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# MECHANICAL PROPERTIES OF SINGLE KERNEL OF WHEAT IN RELATION TO DEBRANNING RATIO AND MOISTURE CONTENT*

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A b s t r a c t. The paper presents the results of investigations on the mechanical properties of wheat kernels, obtained on the basis of uniaxial compression test. The results showed that both the debranning ratio and the kernel moisture content had a significant influence on the kernel mechanical properties. Debranning caused a decrease of kernel deformation up to the rapture point. The kernel moisture content also had an influence on this deformation – as the moisture content increased from 12 to 16% the deformation increased. Debranning also caused a decrease of rapture force and force at the end of compression (average of about 43 and 230%, respectively). The moisture content had no significant influence on these forces. Only for undebranned kernel the increase of moisture from 12 to 14% caused a decrease of rapture force. The changes of kernel loading force in the end of the compression were described by the linear regression equation, where the kernel ash content and the mass of individual kernel were taken as independent variables ($R^2$ = 0.914).

K e y w o r d s : wheat, mechanical properties, debranning, moisture

## INTRODUCTION

Many scientists are still interested in the mechanical properties of raw materials. On the basis on these properties, the correct working parameters of harvesting and processing machines can be selected. With reference to cereal kernel, in particular for wheat, we can also conclude about the end-use and the milling properties.

The mechanical properties of cereal kernels depend on many factors, such as genetic heritage, agro-technical methods or agro-environmental conditions [12]. They can also be modified during processing. With reference to wheat mechanical

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properties the most often described parameter is kernel hardness. But wheat hardness has no universally accepted definition. Some workers define hardness as the mechanical property of the individual wheat kernel, or resistance to deformation or crushing, whilst others define hardness as the property of mass of kernels [1,3]. Such a large amount of methods is caused by difficulties with wheat hardness evaluation. These difficulties result from complicated kernel structure and shape, small size, diversity in geometrical properties and presence of crease in kernel.

The mechanical properties of kernel depend mainly on the endosperm properties and the bran layers (fruit and seed coat, nucellus and aleurone) properties. During white flour production the bran layers should be removed from the endosperm. In the conventional milling system the bran layers are not removed prior to milling and separation of bran form the endosperm is carried out after each stage of grinding mainly by using sieving machines. In order to improve the milling process the properties of kernel bran layers can be modified [9]. However, the removal of the peripheral bran prior to milling (PeriTec milling system) results in higher extraction and higher quality of the finished product and the milling break system can be shortened [8].

There are few works concerning the mechanical properties of wheat kernel before and after debranning. Therefore, the aim of the present work was to determine the influence of wheat debranning ratio and moisture content on kernel mechanical properties.

## MATERIALS AND METHODS

The investigations were carried out on Polish spring wheat cultivar (*Triticum aestivum, ssp. vulgare*) Turnia collected in 2002. This cultivar belongs to class E and flour obtained form this cultivar is characterized by very good baking value. Kernels were debranned using debranning machine Ekonos, courtesy of Lubella S.A. from Lublin. After the first stage of debranning, part of the kernels was separated and the rest was taken in to the second stage. Three kinds of samples were taken for the investigation: kernels without debranning, kernels after the first and after the second stage of debranning. The kernels were evaluated for their geometrical properties (length, width and thickness) [2], mass of kernels and ash content [10]. The debranning ratio was calculated according to the equation:

$$d_r = \frac{\Delta m_b}{\Delta m_t} \cdot 100\% \tag{1}$$

where: $\Delta m_b$ – the difference between the kernel ash content before and after debranning (%), $\Delta m_t$ – the difference between the total kernel ash content before debranning and endosperm ash content (%).

Samples were conditioned for 24 hours to 12, 14 and 16% moisture levels by the addition of distilled water. Subsequently, individual kernels were weighted and placed on the bottom plate of universal testing machine ZWICK Z020/TN2S (the kernel crease towards the bottom plate) and compressed with a constant speed of 10 mm $min^{-1}$ until a constant distance of 0.5 mm between the plates was achieved. Changes in the loading force in relation to the kernel deformation were recorded by means of a computer kit. On the basis of the obtained compression curves (Fig. 1) the following parameters were determined: forces ($F_1$ and $F_2$), deformations ($\Delta h_1$ and $\Delta h_2$), values of work and individual work (work divided by kernel mass) for the rapture point (1) and in the end of the compression (2). The strain ($\Delta h_1$') was also calculated ($\Delta h_1$ divided by the kernel thickness).

