

Influence of technical and technological parameters on the barley dehulling process

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Abstract

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Introduction. The research aim is to determine effect of duration of dehulling, the barley size and moisture, the rotation speed of abrasive discs, the abrasive grit and the load factor of the dehuller on the dehulling index.

Materials and methods. The dehulling was carried out in laboratory dehuller (model ULZ-1) at the rotation speed of abrasive discs of $29.6 \pm 0.015 \text{ s}^{-1}$ (1775 \pm 0.9 rpm) and $42.3 \pm 0.013 \text{ s}^{-1}$ (2540 \pm 0.8 rpm) and removing of barley husks and meal was conducted in the laboratory aspiration duct of 60 mm width.

Results and discussion. The research has shown that the increase in the dehulling duration the weight of the barley loaded to the dehuller, the rotating rate of abrasive discs and the load coefficient of the dehuller working chamber leads to the dehulling index rise. There exists the non-linear dependence between the load coefficient of the dehuller working chamber with the minimum point of the dehulling index for the large fraction of barley 0.27–0.28 and for the small fraction of barley 0.24–0.25.

The influence of the barley weight and the load coefficient of the working chamber of the dehuller on the dehulling index occurs according to the curvilinear dependence with the minimum point of the dehulling index for the large barley fraction of 0.27–0.28 and for the small barley fraction of 0.24–0.25. The increase in the processing duration and the load coefficient of the working chamber of the dehuller leads to the increase of the dehulling index, but at the same time the minimum point of the dehulling index decreases from 0.29 to 0.25.

As the size of the barley grows, the dehulling index decreases. The gain in moisture of the barley leads to the decrease of the dehulling index according to the linear dependence for both large and small barley fractions. Moreover, the small fraction has the bigger values of the dehulling index than the large one.

The moisture influence on the dehulling index has linear dependence for both large and small barley fractions. As moisture increases the dehulling index decreases linearly, but at the same time the large barley fraction had lower values of the dehulling index than the small one.

The increase in abrasive discs grit leads to the dehulling index decrease according to the curvilinear dependence. At the grit of 80 the dehulling index gets the constant value and its change depends on the duration of processing.

Conclusion. The influence of technological parameters of barley grain on the dehulling index has linear dependence, and machine parameters affect the dehulling index according to curvilinear dependency. These results must be considered when evaluating the effectiveness of dehulling and the development of the process model.

Introduction

The barley grain is the basis for various food products, such as groats and flour. During the barley processing it is treated to separate the hull. The process of dehulling has not been studied enough so as to predict its effectiveness during the use of various hullers.

The process of barley dehulling is influenced by the load on the machine, the distance between abrasive discs and the sieve plate, the abrasive discs grit, and the treatment duration in the dehulling machine (Izydorczyk et al., 2016). This process is also influenced by the moisture and the size of barley (Bhatty, 1997; Sharma et al., 2010). Different barley varieties have different capacities for the dehulling (Edney et al., 2002; Felizardo et al., 2018).

Abrasive surfaces with the lower grit lead to quicker removing barley hull, whereas abrasive surfaces with greater grit result in a thinner product (Flores et al., 2007; McCluskey, 2016). The dependence between abrasive discs grit and dehulling index is not stated, therefore further investigation is required.

The increase of the grain weight in the dehulling machine leads to the increase of the dehulling index according to the nonlinear dependence (Kharchenko et al., 2017; Vereshchinskii, 2011); the dependences of the dehulling index during the moisture change, the size and the weight of the loaded grain in the machine have not been studied yet.

The increase in the barley treatment duration leads to the linear increase of the dehulling index (Kharchenko et al., 2017; Sharma et al., 2010), but there is no explanation of the dehulling index linear dependence from the treatment duration.

Baltabaev et al. (2011) studied the effectiveness of barley dehulling in the horizontal dehulling machine of continuous operation. This analysis shows that at the rotation speed of the rotor of 1800 rpm the dehulling coefficient is higher than at the rotation speed of 1500 rpm, but at the rotation speed of the rotor of 1650 rpm the coefficient is much less than at the speed of 1500 rpm. This data requires verification and justification. Baltabaev et al., (2011) showed the linear dependence of the dehulling index from the dehulling duration in the machine at varying rotation speeds of the rotor of the machine.

Olkku et al. (2005) illustrated the linear dependence of the husk weight change from the barley moisture; however, there are no similar dependences between the barley moisture and the dehulling index. The increase of the barley moisture to 14% decreases the dehulling duration (Sharma et al., 2010). The impact of the barley moisture and the size on its dehulling effectiveness requires further investigations (Edney et al., 2002).

