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COMPARISON OF POWER CONSUMPTION DURING THRESHING OF DENT AND SWEET CORN COBS

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Summary. The power consumption during threshing of dent and sweet corn were compared. The threshing of San, Buron and Piorun dent variety and Candle, Golda and Jubilee of sweet corn variety was carried out. The threshing of dent corn was carried out on the cobs which were harvested in physiological stage and dried after harvesting. The threshing of sweet corn cobs was carried out on the cobs which were harvested in late milk stage of maturity. To make the threshing of sweet corn cobs possible, they were frozen by liquid nitrogen spray. It was found that power consumption during the threshing of frozen sweet corn cobs is similar to power consumption during the threshing of dried dent corn.

Key words: corn, kernels, threshing, power consumption.

INTRODUCTION

The removing of sweet corn kernels for consumption is made by devices for cutting the kernels off the cob. The high moisture content (70-78%) and half-liquid meat causes that at cutting and during subsequent wet-processing, including washing and blanching of the severed kernels, significante losses of kernel mass occur [Dougherty 1976, Mustafa et al. 2004]. Apart from kernel losses the problems of waste disposal appears. The waste includes corn core with kernels remains and technological water which contains both the solid and liquid part of kernel meat [Robertson et al. 1980].

One method of reducing kernel losses is application of threshing to kernel separation. Because of high moisture content and soft kernels pericarp it is not possible to directly use threshing to separate sweet corn kernels. To make it possible, sweet corn cobs must be frozen before threshing [Szymanek 2008].

The threshing of corns in physiological stage of maturity and at moisture content below 40% is possible using harvesters and stationary threshing machine. The factors influencing the quantity and quality of threshing are well-known and were an object of much scientific research [Byg et al. 1966, Dreszer and Gieroba 1980, Anazodo et al. 1981, Paulsen and Nave 1987, Kravchenko and Kuceev 1987, Petkevichiusa et al. 2008]. The corn cobs threshing process is closely related with biometrical parameters [Gokoev 1966] and mechanical characteristics [Huszar 1982, Zagajski and Dreszer 2007].

Anazodo [1980] found that moisture content of kernels is a much more influential factor of the threshing process than cobs moisture content. Alonge i Adegbulugbe [2000] found that kernel damages are closely related to kernel moisture content. The threshing at higher moisture is related to higher kernel damages [Kustermann 1987]. Waelti and Buchele [1969] showed that in moisture range from 15% to 38% the kernel damages are positively corelated with their moisture linear dependence $y = ax + b$ where: $y = \log_{10}$ (damages) and $x = \log_{10}$ (kernels moisture). Hellevang i Wilcke [1996] found that the quantity of mechanical damages considerably decrease when the moisture content is on the level of 22%. The study of Harrison [1991] on the threshing unit of International Harvester 1460 showed that an increase of working gaps by 1mm resulted in a decrease of power consumption from 0.5 to 2 kW. Kutzbach and Grobler [1981] found that the threshing process should take into account the mechanical resistance to impact of drum bars. Balastreire and Herum [1978] proved that kernel resistance of impact is related with moisture content.

The objective of this work was comparisson of power consumption during threshing of dent and sweet corn cobs.

MATERIAL AND METHODS

The research of threshing was carried out on sweet corn cobs of Candle, Golda and Jubilee varieties and on dent corn cobs of San, Buran and Piorun varieties. The cobs were gained from experimental field localized in IHAR Radzików and Skrzelew. The sweet corn cobs were manually harvested in the processing stage of maturity (late milk). The stage of maturity was determined on the basis of cobs appearance and kernels meat consistency. The researches on dent cobs were carried out directly after harvest (Variant I) and in two periods of storage (Variant II and III). The dent corn cobs for research variant I were manually harvested in physiological stage of maturity, about 2 weeks after appearance of black-layers [Sulewska et al. 2006].

Characteristics of the test material is shown in Table 1.

Table 1. Characteristics of test materials

Content	Moisture, %	Max. diameter of cob, mm	Max. diameter of cob pith, mm	Mass of cob, g	Length of cob, cm
Research variant (code)	Dent corn cobs				
	San				
I (SI)	32.6			162. 4	
II (SII)	24.8	43.3	19. 9	126.4	21.3
III (SIII)	17.8			89.7	
	Buron				

I (BI)	34.8	41.2	19.3	178.4	22.4
II (BII)	25.5			136.8	
III (BIII)	19.8			104.6	
	Piorun				
I (PI)	35.4	44.1	20.6	188.4	23.1
II (PII)	26.6			146.7	
III (PIII)	16.4			92.1	
	Sweet corn cobs				
	Candle				
I (C)	74,1*	50.2	34.2	316.2	21.3
	Golda				
I (G)	72,8*	47. 6	32.5	289.1	23.1
	Jubilee				
I (J)	71.1*	46.7	31.9	326.4	22.4

* at harvest

Characteristics of the test material was determined by testing 100 cobs for each research variants. The test material was harvested at random from different plantation sites. Any cobs that were not appropriately shaped or not fully kernelled were eliminated from the tests. Only straight cobs with even geometric dimensions were considered eligible for testing.

