the breaking processes under optimum conditions, which in consequence leads to the decrease of product's costs and elevation of production profitability. Extending knowledge on the breaking process, namely crushing, leads to the improvement of fodder quality. Meal from crushers and cylindrical mills are of very advantageous granulometric composition (they contain relatively low quantities of dusty fraction, do not induce diarrhea nor gastric disturbances at animals), and energy requirements for crushing are even to 50% lower than in the case of beater mills [Korpysz, 1994; Kowalik & Opielak, 2002].

Studies upon breaking the barley of Rudzik cv. [Romański, 1998, 1999] revealed that the dimensions of a working gap, grain moisture content as well as rotational speed of cylinders in a crusher affected its efficiency.

The study was aimed at evaluating the influence of different rotational velocities of crusher's cylinders on breaking level of maize grains. Works included maize grains of 12, 20, and 30% moisture content at various rotational speeds of cylinders and various widths of a working gap.

MATERIAL AND METHODS

Experimental stand. The maize grains were broken in a two-cylinder crusher (Figure 1). The crusher was modified in relation to original device. One-engine cylinder drive was replaced with two-engine solution, which resulted in independent drive of every cylinder. One engine was supplied from a power system, the other – through inverter, which made it possible to continuous change of rotations. The regulation was realized due to the change of frequency of supplying current with no need of changes in band transmission.

Considerable modifications took place in crusher's feeder (Figure 1). A gravitational feeder was replaced with a band supplier with band speed of 0.2 m/s, which allowed for uniform load of the crusher with grains.

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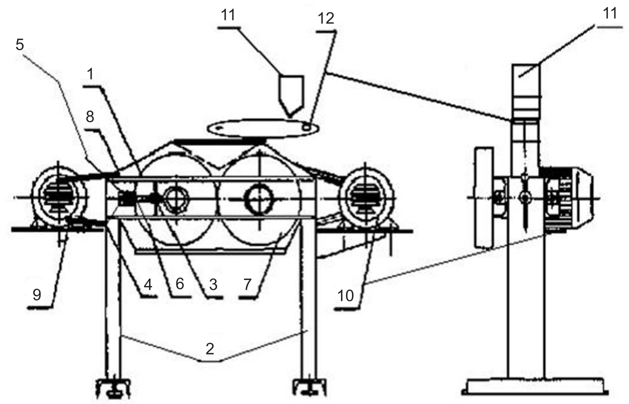

FIGURE 1. Modified grain crusher (1, 2 – frame; 3, 4, 5 – gap regulation system; 6, 7 – driving cylinders; 8 – cover; 9, 10 – driving system; 11 – feeder; 12 – band supplier).

Raw material's physical properties. Fodder maize for experiments had 11.8% of initial moisture content. It was sieved through 6.3 mm mesh sieve prior to study. Damaged grains, straw, cone remains, and stones were removed.

The following physical properties were determined: (1) loose density acc. to PN ISO 7971-2: 1998; (2) density after shaking acc. to PN ISO 8460:1999; (3) chute angle acc. to BN-87/9135-11; and (4) moisture content by means of a drier method acc. to PN -91/A-74010.

Breaking process. The study was carried out at working gaps of 2 mm, 1.5 mm, 1 mm, 0.5 mm, and 0.2 mm width. Rotational speed of one cylinder was constant and amounted to 400 rpm; the other's cylinder velocities were: 400, 440, and 480 rpm.

Moisture content of maize grain was adjusted to one of three values: 12%, 20%, and 30%. It was determined by means of a drier method according to Polish Standard [PN-91/A--74010]. The amount of water necessary to wet maize grain up to the desired moisture content was calculated using the following formula:

$$M_w = \frac{x_2 - x_1}{100 - x_2} M_{rz}$$

where: M_W – water to add; M_{rz} – weight of wetted grain; X_1 – initial moisture content; and X_2 – desired moisture content.

Moisturizing was performed in closed plastic containers of 3 kg capacity under cooling conditions. Samples of 1 kg of grain weighed with 1 g accuracy were taken for experiments.

