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AN ANALYSIS OF THE SPELT DEHULLING PROCESS IN A CYLINDER SEPARATOR

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ABSTRACT

Spelt is one of unprofitable wheat types and requires an additional hulling process, in which the husks are removed from the grain. A device for dehulling spelt kernels was proposed. The described solution consists of a stainless-steel wire mesh cylinder with 4×20 mm and 4×30 mm longitudinal openings and a rotor with adjustable blade angles. Kernels were dehulled at the following angular speeds of the shaft: 16.76, 23.04, 29.32, 35.60, and 41.89 rad·s^{-1}, and the following rotor blade angles: 50°, 60°, 70°, 80°, and 90°. The efficiency of glume and glumelle removal, the proportion of damaged kernels, and kernel and husk separation efficiency were evaluated during the experiment. The highest of kernel separation efficiency η_z was 81.86% using a wire mesh cylinder with 4×30 mm longitudinal openings and 81.60% for a wire mesh cylinder with 4×20 mm longitudinal openings.

Introduction

Food and agriculture markets are increasingly competitive, and consumers show a growing interest in food products that are not only attractive, but also deliver health benefits. The demand for organically grown crops continues to increase (Kawa and Cyran, 2015; Olech and Kuboń, 2016). In recent years, spelt has gained popularity on account of its appealing taste and health-promoting properties (Boukid et al., 2018).

Spelt grain is processed into flour, groats, flakes, pastry, pasta, bread, spirits, and beer (Ceglińska and Gromulska, 2008; Majewska et al., 2007). Spelt has attracted consumer interest because it is more nutritious than common wheat. Spelt grain contains high biological value protein, unsaturated fatty acids, B and PP vitamins, and minerals such as zinc, potassium, calcium, and iron (Kępińska-Pacelik and Biel, 2021; Kohajdová and Karovicova, 2008; Bojňanská and Franĉáková, 2011; Bonafaccia et al., 2000; Majewska et al., 2007; Abdel-Aal and Hucl, 2002; Wieser, 2001). Spelt and other ancient cereal species have lower environmental and agronomic requirements than common wheat (lower fertilization levels, extensive plant protection), and their grain is characterized by very high quality (high content of protein, gluten, minerals, and vitamins) (Piergiovanni et al., 2009; Rachoń et al., 2016; Rachoń et al. 2017; Suchowilska et al., 2012; Rachoń, et al., 2018; Luo et al., 2000; Sulewska, 2004; Escarnot et al., 2012; Sawicka and Krochmal-Marczak, 2012; Anders, 2023; Rachoń et al., 2015).

Spelt kernels are enclosed by glumes and glumelles which provide protection against pests and diseases and increase spelt's resistance to infections, fungi, atmospheric pollutants, and even radiation (Kordan et al., 2007; Choszcz et al., 2010). Spelt grain requires additional processing after harvest because glumes and glumelles have to be removed before milling (Longin et al., 2016). Combine-harvested spelt is a mixture of grain and spikelets. Husks account for around 25–35% of the harvested grain mass (Medović, 2003). Agricultural processing plants are unable to optimize spelt dehulling operations due to the absence of reliable information about the characteristic properties of spelt grain, which compromises processing efficiency and decreases profits (Liubych et al., 2019). Grain cleaning and dehulling operations produce large amounts of husks (Wiwart et al., 2017). Discarded husks can be used for various purposes, including in the production of pillows and mattresses (Mielke and Rodemann, 2007), as a renewable energy source (Brlek et al., 2012; Jovičić et al., 2015; Wiwart et al., 2017), and in animal feed production (Kalmendal and Bessei, 2012). Husks can be also composted (Jovičić et al., 2015), used as litter (Wiwart et al., 2017; Dziki, 2023), processed into construction materials (Bucur et al., 2017), or distributed in the field to improve soil fertility (Konvalina, 2014; Moudry 2011). However, wheat husks should not be used as litter due to their high mycotoxin content, and they should be incinerated (Wiwart et al., 2017), ideally in granulated form (Wiwart et al., 2017, Brlek et al., 2012; Weiß and Glasner, 2018; Bernas, 2020), to generate energy.

