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EVALUATION OF THE DISC THRESHING DEVICE IN ASPECT OF POWER CONSUMPTION AND QUALITY OF SEPARATED MAIZE GRAIN

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Summary. Power consumption during the threshing of maize cobs of San, Buron and Piorun variety as well as quality of the separated grain was evaluated. A stationary threshing device with disc threshing unit was used. The quality of the separated grain and power consumption were determined in dependence of the variety, rotational speed of the threshing disc as well as vibration frequency of the sieve. It was found out that the quality of the separated grain was significantly influenced by the vibration frequency of the sieve, while the power consumption by the rotational speed of the threshing device. It was found out that there were statistically significant differences among the tested varieties.

Key words: maize, grain, threshing, power consumption, quality

INTRODUCTION

Nowadays generally the method of grain maize harvesting is direct harvest and threshing process on the field by using adapted or special combine harvesters. The quality of separated grain depends on its moisture content. Harvest at moisture content above 35% can involve an increase of grain loss and of the amount of non-separated from the cob grain. This situation might cause higher grain damage which rapidly increases with the increase of moisture content. So, the harvest of maize grain should be carried out at full dough maturity stage and at moisture content below 35%. However, the harvest at moisture content ranging from 38-40% is possible by using combine harvesters. The level of grain damage is influenced by threshing device construction [Waelti and Buchele 1969, Kowalik 2005].

Since the mid 20^{th} century in the USA combine harvesters have been produced with threshing device modeled on the basis of maize sheller device. Its work consists in the combining of the threshing bar's beating action (vibration) process with an intensive rubbing of grain in the threshing gap [Harrison 1991].

Modern combine harvesters use threshing devices with an axial-flow of the threshing material [Kravchenko and Kuceev 1987, Szymanek, Tanaś, Zagajski and Dreszer 2008].

In combine harvesters with an axial-flow threshing device, in relation to classical combine harvesters with a tangential threshing device, the separation action results from the rubbing of the threshing drum as well, so the grain damage is lower. The higher the moisture content of the threshed grain, the greater the difference is. At lower moisture content (25-30%) the influence of the kind of threshing device construction on the quality of separating process is much smaller [Kutzbach, Grobler 1981, Paulsen and Nave 1987, Petkevichiusa, Shpokasa, Kutzbach 2008].

The factors affecting the threshing process of maize are generally known and were the subject of research by a lot of authors [Byg et al. 1966, Dreszer and Gieroba 1980, Anazodo et al. 1981]. The threshing process is strictly connected with biometrical parameters [Gokoev 1966, Kravchenko and Kuceev 1987, Szymanek et al. 2008] and its mechanical properties [Huszar 1982, Zagajski and Dreszer 2007].

Apart from combine harvesters, also stationary threshing devices and equipment with disc threshing working units are used for maize threshing.

The objective of this work was to determine the influence of maize variety, rotational speed of threshing disc and vibration frequency of the sieve on the quality of separated grains and power consumption during the threshing process.

Material and methods

The dent maize cobs of San, Borun and Piorun varieties were used in the study. They were obtained from the crop grown until the full dough stage of maturity in the period of about 2 weeks after the appearance of black layer on the lower parts of grain [Sulewska et al. 2006].

Table 1 presents the characteristics of maize cobs.

Table1. Characteristics of maize cobs

Contents	Variety		
	San	Buron	Piorun
Weight of cob without husk, g	165.5	178.6	189.4
Length of cobs , cm	21.3	22.4	23.1
Max. diameter of cobs, mm	43.3	41.2	44.1
Number of kernel rows, pcs.	16	16	18
Number of kernels per row, pcs.	38	42	36
Moisture content of grain, %	32.8	35.4	31.3

Characteristics of manually harvested maize cobs were determined on the sample of 100 pieces for each variety. The maize cobs selected for the study were healthy, of a straight shape and a high degree of kernel filling. The weight of cobs was measured using the laboratory weight KBC G-65/250- PREMED and according to the standard PN-ISO 6540:

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

where:

m_0– weight of moisture sample, g

m_1 – weight of sample after drying, g

m_2– weight of sample before preconditioning, g

m_3 – weight of sample after preconditioning, g.

The tests determining the influence of variety, rotational speed of threshing disc and vibration frequency of the sieve were performed on the testing stand (Fig. 1) and consisted in laboratory threshing with the disc threshing device (Promar, Pl) and wattometr (Lumel PP 83, Pl).

