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FACTORS INFLUENCE ON ENERGY CONSUMPTION OF DISINTEGRATION SWEET CORN COB

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Summary. The paper presents the results of the research on energy consumption in the process of cutting and crushing corn sweet cob. The cutting were realized on testing machine Instron 4302 and the crushing on the knife crusher H151/0. The measurements of energy consumption were taken on a research stand. An influence was tested of the variety, hole diameter of sieve and angle of setting knife on the analysed parameters. The density of corncobs influenced the change in consumption of energy

Key words: sweet corn, cob pith, energy, disintegration

INTRODUCTION

High requirement of the renewable source energy is the cause of searching cheap production technology and managing some of the plant materials for energy purpose [Zdrojewski and Peroń 2002]. One such product is corn waste i.e: stalks, leaf stalks, cores, leaf cobs. It is about 50% of the whole seed corn mass [Myers 1992] and about 70% in production of canned maize [Love 1990, Bagbay and Widstrom 1997, World Bank… 1998, Fritz *et al.* 2001].

The cores are widespread natural resource of fuel in energy production [Barnard, Kristoferson 1983, Soltes 1983, Enweremadu *et al*. 2004]. The cores are quite cheap as a large volume refuse product in the production of maize. Its mass density is at the level of 0,3 $g{\cdot}cm^{-3}$ at size particle from 0,95 to 2 mm [Vaughan *et al.* 2001] and the calorific value at about 1870 $kJ{\cdot}kg^{-1}$ [Zdrojewski and Peroń 2002]. On average there is about 18 kg of cores in 1000 grain maize [Bagby and Widstrom 1997].

Rising consumption and the cultivation of sweet corn is the cause of processing establishment evaluation concerned with the maize provided for food and simultaneously plenty of the organic refuse, mainly cores [Warzecha 2003, Waligóra 2004].

The cores received from production of seed grain are much moister, nearly 50% more than the cores received from sweet corn production. It is the result of not cutting the whole grain from core [Feibert and Shock 1996, Brecht 1998].

The cores management for the heating, feed or manure purposes is connected with its size reduction which is a complicated and energy-consuming process [Grochowicz 1996, Zawiślak 1997, Molendowski 2001, Opielak and Komsta 2001]. The aim of the study was to determine energy consumption during cutting and disintegrating the cores of sweet corn.

MATERIAL AND METHODS

The study was conducted on the cores of sweet corn variety: Golda, Candle and Jubilee. The characteristics of the material is shown in Table 1.

Table 1. Characteristic parameters of the sweet corn cores

Characteristics	Variety					
	Golda	v. c.[1],	Candle	v. c., %	Jubilee	v. c., %
Length, cm	18.6	3.2	19.2	2.4	20.1	2.9
Diameter, cm	3.2	0.8	2.9	0.9	3.4	3.1
Mass, g	105.6[a]	6.1	91.2[ba]	6.8	134.2[cab]	5.9
Moisture content, %	70.2	1.2	71.2	0.9	69.1	1.3
Density, $kg \cdot m^{-3}$	701.2[a)]	5.6	717.4[ba]	6.3	739.7[cab]	6.7

[1)] – variation coeficient,
[a,b,c)]– the same letters at values denote statistically significant diferences

The studied cores were received immediately after grain was cut on the cutter machine corn Cutter SC-120 FMC FoodTech brand at rotation speed cut head of 1600 rpm and linear velocity of the corn feeder of $0.31\ m \cdot s^{-1}$.

The energy consumption of cores cutting was conducted on the quasistatistics condition on the Instron 4302 (Fig. 1) apparatus at linear velocity head of $10\ m \cdot min^{-1}$ and at the load of 10 kN.

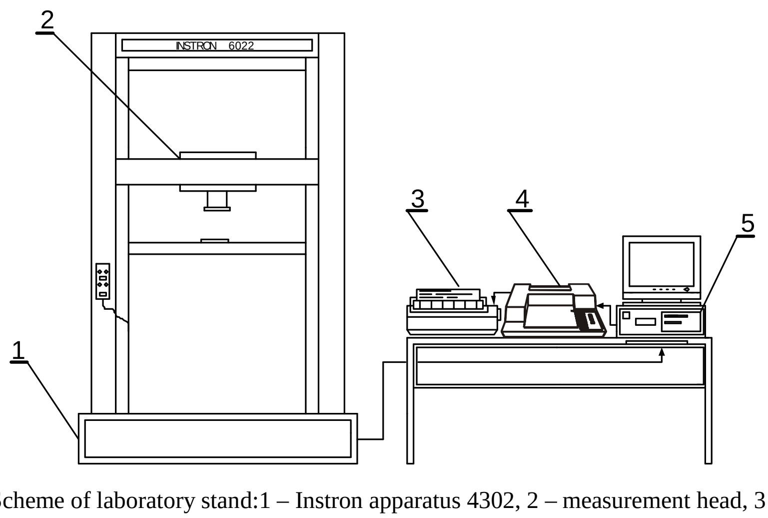

Fig. 1. Scheme of laboratory stand:1 – Instron apparatus 4302, 2 – measurement head, 3 – printer, 4 – ploter, 5 – computer

Cutting labor L_c was determined on the basis of the formula

$$L_c = F \cdot s \tag{1}$$

where:

F – cutting force, N

s – displacement of knife, mm.