The similarity of the barley size also influences the dehulling index (Izydorczyk et al., 2016). Sharma et al. (2010) showed that there exists negative correlation between the dehulling coefficient and the bulk density. The barley with the bigger kernel weight requires more time for processing to achieve necessary values of the dehulling index (Edney et al., 2002). This proves the influence of the barley size on the dehulling index and requires further investigations of the influence of the barley size and moisture on the dehulling index under the conditions of varying treatment duration, weight of the loaded grain into the dehuller, different load coefficient of the machines' working chamber.

The research aim is to determine effect of duration of dehulling, the barley size and moisture, the rotation speed of abrasive discs, the abrasive grit and the load factor of the dehuller on the dehulling index.

Materials and methods

Preparation of the barley samples

The barley grain was cleaned in the laboratory aspiration channel before carrying out research to separate light impurity. The removing of impurity and separation into the large and small fraction was conducted in the Carter-Day dockage tester (Carter-Day Co., Minneapolis, MN) (Arya et al., 2011; Fan et al., 2000; McCluskey, 2016; Sissons et al., 2000). The riddling of the grain sieve of 3.0×20 mm allowed to get a large fraction and the scalp of the grain sieve of 3.0×20 mm and the riddling of the grain sieve of 1.8×20 mm allowed to get a small fraction of the barley grain. The scalp of the grain sieve of 1.8×20 mm removed small impurity and directed it to wastes.

After their cleaning and fractions' separation there was defined the grain moisture (ISO 712:2009(E). Cereals and cereal products. Determination of moisture content), the weight of 1000 grains on a dry basis (ISO 520:2010. Cereals and pulses – Determination of the mass of 1000 grains) and the bulk density (ISO 7971-3:2009(E). Cereals – Determination of bulk density, called mass per hektolitre) in each barley grain fraction.

The barley with the weight of 1000 grains on a dry basis $A=56$ g and the bulk density $\gamma=711\pm 8$ kg/m³ was attributed to the large fraction, and the barley with the weight of 1000 grains on a dry basis $A=43$ g and the bulk density $\gamma=686\pm 3$ kg/m³ was attributed to the small fraction. The initial moisture of both fractions was 12.6±0.2%.

Studying the impact of the duration of treatment on the barley dehulling

The barley dehulling was carried out in the dehuller ULZ-1 (Olis, Odesa, Ukraine), with the abrasive discs 14AF46K7V and the grit 40. The size of the openings of the grain sieve in the dehulling machine was $\varnothing 2.3$ mm.

The studying of the impact of the duration of treatment on the barley dehulling index was carried out according to the following methods. The sample weight of 100±0.01 g was loaded into the dehuller and hulled during 20, 40, 60, 80, 100 s. The change of the dehulling duration was provided with the timer of the dehulling machine. The large and the small barley fractions were hulled separately under similar conditions.

The studying of the dehulling kinetics of the large and small barley fractions was conducted at the rotation speeds of the dehuller's abrasive discs $\omega=29.6\pm 0.015$ s⁻¹ (1775±0.9 rpm) and $\omega=42.3\pm 0.013$ s⁻¹ (2540±0.8 rpm). The rotation speed was changed by means of throwing over the belt on the engine pulley and abrasive discs.

The rotation speed of abrasive discs was measured by means of the optical tachometer Testo 460. The reflecting tape was attached to the dehuller's pulley, then the dehuller was turned on in the idle position without grain, the tachometer beam was pointed at the pulley and the readings of the tachometer were taken.

Dehuller works as follows (Figure 1). The grain is loaded into the hopper (11). At a certain time, the latch (10) opens and the grain is poured into the working chamber between the abrasive discs (8), the screen (9) and the housing (1). The distance between the abrasive discs (8) and the screen (9) is 0.015±0.001 m. Grain moves in a circle admiring abrasive discs (8). During the movement, the grain interacts with the screen and the friction between grains. After stopping the dehuller, the latch (12) opens and the dehulling products are poured into the middle hopper. Products that have passed through the screen are collected in two side bins. Abrasive discs (8) with a diameter of 0.150±0.0001 m are firmly pressed together and do not have gap between them.

After the dehulling the mixture of the derived products was passed through the laboratory aspiration channel with 60 mm width, where the separation of the husk and the meal from the kernel occurred. To avoid getting of separate grains into the husk tank, the air flow rate in the channel was decreased by means of speed reduction of the fan impeller by using variable speed drive. After each replicate the kernel was visually examined for the presence of the husk and the meal. Whenever necessary, the cleaned kernel was passed through the aspiration channel repeatedly. The mixture of the husk and the meal was also examined for the presence of the kernel. The Figure 1 shows the scheme of the barley dehulling (Kharchenko et al., 2018).

The cleaned barley kernel was weighted and the dehulling index was calculated according to the formula (Donkelaar et al., 2015; Felizardo and Freire, 2018; Lawton et al., 1989):

$$I = \frac{m_1 - m_2}{m_1} \cdot 100 \quad (1)$$

where I is the barley dehulling index, %; m_1 , m_2 are the weight of the grain before the dehulling and the weight of the barley kernel after the dehulling correspondingly, g.