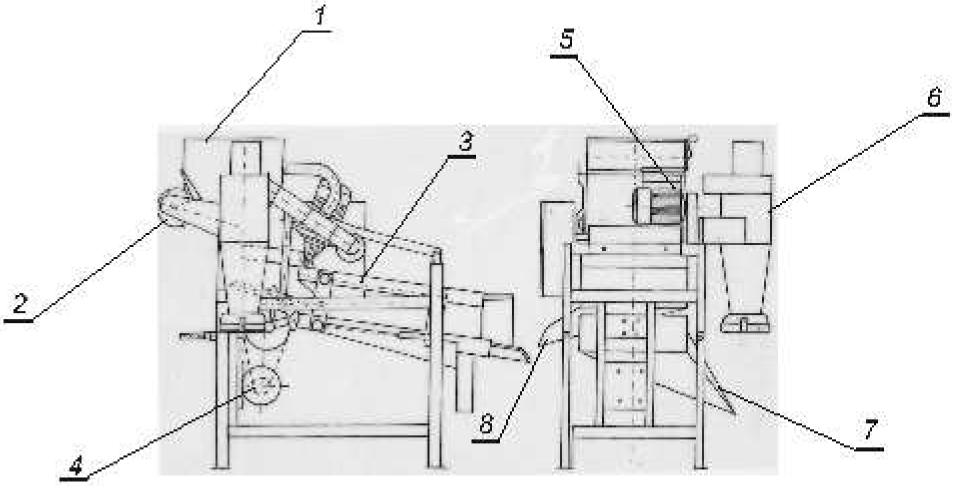

Fig. 1. Threshing device for cob maize threshing: 1 – hopper, 2 – driver of threshing disc, 3 – sieves, 4 – driver of sieves, 5 – drive of ventilator, 6 – outflow of ventilation, 7 – chute of good grain, 8 – chute of grain offal

The technical and working parameters of the testing device use were presented in Table 2.

Table 2. Parameters of the threshing device

Content	Value
Rotational speed of threshing disc, rot/min	900; 1200; 1500
Outlet gap, mm	20
Angle slope of sieve, 1°	8
Vibration frequency of sieve, deflexion/min	200; 300; 400
Amplituda sit, mm	15
Sieves, mm: - top - bottom	 ϕ 17.5 2.5x25
Power of electric motor, kW: - driver of ventilation - driver of sieves - driver of threshing disc	 0.37 0.37 0.55
Capacity, cobs/h	1400

The changes of rotational speed of threshing disc and vibration frequency of sieve were made by changing rotational speed of the driving electric motors by using frequency converter (Telemecanique At V 18V, F). The speed indicator (Prova RM-1000, TW) with accuracy 0.01% was used for the measurement of rotational speed of the threshing disc.

The quality of separated maize grain was determined by the formula:

$$U - \frac{m_c}{m_z} \cdot 100\%, \qquad (2)$$

where:

U – share of good grain %,

m_c – weight of good grain g,

m_z – weight of grain in sample g.

The share of good grain was determined on the sample of 400 g in 3 replications.

The power consumption of cobs threshing and grain cleaning was determined with accuracy of 0.001 kW by the formula:

$$P_u = P_o - P_j \text{ [kW]}, \qquad (3)$$

where:

P_u – useful power of consumption kW,

P_o – power consumption at threshing and cleaning kW,

P_j – power consumption at neutral gear kW.

The useful power consumption was carried out on the sample of 30 cobs in 3 replications for each combination of independent variables.

The experiment of determining power consumption (P) and grain quality (U) was performed by the model:

$$P, U = f\,(o, n, f), \qquad (4)$$

where:

o – maize variety,

n – speed of threshing disc rot/min,

f – frequency of vibration deflexion/min.

An estimation of results was realized on the basis of analysis of variance and multiple regression by using Statistica 6.0 Pl. Comparison of means was conducted with the Fisher's least significant difference (LSD) test at the significance level $p = 0.05$. In addition, the confidence interval for mean values was given.

RESULTS

The analysis of variance for $P = f\,(o,n,f)$ (Tab. 3) showed that interaction speed of threshing disc (n) and frequency of sieve vibration (f) as well as variety (o), speed of threshing disc (n) and frequency of sieve vibration (f) do not affect in a statistically significant way the dependent variable (P).

Table 3. Analysis of variance for $P = f(o,n,f)$

Specification	Sum of squares	Degree of freedom	Mean square effect	Test F	Significance level
o	9769	2	4885	2413	0.0000
n	1051	2	525	260	0.0000
f	223	2	111	55	0.0000
o*n	79	4	20	10	0.0000
o*f	1	4	0	0	0.9716
n*f	71	4	18	9	0.0000
o*n*f	20	8	3	1	0.2922
Error	109	54	2		

On the basis of F test we can state that the variety accounts for about 88% of total variability of dependent (P), while only for 9% of dependent (n).

Figure 2 presents changes for $P = f(o,n,f)$.