After harvest, spelt spikelets require additional processing in a process that is commonly referred to as threshing (Kulathunga et al., 2020). Spelt spikelets are dehulled in specialist machines (Anders et al., 2020; Kulathunga et al., 2020; Mykhailov et. al., 2022) equipped with a wire mesh cylinder and a rotor with beaters. The most frequently used are impact shellers, in a modified thresher, an abrasive disc dehuller, in a modified thresher, an abrasive disc dehuller, shelling machine, and tangential dehuller. In Poland modified clover hullers for additional threshing of spelt are often used. However, their effectiveness is not very satisfactory because the spelled grain is surrounded by tightly fitting husks (Tyburski and Babalski, 2006; Choszcz et al., 2010; Kulathunga et al., 2020). Shelling equipment is not very effective in separating spelled grain from the husk, and the material requires further cleaning and sorting for separation. Spelt kernels are enclosed by tightly inter-locked glumes, and the dehulling process is energy-intensive and often has to be repeated several times. For instance, Anders et al. (2020) proposed a spelt dehulling machine featuring a wire mesh cylinder with longitudinal openings; in the machine, glumes are separated by mechanical impact of friction.

The objective of this study was to determine the effect of selected factors on the efficiency of glume and glumelle removal from spelt kernels.

Materials and Methods

The experiment involved spikelets of spelt cv. Schwabenkorn (85% purity, relative moisture content – 11.56±2.00%). Spelt grain was purchased at an organic farm in Praslity (54°01′55″N 20°21′29″E, Region of Warmia and Mazury, municipality of Dobre Miasto).

The proposed dehuller (Fig. 1) (Kolankowska and Choszcz, 2019; Kolankowska and Choszcz, 2017) consists of two wire mesh cylinders with 4×30 mm (Fig. 2) and 4×20 mm (Fig. 3) longitudinal openings, where glumes and glumelles are separated from spelt grain by the mechanical impact of friction. The open area factor was 0.14 for the wire mesh cylinder with 4×30 mm openings and 0.40 for the wire mesh cylinder with 4×20 mm openings. Wire mesh cylinders with longitudinal openings have a larger abrasive area than wire mesh screens in industrial spelt dehullers or in modified clover hullers. A larger abrasive area increases the efficiency of spelt dehulling due to the characteristic parameters of the process.

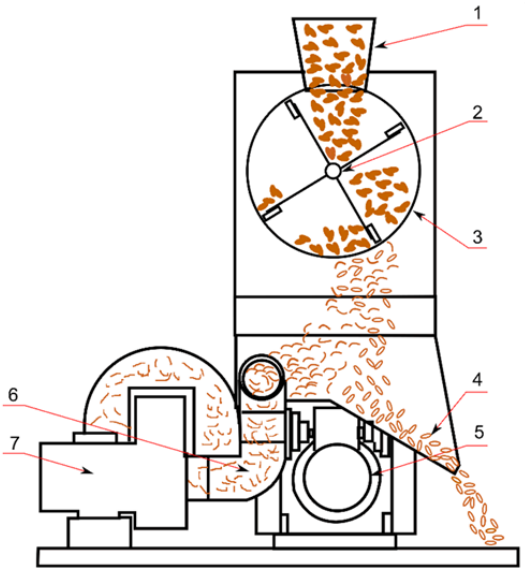

Figure 1. Diagram of the spelt dehulling process: 1 – the hopper of spelt spikelets, 2 – rotating impeller, 3 – wire mesh cylinder, 4 – spelt kernels in the discharge chute, 5 – gearmotor, 6 – husks in the pneumatic channel, 7 – radial fan motor.

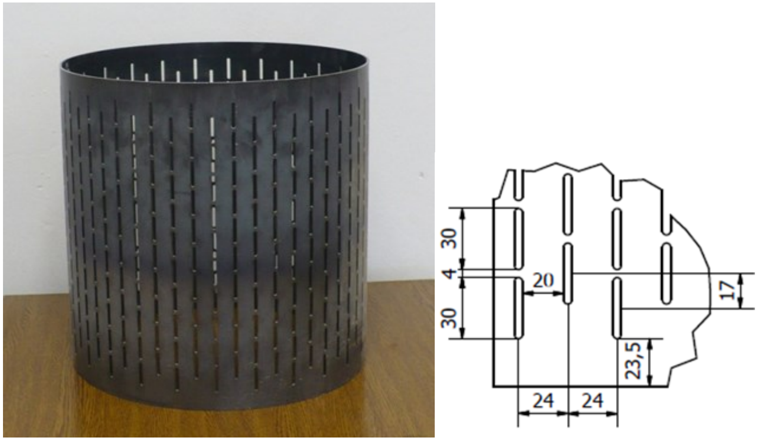

Figure 2. General view and diagram of the wire mesh cylinder with 4×30 mm longitudinal openings (Kolankowska, 2019).