The weight was measured using a balance (WPE 2000p, RADWAG) with an accuracy of 0.1 g. Three samples were used and the average moisture content was reported.

The moisture content as a percentage of moisture based on wet weight of the kernels was determined using the oven drying method according to PN-ISO 6540. The oven drying KBC G-65/250 (PREMED) was used. The moisture content was calculated according to the formula:

$$W = 100\left(1 - \frac{m_1 m_3}{m_0 m_2}\right) \ [\%], \tag{1}$$

where:

m_0– mass of sample [g],

m_1 – mass of sample after drying [g],

m_2– mass of sample before initial conditioning [g],

m_3 – mass of sample after initial conditioning [g].

The cobs were frozen by spraying liquid nitrogen (LN) for 6 minute-periods at a temperature of circa -120 °C. The conditions of testing were well-chosen on the basis of own initial researches. They ensure the total freezing of kernels as well as the lowest damages of kernels at threshing. The cobs were frozen in a cooling room in which liquid nitrogen was sprayed from the Dewar flask (Taylor-Wharton, LD 25) through a withdrawal device. The thermometer (TES-1306, TW) with K type thermocouple and with accuracy 0.1 °C was used to measure temperature inside the cooling room. The corn cobs were threshed in a thresher with rasp bar drum.

Table 2 shows the technical and working parameters of the thresher.

Table 2. Technical and working parameters of the thresher

Contents	Value
Angle of drum belting, 1°	108
Clearance, mm: - inlet - outlet	40-26* 15-24*
Threshing speed, rpm	550
Length diameter, mm	420
Drum diameter, mm	380
Number of rasp bar, pcs.	6
Engine power, kW	3.0

* in dependence of mean cob diameter

The speed of threshing drum was well chosen on the basis of the author's researche and literature. The required speed of drum was achieved by using frequency transformer Telemecanique At V 18V. The optical revolution counter Prova RM-1000 with accuracy to 0.001% was used for measurement of speeds. The clearance between drum and threshing floor was determined in dependence of mean cob diameter (Fig. 1) [Wojciechowski 1979].

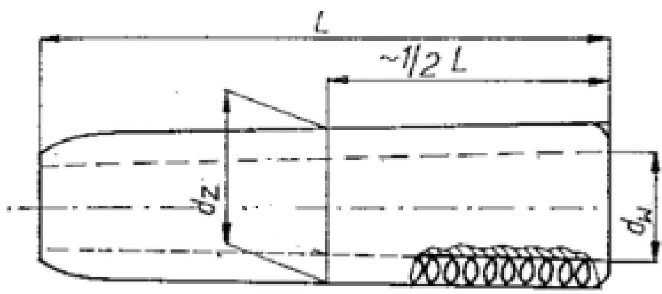

Fig. 1. The schema of corn cobs

The inlet clearance (S_O) was counted according to the equation (2):

$$S_O = d_Z - d_W,\ [\text{mm}], \tag{2}$$

the outlet clearance (S_i) according to the equation (3):

$$S_i = d_z - \frac{2}{3} S_o, [mm], \tag{3}$$

where:
S_O – inlet clearance [mm],
S_i – outlet clearance [mm],

L – length of cob [mm],
d_z – diameter of cob [mm],
d_w – diameter of cob pith [mm].

Kravchenko and Kuceev [Kravchenko and Kuceev 1987] claim that the clearance between the drum and the concave should be from 10 to 15 mm smaller than the cob diameter.

The power consumption at threshing was measured by using power register Lumel PP83. The register enabled computer measurement and data recording of power consumption of thresher: without charge (N_j) and with charge (N_o). The accuracy of measurement was 0.001 kW. The useful power losses on proper threshing were counted as the difference:

$$N_u = N_o - N_j \text{ [kW]} \tag{4}$$

The 12 cobs were at the same time thrown into charging hoper after stabilizing the threshing drum speed. The measurements of useful power were carried out on a sample of 12 cobs in three replications for each variant.

The data were analysed using a one-way ANOVA and multiple comparisons (Tukey's least-significant-difference test) using Statistical Analysis System, Statistica 7PL, StatSoft) with a significance level of $p<0.05$. For comparison, the 95% **confidence interval** for the **arithmetic mean** was used.

RESULTS AND DISCUSSIONS

An analysis of variance showed that the research variant significance influence on power consumption *Nu* (Tab. 2).