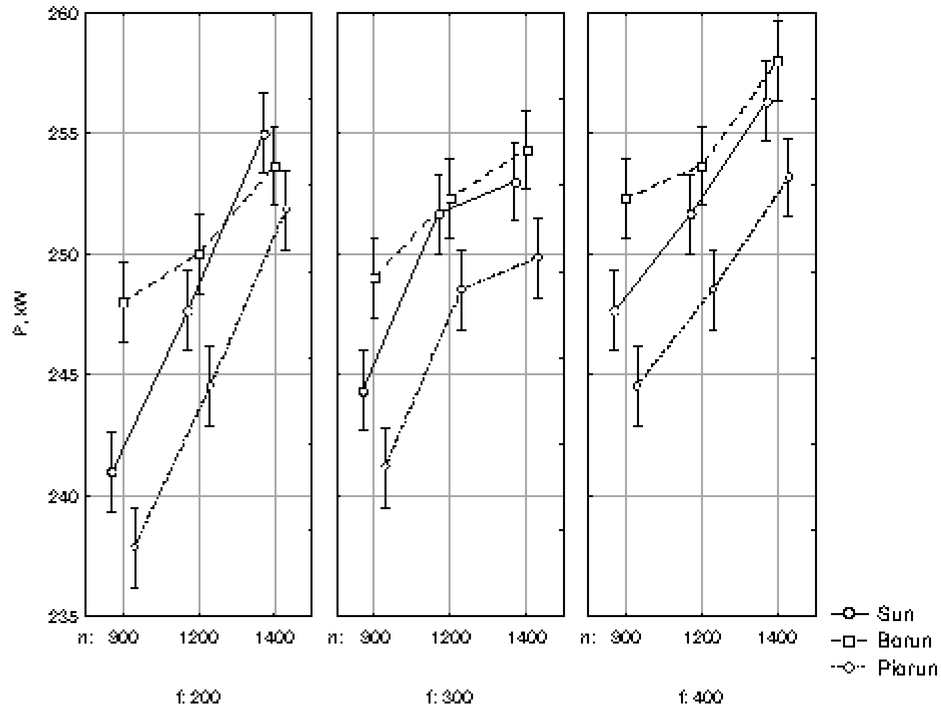

Fig. 2. Changes of P mean value with confidence interval of 95% for $P = f(o,n,f)$

The mean value of variable *P* at *n* = var (900, 1200, and 1400 rot/min) amount for San variety respectively: 241.0kW; 247.6kW; 255.0 kW at *f* = const (200 deflexion/min), 244.3 kW; 251.6 kW; 253.0 kW at *f* = const (300 deflexion/min), 247.6 kW; 251.6 kW; 256.3 kW at *f* = const (400 deflexion/min), for Buron variety respectively: 248.0 kW; 250.0 kW; 253.6 kW at *f* = const (200 deflexion/min), 249.0 kW; 253.3 kW; 254.3 kW at *f* = const (300 deflexion/min), 252.3 kW; 253.6 kW; 258.0 kW at *f* = const (400 deflexion/min), for Piorun variety respectively: 237.8 kW; 244.5 kW; 251.8 kW at *f* = const (200 deflexion/min), 241.1 kW; 248.5 kW; 249.8 kW at *f* = const (300 deflexion/min), 244.5 kW; 248.5 kW; 253.1 kW at *f* = const (400 deflexion/min).

The analysis of variance (Tab. 4) shows that variety (*o*), frequency of sieve vibration (*f*) and interaction speed of threshing disc as well as frequency of sieve vibration (*n*f*) have a statistically significant influence on the dependent variable – share of good grain.

Table 4. Analysis of variance for $U = f\,(o, n, f)$

Specification	Sum of squares	Degree of freedom	Mean square effect	Test F	Significance level
o	21.4	2	10.7	8.3	0.0006
n	6.1	2	3.1	2,4	0.1012
f	70.0	2	35.0	27,2	0,0000
o*n	2.7	4	0.7	0,5	0.7148
o*f	0.3	4	0.1	0,1	0.9945
n*f	27.1	4	6.8	5.3	0.0011
o*n*f	1.5	8	0.2	0.1	0.9966
Error	69.4	54	1.3		

Results of *F* test show that a higher influence of dependent variable affects frequency of sieve vibrations, which accounts for about 62% of total variability of dependent variable. However, variety and interaction (n*f) account only for about 19%.

The mean value of share of good grains (*U*) for San variety at *n* = var (900; 1200 and 1400 rot/min) and at *f* = const (200 deflexion/min) amounts respectively: 93.9% ; 95.6% and 96.4% at *f* = const (300 deflexion/min), respectively by about: 97.6% ; 96.5% and 97.1% and at *f* = const (400 deflexion/min), respectively by about: 95.5% ; 93.3% and 95.7%.