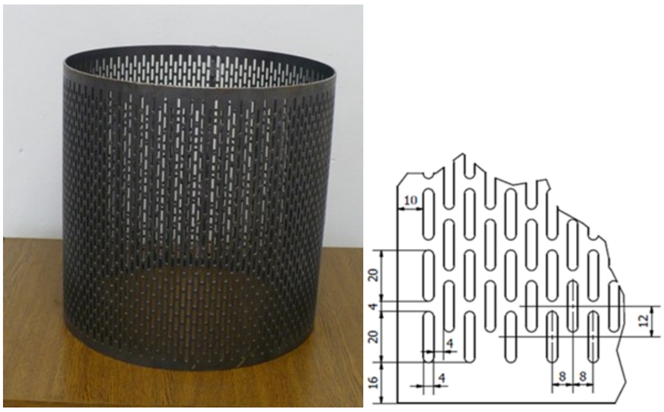

Figure 3. General view and diagram of the wire mesh cylinder with 4×20 mm longitudinal openings (Kolankowska, 2019).

According to the methodology described previously by Anders et al., (2020), the following constant parameters were adopted in the process of dehulling spelt kernels in the test stand (Fig. 1): width of the grain inlet s_z = 10 mm, distance between the cylinder and beaters sr = 2 mm, sample mass m_p = 300 g, rubber impeller blades (red natural rubber (NR), 40ShA, thickness – 6 mm, hardness – 40±5 °ShA, elongation at break – min. 600%, tensile strength – 16 MPa, max. abrasion resistance – 210 mm^3). The values of the rotor blade angle (α_w) were as follows: 50°, 60°, 70°, 80° and 90°, and the angular speed of the shaft (ω_w) was 16.76, 23.04, 29.32, 35.60, and 41.89 rad·s^{-1}. The size of wire mesh openings was selected based on the geometric parameters of spelt grain, and independent variables were set based on the results of a preliminary analysis. The measurements were conducted in triplicate for every combination of variable factors, according to the algorithm presented in Figure 4. The results were processed statistically to calculate kernel separation efficiency η_z (%), husk separation efficiency η_p (%), and the proportion of damaged kernels U_z (%).

Harvested spelt spikelets were threshed, and whole kernels, damaged kernels, spikelets and glumes were separated from threshed material according to the methodology described previously by Anders et al., (2020). Mixture components were separated in a pneumatic separator (Kolankowska and Choszcz, 2018) (air flow rate – 7.5 m·s^{-1}) and a Fritsch Analysette 3 vibratory sieve shaker (Germany, serial No. 03.7200/04463) equipped with five mesh screens with longitudinal openings (4.0×20 mm, 3.5×20 mm, 3.0×20 mm; 2.5×20 mm, and 2.0×20 mm). Separation time was 3 minutes, and the amplitude of vibration was 0.1 mm.

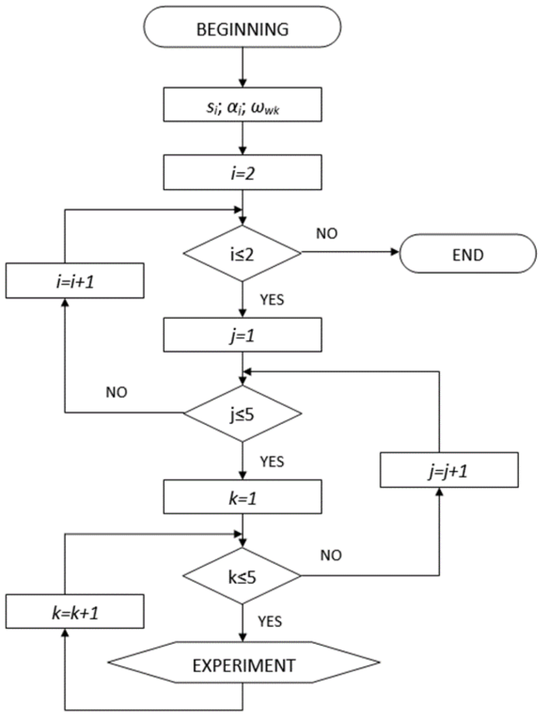

Figure 4. Algorithm for calculating the proportions of different components separated from threshed spelt spikelets: i, j, k – successive numbers (values) of variables (s, α, ω_w).