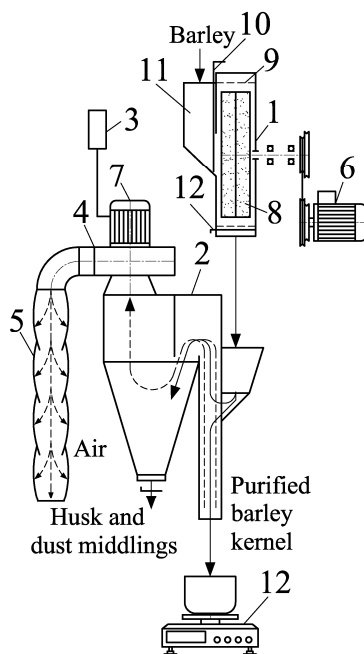


Figure 1. Barley dehulling scheme:

- 1 – dehusser; 2 – laboratory aspiration channel; 3 – variable speed drive; 4 – fan; 5 – filter; 6,7 – engine; 8 – abrasive discs; 9 – the size of the openings Ø 2.3 mm; 10 – choke; 11 – bin; 12 – scale.

The studying of the dehulling kinetics was carried out for both dry and moist, large and small barley fractions. The estimated amount of water was added in large and small barley

fractions, each of 2 ± 0.1 kg, assuming that the final water content of each fraction was 16.0%. The water amount was calculated according to the formula (Barnwal et al., 2010):

$$G_w = G_g \left(\frac{W_1 - W_0}{100 - W_1} \right), \quad (2)$$

where G_w , G_g are the weight of water and the weight of grain, correspondingly, g; W_0 , W_1 are the initial and specified grain moisture, correspondingly, %.

After adding water there was a three days' grain maturing process. During the studying process the actual moisture of the barley of each fracture was defined.

Impact of barley weight and the load coefficient on the barley dehulling index

The impact of barley weight on the dehulling index was found out by increasing the weight of the grain loaded into the dehuller in the amount of 40, 80, 120, 160 and 200 g. Notice that in doing this the rotation speed of abrasive discs of the dehuller was constant and equal to $29.6 \pm 0.015 \text{ s}^{-1}$, the dehulling duration was constant and equal to 25 s. Abrasive discs were not changed and were the same as during research, as illustrated in the clause 2.2. The dehulling index was calculated according to the formula 1.

The load coefficient of the working chamber was calculated in accordance with the formula (Kharchenko et al., 2017):

$$K = \frac{V_g}{V_m} \quad (3)$$

where K is load coefficient of the dehuller's working chamber; V_g is grain volume, loaded into the dehuller, m^3 ; V_m is volume of the dehuller's working chamber, m^3 .

The grain volume was calculated using the formula:

$$V_g = \frac{m}{\gamma} \quad (4)$$

where m is weight of the barley grain, loaded into the dehuller, kg; γ is barley bulk density, kg/m^3 .

The volume of the dehuller's working chamber was calculated using the formula:

$$V_m = \frac{\pi D^2}{4} \cdot H - \frac{\pi d^2}{4} \cdot h \quad (5)$$

where D , d is the diameter of the grain sieve of the dehuller and the abrasive disc correspondingly, m; H , h is the height of the grain sieve of the dehuller and abrasive discs correspondingly, m.

The diameter of the grain sieve was $D=0.165 \pm 0.0001$ m, the diameter of discs was $d=0.15 \pm 0.0001$ m. The height of the grain sieve was $H=0.058 \pm 0.001$ m, the width of abrasive discs was $h=0.04 \pm 0.0001$ m.

The analysis was conducted separately for the large and small fractions of both dry and moistened grain.

After each replication the dehulling products were passed through laboratory aspiration channel to separate the husk from the dust middling. The dehulling index was calculated using the methods described in the clause 2.2.

Impact of loading and duration of treatment on the barley dehulling index

The large barley fraction was hulled in the amount of 40 ± 0.1 g to 200 ± 0.1 g at intervals of 40 g. The rotation speed of abrasive discs was constant and equal to 29.6 ± 0.015 s⁻¹. The dehulling duration varied from 40 to 100 s at intervals of 20 s. The research was conducted only with the large fraction with the level of moisture $12.6\pm 0.2\%$. The product purification as well as the dehulling index determination was carried out similarly to the description in the clause 2.2 (Kharchenko et al., 2018).

Impact of moisture on the barley dehulling index

To define the impact of the barley moisture on the dehulling process effectiveness, the large and small fractions of the barley were moistened to 16.0%.

Moisturizing and maturation of the barley was carried out according to the following techniques. Six containers with compact lids were filled with 200 ± 0.1 g of barley. The amount of water calculated using formula 2 was added in each container. It was thoroughly mixed for 10 minutes and left in closed containers for three days for maturation and homogenous distribution of moisture over the barley grain (Kharchenko et al., 2018).

