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, Bagby 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·cm\(^{-3}\) at size particle from 0.95 to 2 mm [Vaughan et al. 2001] and the calorific value at about 1870 kJ·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 [Warzech 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

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Golda</th>
<th>Candle</th>
<th>Jubilee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length, cm</td>
<td>18.6</td>
<td>3.2</td>
<td>20.1</td>
</tr>
<tr>
<td>Diameter, cm</td>
<td>3.2</td>
<td>0.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Mass, g</td>
<td>105.6</td>
<td>6.1</td>
<td>134.2</td>
</tr>
<tr>
<td>Moisture content, %</td>
<td>70.2</td>
<td>1.2</td>
<td>69.1</td>
</tr>
<tr>
<td>Density, kg·m⁻³</td>
<td>701.2</td>
<td>5.6</td>
<td>739.7</td>
</tr>
</tbody>
</table>

1) – variation coefficient, a,b,c) – the same letters at values denote statistically significant differences

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·s⁻¹.

The energy consumption of cores cutting was conducted on the quasistatics condition on the Instron 4302 (Fig. 1) apparatus at linear velocity head of 10 m·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

\[
L_c = F \cdot s
\]  

(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.

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

\[
E_e = E_i - E_{n0}
\]  

(2)

where:
- \( E_i \) – the total consumption of electric energy during working of the shredder, MJ,
- \( E_{n0} \) – the consumption of electric energy during neutral gear, MJ.
The unit value of electric energy consumption was determined by:

\[ E_i = \frac{L_i}{m} \]  \hspace{1cm} (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:

\[ W = \frac{W_i(M_f - M_i)}{100 - M_f} \]  \hspace{1cm} (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°.

![Figure 3](image.png)

**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 \( L_c \)

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

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·Mg\(^{-1}\) for Golda variety, from 222.0 to 147.3 MJ·Mg\(^{-1}\) for variety Candle and from 21.30 to 155.3 MJ·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·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.
Table 3. The analysis of variance to test for the effect variety and diameter of corncob crushing energy $E_j$

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Sum of squares</th>
<th>Degree of freedom</th>
<th>Mean square effect</th>
<th>Test $F$</th>
<th>Significance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety ($v$)</td>
<td>3288</td>
<td>2</td>
<td>1644</td>
<td>5.420</td>
<td>0.007</td>
</tr>
<tr>
<td>Diameter of corncob ($d$)</td>
<td>45598</td>
<td>2</td>
<td>22799</td>
<td>75.169</td>
<td>0.000</td>
</tr>
<tr>
<td>Interaction $v \times d$</td>
<td>1751</td>
<td>4</td>
<td>438</td>
<td>1.444</td>
<td>0.235</td>
</tr>
<tr>
<td>Error</td>
<td>13649</td>
<td>45</td>
<td>303</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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


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