Table 2. The analysis of varaiance table

Source of variation	Sum of squares	Degree of freedom	Mean square effect	Test F	Significance
Free word	182.37	1	182.3732	1901.11	0.00005
Nu	1.58	11	0.1443	23.59	0.0001
Error	0.36	60	0.0061		

Table 3 shows the results of Turkey's test in form of homogeneous group for influence power consumption *Nu* in dependence of research variants.

Table 3. Turkey's test for *Nu*

Number of subclass	Variable	Nu (kW)	Number of subclass						
			1	2	3	4	5	6	7
3	SIII	1.29	****						
2	SII	1.44		****					

9	PIII	1.43		****					
6	BIII	1.47		****	****				
12	G	1.53		****	****	****			
11	J	1.62			****	****	****		
5	BII	1.63				****	****		
8	PII	1.64				****	****	****	
10	C	1.65				****	****	****	
1	SI	1.71					****	****	****
4	BI	1.79						****	****
7	PI	1.81							****

Figure 2 shows changes of *Nu* in dependence of research variants.

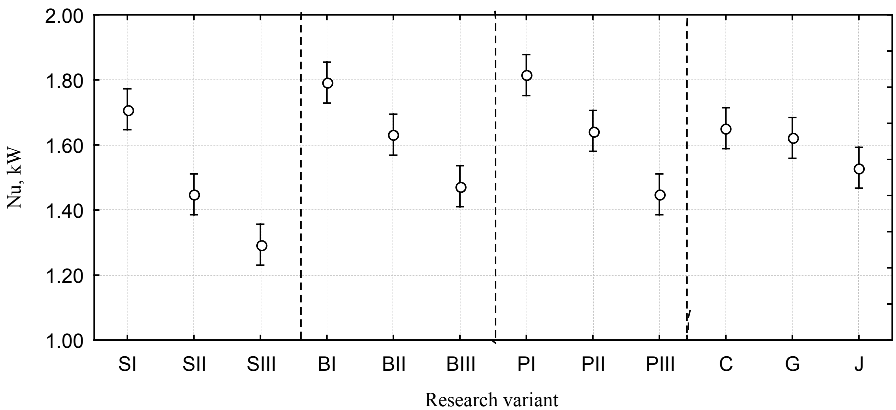

Fig. 2.Changes of *Nu* in dependence of research variant and with 95% confidence intervals

The research of corn cobs threshing showed that power consumption, as expected, is different from kernel moisture content. The higher value of moisture content, the higher value of power consumption is. In range from 32.6 to 17.8% for San variety there was observed a decrease of power consumption from 1.71 (SI) to 1.2 kW (SII). Respectively, there were observed decreases for Buran variety from 1.79 (BI) to 1.47 kW (BIII) in moisture content from 34.8 to 19.8% and for Piorun variety from 1.81 (PI) to 1.44 kW (PIII) in moisture range from 35.4 to 16.4%.The power consumption of threshing frozen sweet corn cobs amount from 1.65 kW for Candle (C) variety at 74.1% moisture content, and respectively 1.62 kW at 72.8% for Golda (G) variety and 1.53 kW at 71.1% for Jubilee (J) variety (Fig. 1 and 2).

The influence of moisture content of sweet corn kernels before freezing suggests that it highly affects the threshing process. At moisture content ranging from 74.1 to 71.1% there was found a decrease of power consumption by about 11%.

CONCLUSION

The research showed that the threshing of frozen sweet corn cobs does not involve an increase of power consumption in comparison to classic threshing. The obtained mean values of power consumption for sweet corn are contained in the range of power consumption for dent corn. This means that the construction of classic threshing-machine does not have to be strengthened. The mean values of power consumption of sweet corn threshing oscillated between mean values achieved for research variants I and III, that is for the threshing of dent corn cobs at moisture content about 25%. There was observed a negative correlation between kernel moisture content and power consumption.

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PORÓWNANIE POBORU MOCY W CZASIE OMŁOTU KOLB KUKURYDZY PASTEWNEJ I CUKROWEJ

Streszczenie. Porównywano pobór mocy podczas omłotu kolb kukurydzy pastewnej odmiany San, Buran i Piorun oraz kukurydzy cukrowej Candle, Golda i Jubilee. Omłot kukurydzy pastewnej realizowano na kolbach zebranych w stadium dojrzałości fizjologicznej oraz podsuszonych. Z kolei omłot kolb kukurydzy cukrowej przeprowadzono na kolbach zebranych w okresie dojrzałości późno mlecznej. W celu umożliwienia omłotu kolb kukurydzy cukrowej poddawano je mrożeniu w strumieniu par azotu. Badania wykazały, że pobór mocy przy omłocie zmrożonych kolb kukurydzy cukrowej jest zbliżony do poboru mocy przy omłocie podsuszonych kolb kukurydzy pastewnej.

Słowa kluczowe: kukurydza, ziarno, omłot, pobór mocy.