After moisturizing the dehuller was loaded with 160 ± 0.1 g of barley, the dehulling occurred with further separation of hull in the aspiration channel. The dehulling index was calculated using techniques showed in clause 2.2. The dehulling duration for all the sample weights was 25 s, at the rotational speed of abrasive discs 29.6 ± 0.015 s⁻¹. The residue of the moistened grain was used to define the actual moisture (Kharchenko et al., 2018).

Abrasive discs' grit impact on the barley dehulling index

To find out the impact of abrasive discs' grit on the dehulling index three abrasive discs were used: 14AF46K7V, 14AF60K7V, 14AF80K7V with the grit 40, 60, and 80 correspondingly. The large fractions of barley were hulled with the alternate change of abrasive discs in the dehuller. The rotation speed of abrasive discs was 29.6 ± 0.015 s⁻¹. The sample weights of 100 ± 0.1 g were put into the dehuller and hulled for 20, 40, 60, 80, 100 s. Purification of dehulling products was carried out in accordance with techniques shown in clause 2.2.

Results and discussion

Impact of the barley size and moisture on the dehulling index at varying speeds of abrasive discs rotation

The Figure 2 shows the results of dehulling kinetics research of large and small barley fractions with the moisture of $12.6\pm 0.2\%$, various speeds of abrasive discs' rotation of the dehuller 29.6 ± 0.015 s⁻¹ and 42.3 ± 0.013 s⁻¹.

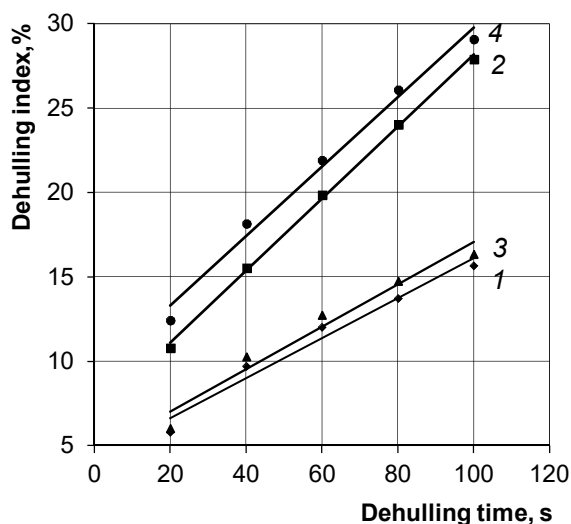


Figure 2. Effect of dehulling duration of barley on dehulling index:

Moisture of barley – $12.6 \pm 0.2\%$;

1 – $A=56$ g, $\omega=29.6 \pm 0.015$ s⁻¹;

2 – $A=56$ g, $\omega=42.3 \pm 0.013$ s⁻¹;

3 – $A=43$ g, $\omega=29.6 \pm 0.015$ s⁻¹;

4 – $A=43$ g, $\omega=42.3 \pm 0.013$ s⁻¹

(A is the weight of 1000 grains on a dry basis, g; kg/m³; ω is rotational speed of abrasive discs, s⁻¹)

The Figure 2 shows that the increase of the rotation speed of abrasive discs leads to the increase of the dehulling index ($P < 0.05$) of both large and small barley fractions. The inclination of the lines increased for both barley fractions ($P < 0.05$), that testifies to the higher intensity of abrasive discs' impact on the barley grain as the rotation speed of abrasive discs rises.

All things being equal, the dehulling index of the small fraction was higher than the dehulling index of the large barley fraction ($P < 0.05$). It gives the evidence that the dehulling resistance of the small barley fraction at the moisture of $12.6 \pm 0.2\%$ is less than the dehulling resistance of the large fraction at the same grain moisture. At the barley moisture of $12.6 \pm 0.2\%$ the impact of the barley size on the dehulling index was significant only at the rotation speed of abrasive discs of 42.3 ± 0.013 s⁻¹ ($P < 0.05$). The impact of the barley size on the dehulling index at the rotation speed of abrasive discs of 29.6 ± 0.015 s⁻¹ was not significant and ranged up to 1.0% ($P > 0.05$). The experiment has let us to conclude that the slower is the rotation speed of the dehuller's abrasive discs, the less the size of the grain influences the dehulling index.

The Figure 3 shows the results of dehulling index research of the large and small barley fractions at the moisture of $16.0 \pm 0.2\%$ and the rotation speed of abrasive discs of 29.6 ± 0.015 s⁻¹ and 42.3 ± 0.013 s⁻¹.