Each sample was analyzed to determine kernel and husk separation efficiency (η) and the proportion of damaged kernels (U_z) based on the mass of mixture components separated in the first stage of the experiment (Grochowicz, 1994):

– kernel separation efficiency (η_z):

$$\eta_z = \frac{m_z}{m_c} \cdot 100\% \quad (1)$$

– husk separation efficiency (η_p):

$$\eta_p = \frac{m_p}{m_m} \cdot 100\% \quad (2)$$

– the proportion of damaged kernels (U_z):

$$U_z = \frac{m_u}{m_c} \cdot 100\% \quad (3)$$

where:

m_z – mass of separated kernels, (g)
m_c – mass percentage of kernels in a sample, (g)
m_p – husk mass, (g)
m_m – mass percentage of husks in a sample, (g)
m_u – mass of damaged kernels, (g)

Measurement results were analyzed statistically using Statistica PL v. 13.1 software (Stanisz, 2007; Rabiej, 2012). A correlation analysis and a stepwise multivariate polynomial regression analysis for a second order polynomial model were performed.

Results and Discussion

Dehulling process

After collecting the material and compiling the results of the evaluation of the dehulling process, kernel separation efficiency was determined at 72.37% in the wire mesh cylinder with 4x20 mm longitudinal openings, and it was 5% lower at 67.21% in the cylinder with 4x30 mm longitudinal openings. Husk separation efficiency in wire mesh cylinders with 4x20 mm and 4x30 mm longitudinal openings reached 70.67% and 68.25%, respectively. The average proportion of damaged kernels was low at 1.00% in the wire mesh cylinder with 4x20 mm longitudinal openings and 0.59% in the wire mesh cylinder with 4x30 mm longitudinal openings (Tables 1 and 2).

Table 1.
Basic parameters of the process of dehulling spelt kernels in a wire mesh cylinder with 4x20 mm longitudinal openings.

No.	Variable	Mean	Standard deviation	Coefficient of variation (%)
1.	Rotor blade angle α_w (°)	70.00	14.434	20.62
2.	Angular speed ω_w (rad·s^{-1})	29.32	9.067	30.92
3.	Proportion of damaged kernels U_z (%)	1.00	0.699	69.85
4.	Kernel separation efficiency η_z (%)	72.37	8.142	11.25
5.	Husk separation efficiency η_p (%)	70.67	11.015	15.59

Table 2.
Basic parameters of the process of dehulling spelt kernels in a wire mesh cylinder with 4x30 mm longitudinal openings.

No.	Variable	Mean	Standard deviation	Coefficient of variation (%)
1.	Rotor blade angle α_w (°)	70.00	14.434	20.62
2.	Angular speed ω_w (rad·s^{-1})	29.32	9.067	30.92
3.	Proportion of damaged kernels U_z (%)	0.59	0.436	74.25
4.	Kernel separation efficiency η_z (%)	67.21	9.882	14.70
5.	Husk separation efficiency η_p (%)	68.25	8.126	11.91

Anders et al. (2020) separated spike kernels in a wire mesh cylinder with 4x4 mm square openings, and the average proportion of damaged kernels was around 4% higher, average kernel separation efficiency was 15-20% lower, and husk separation efficiency was approximately 28% lower in comparison with the values obtained in the present study.

Kernel damage

The results of the statistical analysis examining the impact of different rotor blade angles and different angular speeds in a dehuller with wire mesh cylinders with 4×20 mm and 4×30 mm longitudinal openings on the proportion of damaged spelt kernels are presented in Tables 3 and 4.

The results of the multiple regression analysis revealed that the linear correlation coefficient for the proportion of spelt kernels that were damaged by the impact of mechanical friction at the tested rotor blade angles ranged from 0.32 to 0.56. An increase in angular speed increased the proportion of damaged spelt kernels. The linear correlation coefficient was 0.6 for the wire mesh cylinder with 4×20 mm longitudinal openings and 0.72 for the wire mesh cylinder with 4×30 mm longitudinal openings.

The models describing the correlations between process variables and the proportion of damaged kernels (Tables 3 and 4) fit empirical data very well. The coefficient of multiple correlation was 0.75 for the wire mesh cylinder with 4×20 mm longitudinal openings, and it exceeded 0.89 for the wire mesh cylinder with 4×30 mm longitudinal openings.

The formula for calculating the percentage of spelt kernels damaged at different rotor blade angles and angular speeds of the shaft is presented graphically in Figure 5. The analysis revealed that the proportion of damaged kernels decreased with a reduction in the rotor blade angle and increased with a rise in angular speed.