Cutting force was related to cross-section of surface in the canter of the core. Cutting was conducted in the setting knife at the angle of knife 45° and 90° to longitudinal axis of +corn cob. Results were determined after 30 trials of each variety and each setting of knife.

Energy consumption of size reduction was determined in the dynamic conditions on the knife crusher H151/0 (Fig. 2) at hole diameter of sieve: 5, 10, 15 mm. Energy consumption of the core crushing was determined with power electric energy converter Lumel PP83.

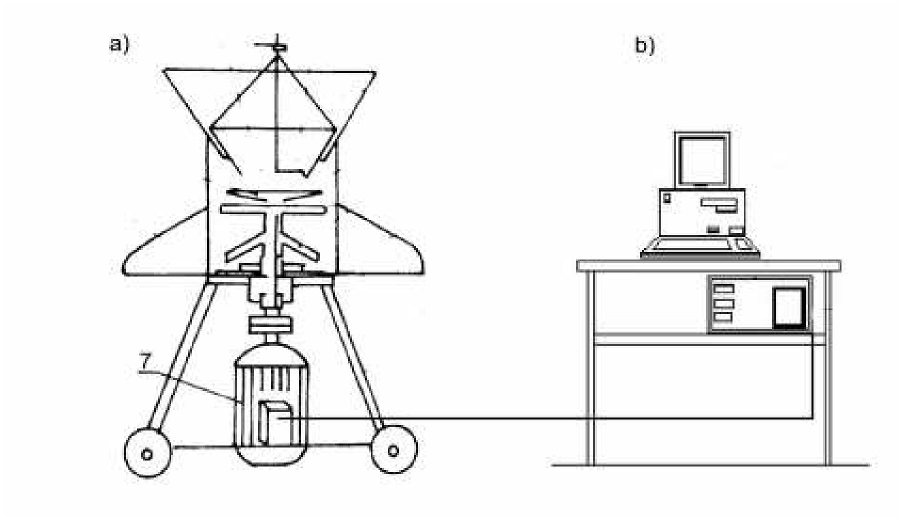

Fig. 2. Schematic diagram of measurement station: a) knife crusher H151/0, b) the registration system of electric horsepower and energy

The consumption of energy at disintegration of sweet corn corncob was determined by the formula:

$$E_u = E_c - E_{bj} \qquad \mathrm{MJ \cdot t^{-1}} \tag{2}$$

where:

E_c – the total consumption of electric energy during working of the shredder, MJ,

E_{bj} – the consumption of electric energy during neutral gear, MJ.

The unit value of electric energy consumption was determined by:

$$E_j = \frac{L_u}{m} \tag{3}$$

where:

m – the mass of disintegration sample, Mg.

The measurements were realized on the sample of 30 corncobs in 6 repetitions for each combination of corncob diameter and varieties.

The moisture of corncob was calculated from the following relation:

$$W = \frac{W_i(M_f - M_i)}{100 - M_f} \tag{4}$$

where:

W_i – initial moisture content of sample, %,

W_f – final moisture content of sample, %.

The moisture was determined in accordance to PN-90/A-75101.03.

The results of measurements were analyzed for significance level of $\alpha = 0.05$ using the computer program Statistica 6.0 PL.

RESULTS AND ANALYSIS

It is generally known, that the cutting and disintegration energy of the biological material is relative to physical properties, including the moisture of the tested material [Zawiślak 1997, Opielak and Komsta 2001].

On the characteristic material results (Table 1) it can be observed that moisture is not statistically significantly differential, so far considerations were realized on the ground that the moisture is similar.

The results of the presented analysis of variance show, that as well varieties as the knife setting are factors which influence statistically significantly the cutting energy of corncob. There was no statistically significant difference between their interaction (Table 2).

The mean value of cutting energy in relation to the tested factors was put in Figure 3. The mean value of cutting energy for setting knife at angle 90° was contained in the interval from 3,6 (variety Jubilee) to 4.6 MJ (Golda) and at angle 45° from 4.2 (Jubilee) to 6.1 MJ (Golda).