While for Borun variety the share of good grain (*U*) was respectively: 93.7%; 95.1%; 95.2% at *f* = const (200 deflexion/min), 99.3%; 96.4%; 95.8% at *f* = const (300 deflexion/min) and 94.3%; 98.1%; 94.5% at *f* = const (400 deflexion/min).

However, for Piorun variety the share of good grain (*U*) amounts, respectively, to: 93.3%; 94.6%; 94.7% at *f* = const (200 deflexion/min), 95.9%; 95.9%; 95.4% at *f* = const (300 deflexion/min) and 93.8%; 92.7%; 94.1% at *f* = const (400 deflexion/min).

Figure 3 shows changes of share of good grain (U) in dependence of *o, n, f* variables.

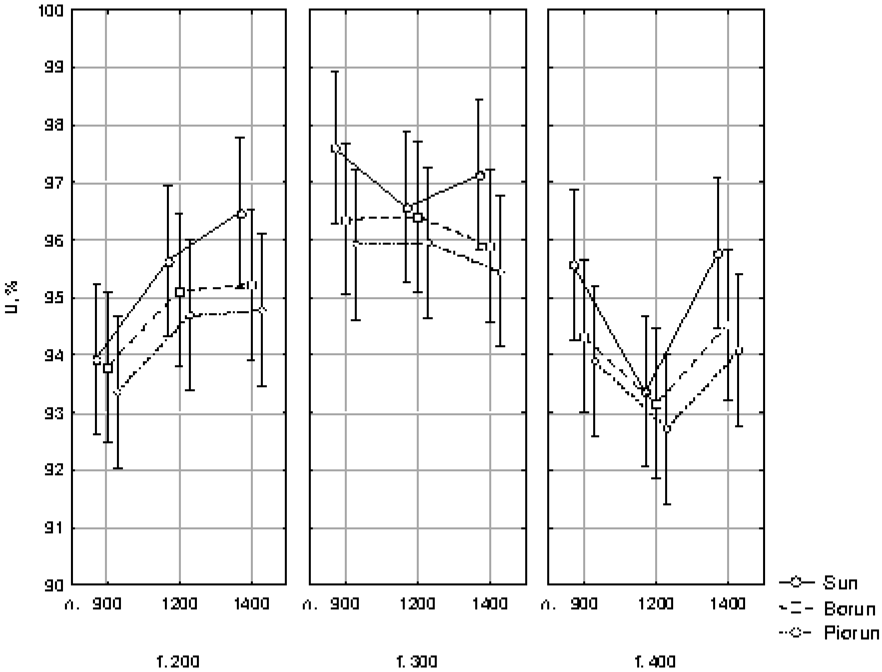

Fig. 3. Changes of U mean value with confidence interval of 95% for
$U = f(o,n,f)$

CONCLUSIONS

1. The studies showed that frequency of sieve vibration (f) and variety (o) are the factors which affect the significanctly statistical influence on the share of good grain. It did not find influence of the threshing disc (n) on the share of good grain (U) in the weight of separated grain. The highest value of U (97.6%) was achieved for San variety at n = 900 rot/min and f = 300 deflexion/min, while the smallest (92.7%) for Piorun variety, at n = 1200 rot/min and f = 400 deflexion/min.
2. Analysis of variance for $P = f(o,n,f)$ showed the statistically significant influence of all the analyzed independent variables. There was stated a tendency of increasing power of consumption (P) with increasing of speed threshing disc and frequency of sieve vibration. The highest value of P (258.0 kW) was achieved for Borun variety at n = 1400 rot/min and f = 400 deflexion/min, while the smallest (237.8 kW) for Piorun variety, at n = 900 rot/min and f = 200 deflexion/min.

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OCENA TARCZOWEGO ZESPOŁU MŁÓCĄCEGO W ASPEKCIE PONOSZONYCH NAKŁADÓW ENERGETYCZNYCH ORAZ JAKOŚCI WYDZIELONEGO ZIARNA KUKURYDZY

Streszczenie. Oceniano zapotrzebowanie na moc w czasie omłotu kolb kukurydzy pastewnej odmiany San, Buron i Piorun oraz jakość wydzielonego ziarna w stacjonarnej młocarni z tarczowym zespole młócącym. Jakość wydzielonego ziarna oraz ponoszone nakłady energetyczne określano w funkcji odmiany, prędkości obrotowej tarczy omłotowej oraz częstotliwości drgań sita. Badania wykazały, że jakość wydzielonego ziarna (udział ziarna celnego) jest w głównej mierze zależna od częstotliwości drgań sita, a zapotrzebowanie na moc od prędkości obrotowej tarczy omłotowej. Badania wykazały również istotne statystycznie zróżnicowanie pomiędzy badanymi odmianami.

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