Table 3.
A regression equation describing the proportion of spelt kernels damaged during the dehulling process in a wire mesh cylinder with 4×20 mm longitudinal openings.

General data: Correlation coefficients are significant at α <0.05, N = 25					
Correlation matrix					
		α_w	ω_w		U_z
α_w		1.0000	-0.0000		**-0.5561**
ω_w			1.0000		**0.6044**
U_z					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term				0.21683	5.30810
ω_w^2	33.15	0.75	0.3645	0.00024	8.02655
$\alpha_w \cdot \omega_w$				0.00017	-5.73921
Formula adopted after stepwise elimination of non-significant effects					
$U_z = 0.0019 \cdot \omega_w^2 - 0.0010 \cdot \alpha_w \cdot \omega_w + 1.1509$					

Table 4.
A regression equation describing the proportion of spelt kernels damaged during the dehulling process in a wire mesh cylinder with 4×30 mm longitudinal openings

General data: Correlation coefficients are significant at α <0.05, N = 25					
Correlation matrix					
		α_w	ω_w		U_z
α_w		1.0000	-0.0000		-0.3178
ω_w			1.0000		**0.7167**
U_z					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term				0.10329	1.85787
α_w^2	57.53	0.89	0.1535	0.00004	4.85529
ω_w^2				0.00024	9.02930
$\alpha_w \cdot \omega_w$				0.00020	-6.71522
Formula adopted after stepwise elimination of non-significant effects					
$U_z = 0.0002 \cdot \alpha_w^2 + 0.0022 \cdot \omega_w^2 - 0.0014 \cdot \alpha_w \cdot \omega_w + 0.1919$					

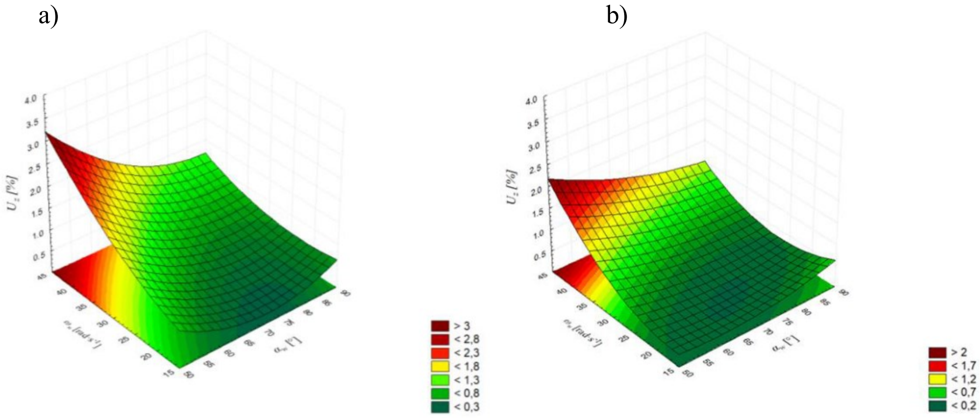

Figure 5. Proportion of spelt kernels damaged (U_z) at different rotor blade angles α_w (°) and angular speeds of the shaft ω_w (rad·s^{-1}): a – in a wire mesh cylinder with 4×20 mm longitudinal openings, b – in a wire mesh cylinder with 4×30 mm longitudinal openings.

Kernel separation efficiency

Kernel separation efficiency in the studied wire mesh cylinders (Tables 5 and 6) was bound by a strong linear correlation with the angular speed of the shaft, and the correlation coefficient ranged from 0.85 to 0.97. Kernel separation efficiency was bound by a weak linear correlation with the rotor blade angle, and the correlation coefficient ranged from 0.06 to 0.15. In turn, multiple regression equations describing kernel separation efficiency in the dehuller provided good and very good fit to empirical data. The coefficient of determination R^2 reached from 0.81 to 0.97.

Table 5.
A regression equation describing kernel separation efficiency during the dehulling process in a wire mesh cylinder with 4×30 mm longitudinal openings.

General data: Correlation coefficients are significant at α <0.05; N = 25					
Correlation matrix					
	α_w		ω_w		η_z
α_w	1.0000		-0.0000		-0.1352
ω_w			1.0000		**0.9676**
η_z					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term	185.33	0.97	1.7546	10.9017	5.8220
α_w				0.2946	-3.3723
α_w^2				0.0021	3.0692
ω_w				0.3141	5.6413
ω_w^2				0.0053	-2.3022
Formula adopted after stepwise elimination of non-significant effects: $\eta_z = -0.9936 \cdot \alpha_w + 0.0064 \cdot \alpha_w^2 + 1.7718 \cdot \omega_w - 0.0122 \cdot \omega_w^2 + 63.4694$					

Table 6.
A regression equation describing kernel separation efficiency during the dehulling process in a wire mesh cylinder with 4×20 mm longitudinal openings.