The change of setting knife from 90 to 45° influence on reducing the mean value of cutting energy about 24% for Golda, about 14% for Jubilee and about 16% for Candle variety.

The difference between the mean value of cutting energy for varieties can be explained by the adequate density of corncob.

The higher mean value of corncob density matched the lower mean value of cutting energy. The change of corncob density from 739.7 (Jubilee) to 701.2 kg·m^{-1} (Golda) resulted in the reduction of the cutting energy about 31% for knife setting at angle 45° and about 23% at angle 90°.

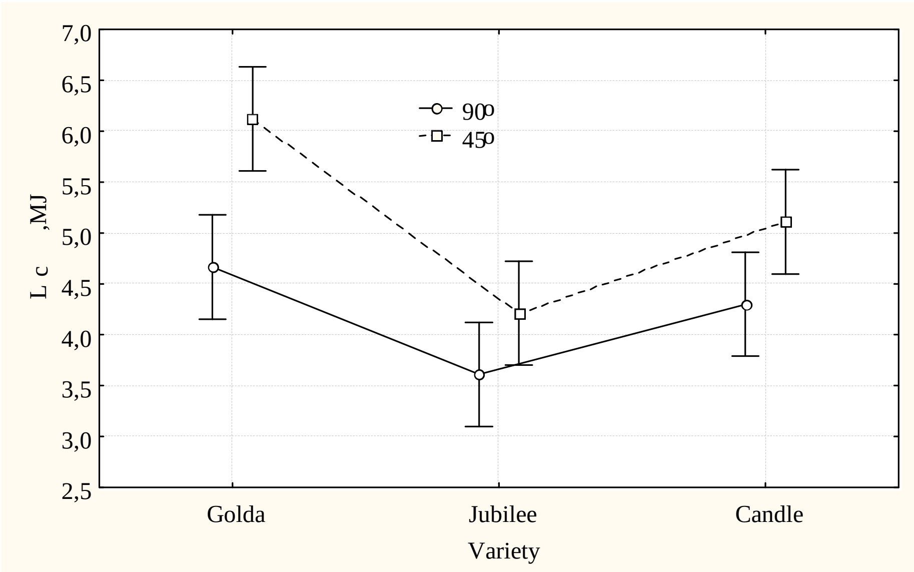

Fig. 3. The mean value of cutting energy with 95% interval confidence in relation to variety and knife setting

Table 2. The analysis of variance to test for the effect variety and knife setting on cutting energy L_c

Specifications	Sum of squares	Degree of freedom	Mean square effect	Test F	Significance level
Setting knife (u)	12.327	1	12.327	21.145	0.000
Variety (o)	19.836	2	9.918	17.013	0.000
Interaction u × o	1.788	2	0.894	1.533	0.226
Error	27.982	48	0.583		

The analysis of variance for the effect variety and diameter of sieve on consumption of unit energy of disintegration showed, that as with cutting energy, only the statically significant influence the main factors, and insignificant their interaction (Table 3).

The increase of hole sieve reduced the consumption of unit energy of crushing from 239.0 to 157.8 $MJ \cdot Mg^{-1}$ for Golda variety, from 222.0 to 147.3 $MJ \cdot Mg^{-1}$ for variety Candle and from 21.30 to 155.3 $MJ \cdot Mg^{-1}$ for Jubilee variety.

The difference between varieties can be explained, as at cutting energy, by the crushing of corncob density. The corncobs density from 739.7 (Jubilee) to 701.2 $kg \cdot m^{-3}$ (Golda) effected on the reduction of unit energy about 11% by 5 mm hole of sieve, about 14% by 10 mm hole of sieve and about 7% by 15 mm hole of sieve.