RESULTS AND DISCUSSION

Table 1 presents some physical parameters of the studied maize grain for particular moisture contents.

Data presented in Table 1 reveal that grain moisture content influenced all measured parameters. The following features increased along with the increase of moisture content: bulk density from 671 kg/m^3 for 12% to 701 kg/m^3 for 30% moisture content; shaken density from 815 kg/m^3 for 12% to 871 kg/m^3 for 30% moisture content; and chute angle on zinc plate from 19° for 12% to 31° for 30% moisture content.

TABLE 1. Physical properties of studied maize grain.

Physical property	Moisture 12%	Moisture 20%	Moisture 30%
Bulk density	671 kg/mL	680 kg/mL	701 kg/mL
Shaken density	815 kg/mL	835 kg/mL	871 kg/mL
Angle of repose on zinc plate	19°	24°	31°

TABLE 2. Regression equations describing the influence of gap width on mean size of maize grain for various rotation.

Ratio	Equation	R^2
12% moisture content		
400/480	d_g=0.465x+0.441	0.95
400/440	d_g=0.4286x+0.33	0.96
400/400	d_g=0.4559x+0.1631	0.95
20% moisture content		
400/480	d_g=0.4754x+1.5452	0.91
400/440	d_g=0.4708x+1.6976	0.88
400/400	d_g=0.4221x+2.2197	0.85
30% moisture content		
400/480	d_g=0.6789x+1.5039	0.98
400/440	d_g=0.6285x+1.8893	0.93
400/400	d_g=0.6138x+2.1936	0.98

These parameters are very significant, namely at designing the technological lines and new devices. Figures 2, 3, and 4 present results of maize grain breaking level for various moisture contents and using various widths of crusher working gap. The achieved dependencies of mean particle size on gap between crusher's cylinders are described using linear equations that are presented in Table 2. Determination coefficients indicate correct selection of these equations.

Experiments revealed that value of average weighed geometric particle *dg* increased along with the increase of its moisture content (Figures 2-4), and decreased when the gap was narrower. The value of *dg* below 2.7 mm for all studied range of crusher's cylinder rotation velocities was characteristic for 12% of moisture content. For gap of 0.2 mm, *dg* value decreased below 1 mm. Increase of moisture content from 12% up to 30% caused over 3-fold increase of *dg* value for 0.2 mm gap width. The value of mean weighed geometric particle changed in the following pattern: (a) increased along with moisture content increase: from 2.506 mm for 12% to 5.326 mm for 30% moisture content and 2.0 mm gap width at cylinder rotation ratio of 1:1; (b) decreased along with the gap width decrease from 2.0 to 0.2 mm: from 2.506 mm to 0.981 mm for 12%, from 4.132 mm to 2.641 mm for 20%, and from 5.326 mm to 2.823 mm for 30% moisture content and cylinder rotation ratio of 1:1; and (c) decreased along with the increase of ratio from 1:1 to 1:1.2: from 2.506 mm to 2.462 mm for 2 mm, from 2.486 mm to 2.129 mm for 1.5 mm, from 1.883 mm to 1.356 mm for 1 mm, from 1.178 mm to 0.920 mm 0.5 mm, and from 0.981 mm to 0.787 mm for 0.2 mm gap width at 12% of moisture content.

No particles of above 6.3 mm size were found in the product achieved due to breaking the maize grain of 12% moisture content. The number of particles of above 6.3 mm for 20% moisture

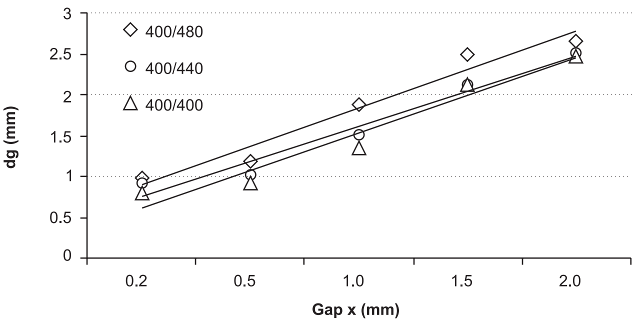

FIGURE 2. Influence of gap width on particle size of broken maize grain with 12% of moisture content for various rotation.