General data: Correlation coefficients are significant at α <0.05 N = 25					
Correlation matrix					
		α_w	n_w		η_z
α_w		1.0000	-0.0000		-0.0652
ω_w			1.0000		**0.8484**
η_z					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term	15.97	0.81	4.0116	28.1617	3.5446
α_w				0.6992	-2.5356
α_w^2				0.0048	2.4969
ω_w				0.8459	1.9082
ω_w^2				0.0121	-1.3976
$\alpha_w \cdot \omega_w$				0.0064	0.3208
Quadratic equation for two independent variables $\eta_z = -1.7729 \cdot \alpha_w + 0.0120 \cdot \alpha_w^2 + 1.6141 \cdot \omega_w - 0.0170 \cdot \omega_w^2 - 0.0020 \cdot \alpha_w \cdot \omega_w + 99.8208$					
Stepwise regression did not change the degree of the polynomial function for two independent variables					

The correlation between kernel separation efficiency vs. the rotor blade angle and the angular speed of the shaft is presented graphically in Figure 6.

a) b)

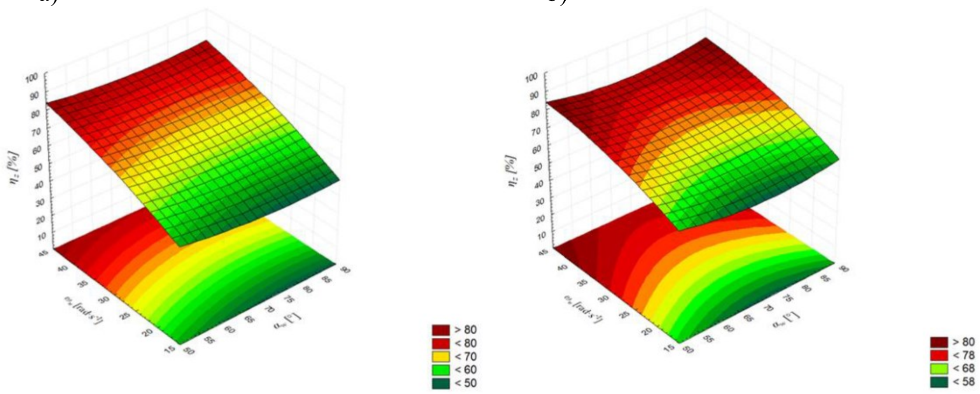

Figure 6. Kernel separation efficiency at different rotor blade angles α_w (°) and angular speeds of the shaft ω_w (rad·s^{-1}): a - in a wire mesh cylinder with 4×30 mm longitudinal openings, b - in a wire mesh cylinder with 4×20 mm longitudinal openings.

Kernel separation efficiency increased in a linear manner with a rise in the angular speed of the shaft. The rotor blade angle exerted a weaker and more ambiguous effect on the evaluated parameter. Kernel separation efficiency was highest at an angular speed of 42 rad·s^{-1} and a rotor blade angle of 45°.

Husk separation efficiency

The results of the statistical analysis examining the impact of different rotor blade angles and different angular speeds on husk separation efficiency in the examined wire mesh cylinders are presented in Tables 7 and 8. Husk separation efficiency in wire mesh cylinders with 4×20 mm and 4×30 mm longitudinal openings was strongly correlated with the angular speed of the shaft (0.84 and 0.88, respectively) and weakly correlated with the rotor blade angle (0.17 and 0.24, respectively). The multiple regression equations describing husk separation efficiency provided good and very good fit to empirical data. The coefficient of determination reached 0.93 for wire mesh cylinders with both 4×20 mm and 4×30 mm longitudinal openings.

The quadratic equations describing husk separation efficiency at different rotor blade angles and different angular speeds of the shaft are presented in Figure 7. Husk separation efficiency was highest at an angular speed of 16.76 rad·s^{-1} and a rotor blade angle of 50°.

Table 7.
A regression equation describing husk separation efficiency during the dehulling process in a wire mesh cylinder with 4×20 mm longitudinal openings.