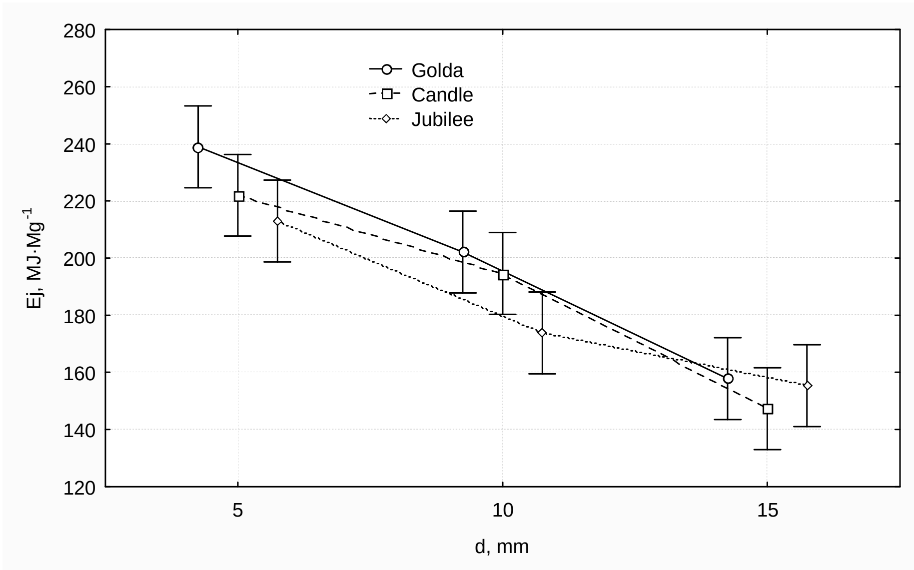

Fig. 4. The mean consumption of unit energy of disintegration with 95% interval confidence in relation to diameter of the hole sieve (d) and variety

Table 3. The analysis of variance to test for the effect variety and diameter of corncob crushing energy E_j

Specifications	Sum of squares	Degree of freedom	Mean square effect	Test F	Significance level
Variety (o)	3288	2	1644	5.420	0.007
Diameter of corncob (d)	45598	2	22799	75.169	0.000
Interaction o × d	1751	4	438	1.444	0.235
Error	13649	45	303		

CONCLUSIONS

1. The mean values of cutting and crushing energy of corncobs are significantly differential.
2. The density of corncobs influenced the change in consumption of energy. The higher density of corncob matched the lower value of cutting and crushing energy.
3. The mean values of cutting energy depended on knife setting and were the lowest at angle 90°, however the mean values of crushing energy depended on diameter of sieve hole and dropped with their increase.

REFERENCES

Bagby M., Widstrom N. 1997: Biomass usses and conversions, [in:] Stanley A. Watson, Paul E. Ramstad, Corn – chemistry and technology.

Barnard G., Kristoferson L. 1983: Agricultural residues as fuel in the third World. Earth Scan Technical, No 4. International Institute for Environment and Development, London, 11–16.

Brecht J.K. 1998: Fresh cut sweet corn kernels. Citrus and Vegetable Magazine, 63(7), 36–37.

Enweremadu C. C., Ojediran J. O., Ogunwa A., Afolabi L.O. 2004: Determination of the energy potentials of orange pomace. Science Focus, 8, 5–9.

Feibert E., Shock F. 1996: Supersweet corn and sweet corn variety evaluations. Malheur Experiment Station. Oregon State University Ontario, Oregon 34.

Fritz V.A., Randall G. W., Rosen C. J. 2001: Characterization and utilization of nitrogen contained in sweet corn silage waste. Agronomy Journal, 93, 627–633.

Grochowicz J. 1996:Technologia produkcji mieszanek paszowych. PWTiL, Warszawa.

Love J.M. 1990: The U.S. processing sweet corn industry. Vegetables and Specialties – Situation and Outlook 251, 20–22.

Molendowski F. 2001: Ocena zmienności jednostkowego oporu cięcia rdzeni kolb kukurydzy. Inż. Roln. 12, 209–214.

Myers D. 1992: Underwood J. Harvesting Corn Residue. Agronomy Fact Sheet 00392. Ohio State University Extension.

Opielak M., Komsta H. 2001: Badania wpływu wilgotności ziarna pszenicy na wydajność rozdrabniacza żarnowego i stopień rozdrobnienia materiału. Inż. Roln. 9, 187–192.

Soltes E.J. 1983: Thermo-chemical routes to chemicals, fuels, and energy from forestry and agricultural residues. [in:] W.A. Cote (ed), Biomass Utilization, Plenum Press, New York, pp. 23–47.

Vaughan T., Seo Ch.W., Marshall W. E. 2001: Removal of selected metal ions from aqueous solution using modified corncobs. Bioresource Technology 78, 133–139.

Waligóra H. 2004: Kukurydza jadalna – znaczenie gospodarcze i rola w żywieniu człowieka. Forum producentów roślin zbożowych, kukurydzy i rzepaku, Polagra-Farm 12–17.

Warzecha R. 2003: Słodki smak kukurydzy. Owoce, Warzywa, Kwiaty 6, 20–21.

World Bank. Pollution and Abatement 1998: Fruit and Vegetable Processing. Draft Technical Background Document. Environment Department. Washington.

Zawiślak K. 1997: Technika rozdrabniania a wymagania jakościowe stawiane produktom. Pasze Przemysłowe, 6, 7, 22–27.

Zdrojewski Z., Peroń S. 2002: Charakterystyka energetyczna osadek kukurydzy – wpływ struktury próbek na pomiar ciepła spalania. Inż. Roln. 5, 509–517.