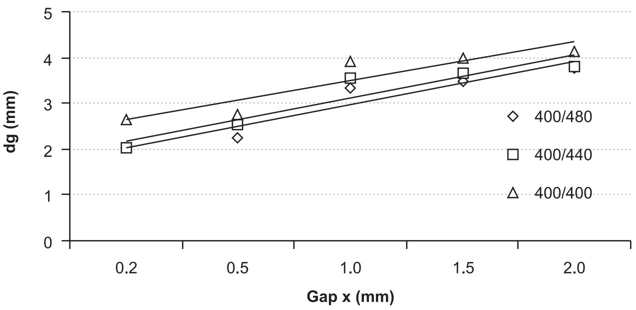

FIGURE 3. Influence of gap width on particle size of broken maize grain with 20% of moisture content for various rotation.

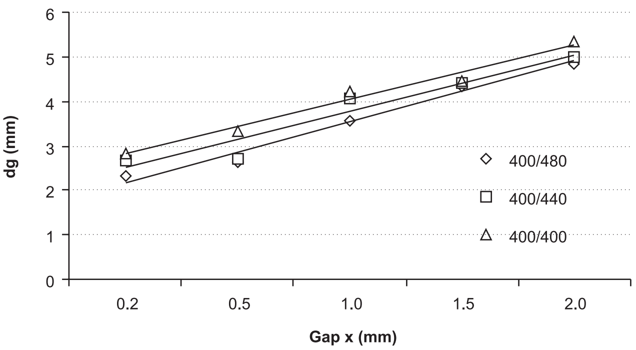

FIGURE 4. Influence of gap width on particle size of broken maize grain with 30% of moisture content for various rotation.

content grains decreased to 41.9% for 2.0 mm, and to 10.8% for 0.2 mm gap width. Percentage of particles of above 6.3 mm varied from 73.8% for 2 mm to 11.2% for 0.2 mm of working gap width.

The amount of dusty particles below 1 mm in size in the product achieved from breaking the maize grain with 12% of moisture content increased from 5.54% for 2 mm to 26.68% for 0.2 mm working gap width. The quantity of dusty fraction for 20% of moisture content increased from 3.5% for 2 mm up to 10.8% for 0.2 mm gap width. Particles of below 1 mm size made up from 2.1% for 2.0 mm to 10.2% for 0.2 mm gap width in bulk grain of 30% moisture content.

Studies performed by Romański & Łuczycka [1999] using triticale and barley grain and applying a two-cylinder crusher (240 mm of cylinder diameter and 150 mm of length) revealed that the thickness of achieved flakes – at 0.4 mm of working gap width and 12% of grain moisture content – was twice as high as gap width and 2.75 times larger at 20% of moisture content. The value of mean geometric weighed particle at the increase of moisture content from 12% to 20% increased by 45%. The content of dusty fraction in barley and triticale meals at moisture content of about 13% did not exceed 6% of the total meal amount. Also other authors were engaged in grain breaking problems [Chaoying *et al.,* 2003a, 2003b; Haros & Suarez, 1997; Koprysz *et al.,* 1994; Koprysz & Roszkowski, 1992; Kowalik & Opielak, 2002; Peyron *et al.,* 2002; Romański, 1998; Shobana & Melleshi, 2007; Svihus *et al,.* 2004; Tiwari *et al.,* 2007; Yus Aniza *et al.,* 2005; Zawiślak, 1997, 2001; Zawiślak & Stadnik, 2002] achieving similar dependencies as those reported herein.

Figures 5, 6, and 7 present results of loose density measurements for the achieved meals depending on moisture content of grain broken and cylinder velocities ratio.