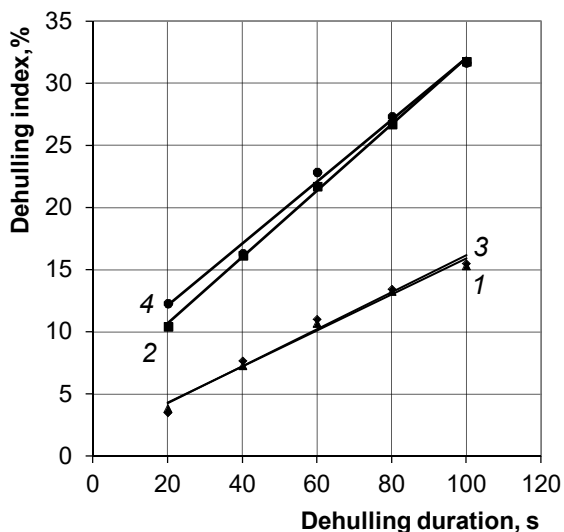


Figure 3. Effect of dehulling duration of barley on dehulling index:

Moisture of barley – $16.0 \pm 0.2\%$;

1 – $A=56$ g, $\omega=29.6 \pm 0.015$ s⁻¹;

2 – $A=56$ g, $\omega=42.3 \pm 0.013$ s⁻¹;

3 – $A=43$ g, $\omega=29.6 \pm 0.015$ s⁻¹;

4 – $A=43$ g, $\omega=42.3 \pm 0.013$ s⁻¹

(A is the weight of 1000 grains on a dry basis, g; kg/m³; ω is rotational speed of abrasive discs, s⁻¹)

Analysis of data presented in Figure 3 show that the size of barley with the moisture content of $16.0 \pm 0.2\%$ does not influence significantly the dehulling of the large and small grain ($P > 0.05$). The most substantial factors that changed the dehulling index were the rotation speed of abrasive discs and the processing duration. Comparing the results shown in Figure 2 and 3 one can see that the size has an impact only during dry barley hulling ($P < 0.05$), whereas the increase of the barley moisture reduces the influence of the barley size substantially. The results shown in Figure 2 and 3 also testify the fact that the rotation speed of abrasive discs is the factor that increases the dehulling index regardless of the barley moisture and size.

The dependence of the dehulling index from the duration of treatment is described with linear dependences (Sharma et al., 2010). This is due to the fact that the grain is an anisotropic body, hence its properties in various areas are different and the strength of the kernel and hull does not influence the kinetics of the process. The hull strength is much higher than the endosperm strength. The strength of fruit membranes, seed coats and the aleurone layer that makes 33 MPa at the grain moisture 10–12%; under the same conditions the endosperm strength is not more than 3 MPa that is 11 times less than the hull strength. Given this, one can suggest that during the cutting of hulls and proceeding to the endosperm there has to occur a shift from linear to curvilinear dependence because the endosperm has lower strength and being equally loaded from the side of abrasive discs it has to separate in higher quantities from the kernel than from the hull. However, the experimental data gives the evidence about the linear dependence of the dehulling index and the grain duration of treatment; besides, the linear dependence testifies to the constant dehulling speed (Lawton et al., 1996). All of this

implies that the kernel and hull strengths do not influence the linear dependences of the dehulling process all other things being equal.

The linear dependence of the barley kernel strength from the dehulling duration (Bhatty, 1997; Kharchenko et al., 2018) can be explained by the influence of the scale factor of the particles that are dehulled. As the size of the particles reduces the number of structural defects decreases that leads to the strengthening of these particles. The grain strength influences the dehulling index if different varieties of the barley are hulled because they have different strength all other things being equal (Bhatty et al., 1998; Brennan et al., 2017).

Impact of the barley size and moisture on the dehulling index at varying grain weight and load coefficient of the dehuller

The Figure 4 shows the impact of the grain weight loaded into the dehuller, the barley size, and the moisture on the dehulling index. As the moisture of large and small barley fractions increased, the dehulling index decreased in comparison with similar conditions of dry grain fractions' dehulling ($P < 0.05$). Dehulling indices of small moistened barley fractions were higher than the indices of dehulling of large moistened fractions ($P < 0.05$). It is proved by the fact that the small fraction had the lower dehulling resistance than the large barley fraction (Edney et al., 2002).

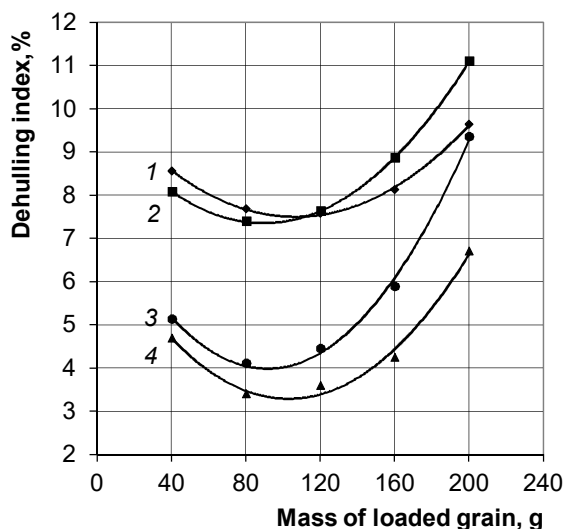


Figure 4. Effect of loaded grain weight on dehulling index:

1 – A=56 g; W=12.6%;

2 – A=43 g; W=12.6%;

3 – A=43 g; W=15.0%;

4 – A=56 g; W=15.0%

(A is the weight of 1000 grains on a dry basis, g; kg/m^3 ; W is moisture of grain,%)

The data in Figure 4 indicate that the barley moisture influences the dehulling index the most with the increase of the barley weight loaded into the dehuller ($P < 0.05$). The reduction of the dehulling index of large and small barley fractions with the moisture increase can be

explained by the fact that the moistened barley changed its structural-mechanical characteristics and moved from brittle to elastic-plastic state that resulted in the increase of the hull viscosity (Bargale et al., 1995) and led to the increase of dehulling resistance.

The calculation of the grain weight loaded into the dehuller as well as the barley-unit enables us to express these values in terms of the coefficient of working chamber load of the dehuller, which is a nondimensional quantity. This gives us an opportunity to compare the effectiveness of dehulling process in various dehullers similar in design. The Figure 5 shows us the dependencies of the dehulling index from the load coefficient of working chamber of the dehuller at various barley moisture and size. The general view of the curves is similar to those provided in Figure 4, but there are some differences that are connected with different bulk density of the large and small barley.

The data in Figure 5 show that curvilinear dependences have minimum points of the dehulling index: for the large barley fraction at load coefficients of working chamber 0.27–0.28, and for the small barley fractions at load coefficients of working chamber 0.24–0.25. The increase of the load coefficient of the device from 0.24–0.28 to 0.53–0.55 leads to the increase in the dehulling index regardless of the barley moisture and size ($P < 0.05$). The increase of the load coefficient of the device from 0.11 to 0.24–0.28 on the contrary, decreases the dehulling index ($P < 0.05$).

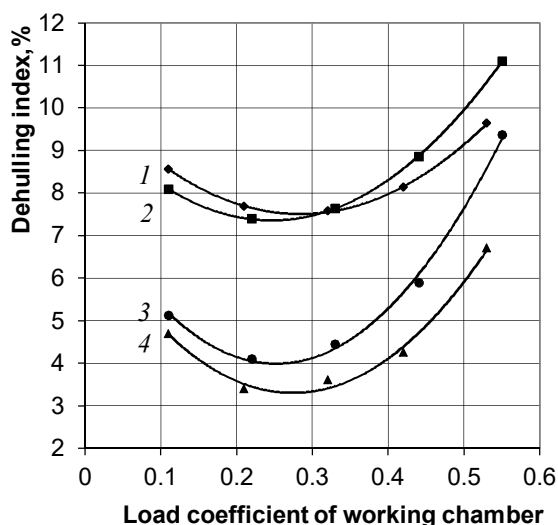


Figure 5. Effect of load coefficient of working chamber and the barley moisture on dehulling index:

1 – A=56 g; W=12.6%;

2 – A=43 g; W=12.6%;

3 – A=43 g; W=15.0%;

4 – A=56 g; W=15.0%

(A is the weight of 1000 grains on a dry basis, g; kg/m^3 ; W is moisture of grain,%)

The curvilinear dependence of the dehulling index and the load coefficient is explained by the interaction peculiarities of abrasive discs and the barley. At load coefficient values of the working chamber of the dehuller from 0.11 to 0.28 the area of pseudo rare grain mass

appears with the random motion of separate barley grains as affected by the rotor rotation. The contact of the grains with the abrasive discs' surface is of short time. And herewith radially extending constituents of the interaction forces dominate those ones tangent to the working surface of the rotor. These conditions do not contribute to the effective barley dehulling (Vereshchinskii, 2011).

The increase of the load coefficient of the dehuller's working chamber from 0.28 до 0.53–0.55 leads to the qualitative change of interaction character of the abrasive discs' working surface with barley grain. The flow of pseudo rare grain mass becomes thicker, the tangent interaction forces increase, the working surface of abrasive discs "grips" the barley grain, that results in more durable phase contact. Under these conditions, the dehulling intensity as well as the processing intensity of the barley surface increases (Vereshchinskii, 2011).

The load coefficient of the working chamber of the dehuller can be considered as a factor that increases the dehulling index provided that the value of the load coefficient of the dehuller's working chamber exceeds the minimum point of the dehulling index, which is in the range of 0.24–0.28.

The differences in the load coefficients for large and small barley fractions can be explained by the fact that the bulk density influences the load coefficient of the working chamber of the dehuller ($P < 0.05$) and this value is a part of the calculation formula 4. The table 01 shows the differences in the load coefficients of the working chamber of the dehuller given that the weight of the loaded barley is equal but the bulk density is different.