General data: Correlation coefficients are significant at α <0.05 N = 25					
Correlation matrix					
		α_w	n_w		η_p
α_w		1.0000	-0.0000		-0.1682
ω_w			1.0000		0.8443
η_p					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term	48.59	0.93	3.3340	23.4047	5.9236
α_w				0.5811	-5.6263
α_w^2				0.0040	6.4077
ω_w				0.7030	2.9956
ω_w^2				0.0101	-0.0758
$\alpha_w \cdot \omega_w$				0.0053	-2.7869
Quadratic equation for two independent variables $\eta_p = -3.2694 \cdot \alpha_w + 0.0255 \cdot \alpha_w^2 + 2{,}1058 \cdot \omega_w - 0.00\,8 \cdot \omega_w^2 - 0.0148 \cdot \alpha_w \cdot \omega_w + 138.6395$					
Stepwise regression did not change the degree of the polynomial function for two independent variables					

Table 8.
A regression equation describing husk separation efficiency during the dehulling process in a wire mesh cylinder with 4×30 mm longitudinal openings

General data: Correlation coefficients are significant at α <0.05 N = 25					
Correlation matrix					
		α_w	n_w		η_p
α_w		1.0000	-0.0000		-0.2378
ω_w			1.0000		**0.8833**
η_p					1.0000
Variable	F-statistic	Coefficient of determination R^2	Standard error of the estimate	Standard error of regression	t-statistic (22)
Free term	86.40	0.93	2.3781	13.5997	9.0703
α_w				0.3993	-4.6962
α_w^2				0.0028	4.3765
ω_w^2				0.0009	14.9738
Formula adopted after stepwise elimination of non-significant effects $\eta_p = -1.8754 \cdot \alpha_w + 0.0124 \cdot \alpha_w^2 + 0.0136 \cdot \omega_w^2 + 123.3532$					

a) b)

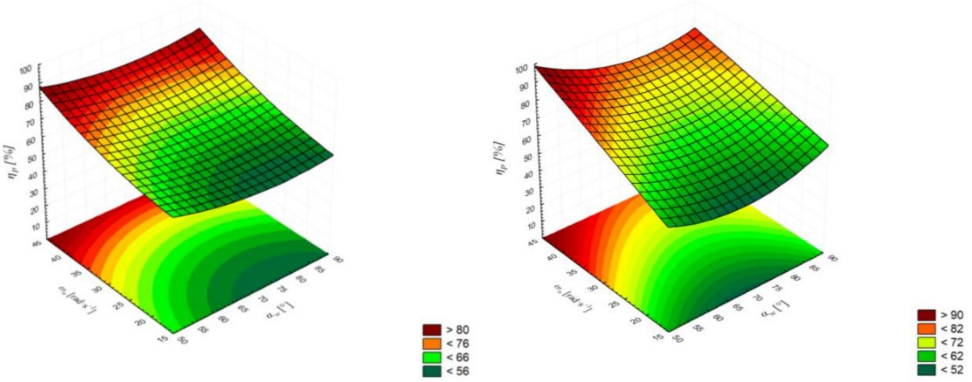

Figure 7. Husk separation efficiency at different rotor blade angles α_w (°) and angular speeds of the shaft ω_w (rad ·s^{-1}): a – in a wire mesh cylinder with 4×30 mm longitudinal openings, b – in a wire mesh cylinder with 4×20 mm longitudinal openings

In the tested dehuller with adjustable angular speed and rotor blade angle, spelt kernels were separated from husks by the mechanical impact of friction. In a dehuller equipped with a wire mesh cylinder with 4×30 mm longitudinal openings, kernel separation efficiency η_z was the highest (81.86%) at an angular speed of 41.89 rad ·s^{-1} and a rotor blade angle of 50°. The above variant was also characterized by the highest husk separation efficiency η_p (84.04%) and the highest proportion of damaged kernels U_z (2.17%). In a dehuller equipped with a wire mesh cylinder with 4×20 mm longitudinal openings, kernel separation efficiency η_z peaked (81.60%) at the angular speed of 41.89 rad·s^{-1} and a rotor blade angle of 80°. In the above variant, husk separation efficiency η_p reached 84.04%, and the proportion of damaged kernels U_z reached 1.38%. In a study by Anders et al., (2020), spelt kernels were less effectively separated from spikelets in a wire mesh cylinder with 4×4 mm square openings. The proportion of damaged kernels was around 10% lower in a dehuller equipped with wire mesh cylinders with 4×30 mm and 4×20 mm longitudinal openings than in a wire mesh cylinder with 4×4 mm square openings. In turn, Taddei et al., (2009) found that the dehulling of einkorn (non-threshing wheat) by impact dehullers, where the spikelets were hit, resulted in a high percentage of damaged kernels, approximately 30%.