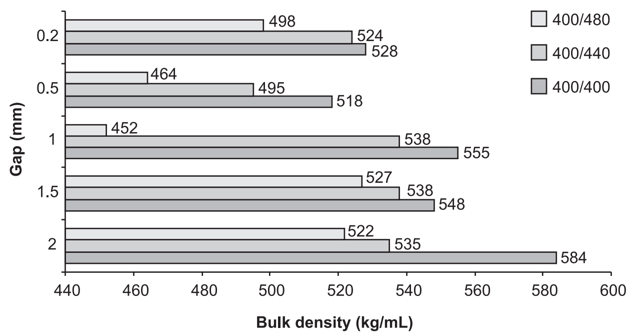

FIGURE 5. Changes of bulk density depending on cylinder rotational speed and working gap width for 12% of moisture content.

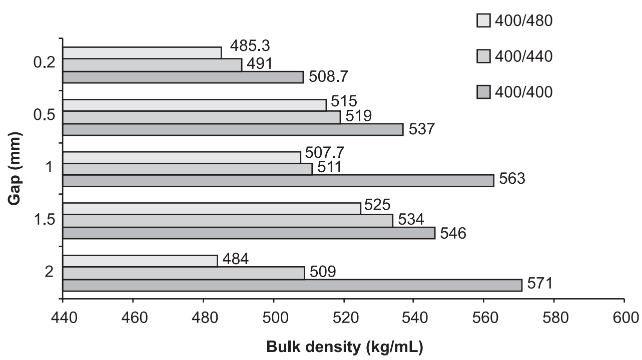

FIGURE 6. Changes of bulk density depending on cylinder rotational speed and working gap width for 20% of moisture content.

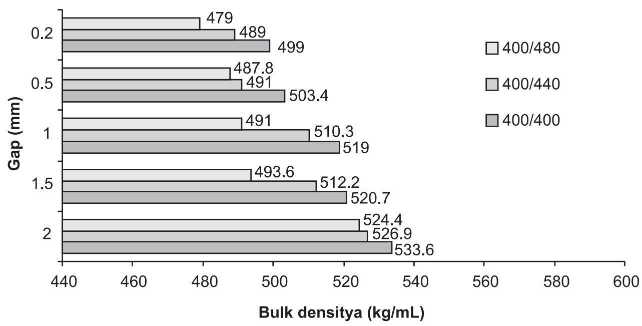

FIGURE 7. Changes of bulk density depending on cylinder rotational speed and working gap width for 30% of moisture content.

Bulk density of meal achieved due to grain breaking was from 479 kg/m^3 for 30% of moisture content, 0.2 mm of gap width, and cylinder rotation velocities of 400/480 rpm to 584 kg/m^3 for 12% of moisture content, 2.0 mm of gap width, and 400/400 rpm of cylinder rotations.

The achieved results indicate that the decrease of loose density value occurred along with the increase of ratio, which can be explained by larger product's breaking.

CONCLUSIONS

1. Mean size of product particle achieved during breaking strongly depends on the gap width in crusher and grain size.

2. Increase of ratio between cylinders in a crusher evokes an increase of dusty fraction percentage in product.

3. Width of a gap in a crusher, rotational speed of cylinders, and grain moisture content influence bulk density of the product achieved.

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WPŁYW PRĘDKOŚCI OBROTOWEJ WALCÓW GNIOTOWNIKA NA EFEKT ROZDRABNIANIA ZIARNA KUKURYDZY

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Przeprowadzono badania nad rozdrabnianiem ziarna kukurydzy przy wykorzystaniu gniotownika o zmiennych obrotach walców. Ziarno poddane procesowi rozdrabniania było o wilgotności 12,0; 20,0; i 30,0%. Rozdrabnianie przeprowadzono stosując szczeliny robocze w gniotowniku 0,2; 0,5; 1,0; 1,5 i 2,0 mm i prędkości walców odpowiednio prędkość obrotowa walca pierwszego względem drugiego: 400/400; 400/440 i 400/480 obr/min. Przeprowadzone badania wykazały, że zwiększenie obrotów jednego z walców w gniotowniku powoduje wzrost ilości części pylistych w otrzymanym produkcie. Wzrost ten stwierdzono zarówno przy zmianie wilgotności jak i dla różnych wielkości szczelin roboczych gniotownika.