Table 1

Load coefficients of the working chamber of the dehuller depending from the barley bulk density

Weight of the grain loaded into the dehuller, g	Load coefficient of large fraction at bulk density 711±8 kg/m ³	Load coefficient of small fraction at bulk density 686±3 kg/m ³
40±0.1	0.11	0.11
80±0.1	0.21	0.22
120±0.1	0.32	0.33
160±0.1	0.42	0.44
200±0.1	0.53	0.55

Influence of the dehulling duration and the load coefficient of the working chamber of the dehuller on the dehulling index of large barley fraction

The Figure 6 gives the results of research of the impact of the load coefficient of the working chamber of the dehuller and the barley duration of treatment on the dehulling index. As the duration of treatment and the load coefficient of the working chamber increase curvilinear dependences change their curvature so as the dehulling index rises ($P < 0.05$). All these testifies to the mutual influence of the load coefficient and the duration of treatment on the dehulling index. This kind of dependencies can be explained by the fact that the increase in the dehulling duration causes more separations of hulls and peripheral particles from the kernel, and the rise in the load coefficient of the working chamber of the dehuller increases additionally the kernel interaction with abrasive discs.

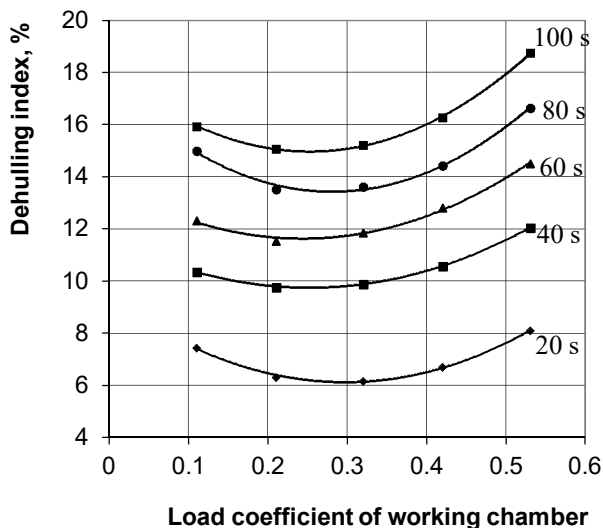


Figure 6. Effect of load coefficient of working chamber on dehulling index at different treatment duration

It should be noted that as the duration of treatment increases, the minimum point of the dehulling index decreases from 0.29 to 0.25 ($P < 0.05$).

Impact of the barley moisture on the barley dehulling index

The Figure 7 gives the results of research of the barley moisture influence on the dehulling index.

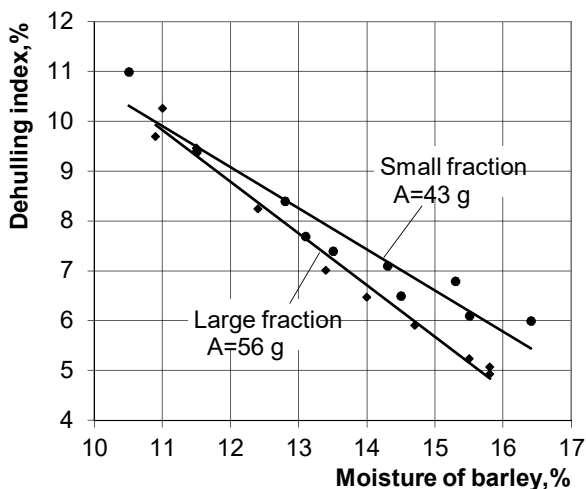


Figure 7. Effect of moisture of barley on dehulling index (Rotation speed of abrasive discs $29.6 \pm 0.015 \text{ s}^{-1}$)

As moisture increased the dehulling index decreased linearly for both large and small barley fractions ($P < 0.05$). The small fraction's dehulling index was higher than the large fraction's dehulling index ($P < 0.05$), and that proves the fact that the large barley creates stronger resistance to the dehulling than the small one (Edney et al., 2002).

The decrease in the dehulling index with the increase in barley moisture can be explained by the fact that the increase of the grain moisture leads to the increase of plastic properties of hulls that during the dehulling process create stronger resistance to dehulling (Bargale et al., 1995; Bhatta, 1997).

Impact of the abrasive discs grit on the dehulling index of the large barley fraction

The Figure 8 gives the results of research of the dehulling index of the large barley fraction with moisture of $10.9 \pm 0.05\%$ in the dehuller with abrasive discs of varying grit all other things being equal. The analysis of data, shown in Figure 8 indicates that as the abrasive discs' grit increases, the dehulling index decreases ($P < 0.05$). This is explained by the decreasing of discs' abrasive grain sizes (Flores et al., 2007).

Direct dependences, given in Figure 8 give the indirect understanding about the impact of the abrasive discs' grit on the dehulling index. Having transformed Figure 8 in a way that X-axis stands for abrasive discs' grit and the Y-axis stands for the dehulling index, we will get the dependences of the influence of abrasive discs' grit on the dehulling index at varying values of duration of treatment. The results of research are given in Figure 9.