Kernel and husk separation efficiency was approximately 15% and 25% higher, respectively, when wire mesh cylinders with longitudinal openings were used, compared with a wire mesh cylinder with 4×4 mm square openings (Anders at al., 2020). According to Tyburski and Babalski (2006), when using an appropriately processed clover beetle for spelt dehulling, the efficiency of separating grains for spelt grown on poor soils and ranged from 40 to 60%, and for spelt grown on more fertile soils it reached 70% of the yield. The authors (Tyburski and Babalski 2006, Budzyński (ed.) 2012, Choszcz et al., 2010) indicate that the dehulling process should be repeated several times and each time the dehulled grain should be sieved in a winnowing machine, which makes it energy-intensive and increases the damage to the grains. With the use of specialized machinery mainly produced in Western Europe, which allows the removal of chaff from about 90% of the grains, maintaining germination capacity of 80-90% (Heger GmbH &Co 2013, Babalski et al. 2013, Tyburski and Babalski 2006).

The spelt grain dehulling process is significantly affected by both analyzed variables, i.e. the angular speed of the shaft (ω_w) and the rotor blade angle (α_w). The proposed models for describing the correlations between kernel mass (M_z), proportion of damaged kernels (U_z), kernel separation efficiency (η_z), and husk separation efficiency (η_p) vs. angular speed and the rotor blade angle can be used to predict a dehuller's performance in the process of removing husks from other cereal species, including einkorn and emmer wheat.

Conclusions

The developed spelled grain dehuller with the possibility of changing the angle of inclination of the rotor blades and the rotational speed of the rotor shaft with the use of mesh cylinders with 4×30 mm and 4×20 mm longitudinal openings is characterized by high efficiency of dehulling the grains from the chaff, while maintaining a low degree of their damage. Among the tested wire cylinders, the wire cylinder with 4×20 mm longitudinal openings had the best characteristics in terms of the separated mass of grains and their low damage.

Dependent variables describing the dehulling process of spelt grain (the proportion of damaged kernels, kernel separation efficiency, and husk separation efficiency) can be represented by linear equations or a second order polynomial model with stepwise elimination of nonsignificant effects, with the rotor blade angle and the angular speed of the shaft as the independent variables.

The multiple regression equations describing the dehulling process in a wire mesh cylinder with 4×20 mm and 4×30 mm longitudinal openings were characterized by good and very good fit to empirical data. The coefficient of determination R^2 ranged from approximately 0.70 to 0.90.

The present findings indicate that the dehulling efficiency of spelt is significantly influenced by both analyzed variables, i.e. the angular speed of the shaft (ω_w) and the rotor blade angle (α_w).

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ANALIZA PROCESU OBŁUSKIWANIA ORKISZU W SEPERATORZE CYLINDRYCZNYM

Streszczenie. Orkisz jako pszenica miewymłacalna wymaga dodatkowego procesu obłuskiwania, w którym zostają usunięte z ziarna plewy i plewki. W pracy przedstawiono rozwiązanie konstrukcyjne obłuskiwacza ziarna orkiszu. W pracy przedstawiono rozwiązanie konstrukcyjne obłuskiwacza ziarna orkiszu. Istotą rozwiązania jest zastosowanie w badaniach powierzchni trącej w postaci sita cylindrycznego stalowego o otworach podłużnych 4×20 mm i 4×30 mm wyposażonego w wirnik z możliwością regulacji kąta pochylenia jego łopat. W urządzeniu stosowano pięć prędkości kątowych wału wirnika: 16,76; 23,04; 29,32; 35,60 oraz 41,89 rad·s^{-1} oraz pięć kątów położenia łopat wirnika: 50°, 60°, 70°, 80°, oraz 90°. Przeprowadzony eksperyment pozwolił ocenić efektywność usuwania plew i plewek z ziarna orkiszu pod kątem: uszkodzeń i skuteczności wydzielenia ziarniaków oraz skuteczności wydzielenia plew. Stosując jako powierzchnię trącą cylinder sitowy o otworach podłużnych 4×30 mm największa skuteczność wydzielenia ziarniaków ηz wynosiła 81.86%. W przypadku cylindra sitowego o otworach podłużnych 4×20 mm największa skuteczność wydzielenia ziarniaków ηz 81.60%.

Słowa kluczowe: *Triticum spelta* L., ziarno, plewy, omłot, obłuskiwanie, wydajność