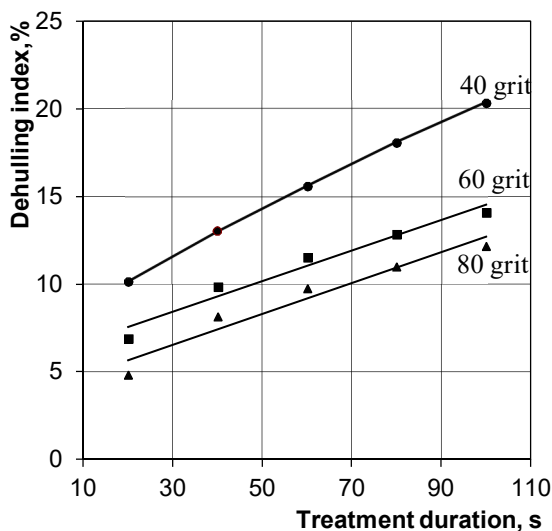


Figure 8. Effect of treatment duration on dehulling index at different grit of abrasive discs

The data, shown in Figure 9, indicate that there exists a nonlinear dependence between the dehulling index and the abrasive discs' grit, which is steadily growing with the increase in the barley duration of treatment. The Figure 9 also shows that the increase in the abrasive discs' grit of 80 leads to the constant value of the dehulling index.

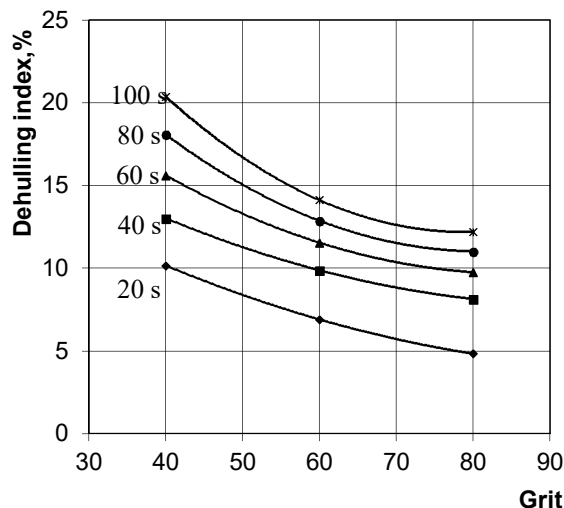


Figure 9. Effect of abrasive discs grit on dehulling index at different treatment duration

This development of the dehulling process results from the decrease of the abrasive grain size that plays a dominant role during the barley hulls' destruction. The increase in the abrasive discs' grit causes the decrease of the overall abrasive grain sizes that leads to the decrease in the number of hulls removed from the surface of the barley kernel by abrasive grains (Flores et al., 2007). Removing of hulls occurs not only by means of friction (Lawton et al., 1989), but also by means of sliding cutting, where the breakdown voltages concentrate on the microcutting abrasive grains and the bulk weight of the material is practically not changed (Agarwal, 2019).

Conclusions

Dehulling index increases at the increase of the barley dehulling duration, abrasive discs' rotation speed and the load coefficient of the working chamber more than 0.24–0.28. The increase in the barley size, its moisture content and the abrasive discs' grit leads to the dehulling index decrease.

The increase of the rotation speed of abrasive discs leads to the increase of the barley dehulling index.

All other things being equal, the large barley fraction's dehulling index is less than the small fraction's dehulling index. The size of the barley grains has a greater impact on dehulling index at low barley moisture content ($12.6 \pm 0.2\%$) and the abrasive discs' rotation speed of $42.3 \pm 0.013 \text{ s}^{-1}$. The decrease in the abrasive discs' rotation speed from $42.3 \pm 0.013 \text{ s}^{-1}$ to $29.6 \pm 0.015 \text{ s}^{-1}$ results in an inessential influence of the barley size on the dehulling index.

The influence of the barley weight and the load coefficient of the working chamber of the dehuller on the dehulling index occurs according to the curvilinear dependence with the minimum point of the dehulling index for the large barley fraction of 0.27–0.28, and for the small barley fraction of 0.24–0.25. The increase in the duration of treatment and the load coefficient of the working chamber of the dehuller leads to the increase of the dehulling

index, but at the same time the minimum point of the dehulling index decreases from 0.29 to 0.25.

The moisture influence on the dehulling index has linear dependence for both large and small barley fractions. As moisture increases the dehulling index decreases linearly, but at the same time the large barley fraction had lower values of the dehulling index than the small one.

The increase of the abrasive discs' grit from 40 to 80 decreases the dehulling index in accordance with the curvilinear dependence. All other things being equal as the abrasive discs' grit reaches 80 or more, the dehulling index stops changing, becoming a constant value.

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