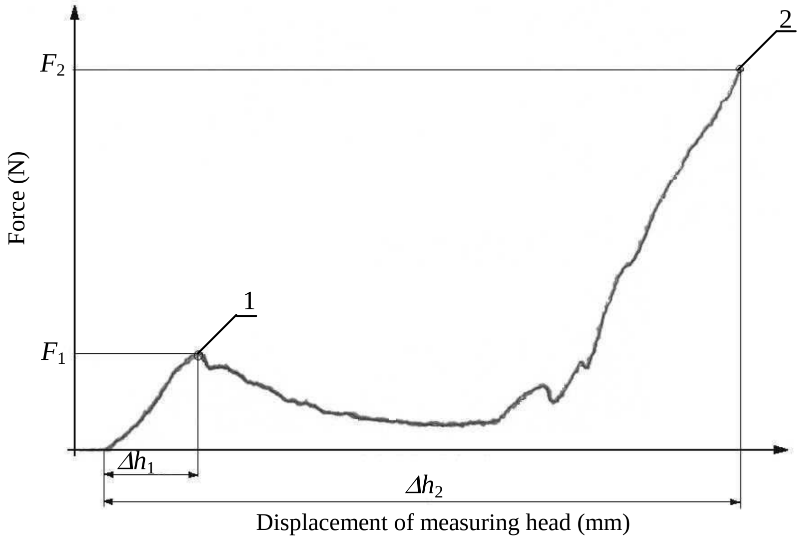


**Fig. 1.** Example of wheat kernel compression curve. 1 – rapture point, 2 – the end of compression

Measurements were replicated thirty times for each fraction. The data obtained were subjected to statistical analysis. The evaluations were analyzed for variance analysis. The significant differences among means were evaluated by Duncan's test. The Pearson's correlation coefficients and regression equations were also evaluated. All statistical tests were carried out at significance level of $\alpha = 0.05$.

## RESULTS

The results showed that debranning caused the highest changes in the kernel length. As the debranning ratio increased, the kernel length decreased by 24% and 45% after the first and the second debranning stage, respectively. The changes of the kernel thickness and width were considerably lower (decrease from 3 to 9%). The debranning ratio was 49% and 73% after the first and the second stage of debranning, respectively.

The results showed that both kernel moisture content and debranning ratio had a significant influence on kernel deformation up to the rapture point ($\Delta h_1$). An increase of wheat moisture content caused an increase of this deformation both for undebranned and debranned kernels. Debranning caused a decrease of $\Delta h_1$ from 55 to 71%, depending on wheat moisture content. However, the differences between this deformation obtained for kernels after the first and the second stage of debranning were not statistically significant (Tab. 1).

**Table 1.** Deformations $\Delta h_1$ and $\Delta h_1$' in relation to wheat kernel debranning ratio and moisture content

| Deformation | Kernel moisture content (%) | Debranning ratio (%) | | |
|---|---|---|---|---|
| | | 0 | 49 | 73 |
| $\Delta h_1$ (mm) | 12 | $0.24^{Aa}$ | $0.13^{Ba}$ | $0.15^{Ca}$ |
| | 14 | $0.31^{Ab}$ | $0.20^{Bb}$ | $0.23^{Bb}$ |
| | 16 | $0.47^{Ac}$ | $0.30^{Bc}$ | $0.29^{Bc}$ |
| $\Delta h_1$' (%) | 12 | $7.2^{Aa}$ | $4.8^{Ba}$ | $5.5^{Ca}$ |
| | 14 | $9.3^{Ab}$ | $6.5^{Bb}$ | $7.2^{Bb}$ |
| | 16 | $14.2^{Ac}$ | $9.7^{Bc}$ | $10.6^{Bc}$ |

* values designated by different capital letters in the lines of the Table are significantly different ($\alpha = 0.05$).
**values designated by different small letters in the columns of the Table are significantly different ($\alpha = 0.05$).

The increase of grain moisture content caused an increase of grain plasticity and thus the higher values of $\Delta h_1$ were observed.

A previous study showed that deformation of kernel up to the rapture point depends on wheat kernel thickness, however nonlinear dependencies were observed [2]. Therefore the kernel strain ($\Delta h_1$') was also calculated. The relations obtained were similar to those obtained for $\Delta h_1$ (Tab. 1).

Table 2 presents the results of measurements of rapture force ($F_1$) and force at the end of compression ($F_2$). The rapture force was always higher for the undebranned kernels, regardless of the wheat moisture content. Debranning caused a decrease of $F_1$ from 30 to 70%. However, the values obtained for kernels after the first and the second stage of debranning were not statistically significantly different.

Kernel moisture content (range of 12-16%) has no statistically significant influence on rapture force for debranned kernels. With reference to the undebranned kernels, an increase of moisture content from 12 to 14% caused a decrease of $F_1$ (by an average of about 30%). On the basis on these results we can conclude that the undebranned kernels, as a result of moisture increase, changed their mechanical properties to a higher extent than the debranned wheat kernels (Tab. 2). This is probably caused by bran layers properties. Mabille *et al.* [7] studied the mechanical properties of wheat seed coats. They found that the elasticity and plasticity of bran increased with increasing kernel moisture content. By contrast, Glenn *et al.* [4] showed that as the moisture content of wheat endosperm increases, the compressive strength, elasticity and energy to compressive failure all decrease.

**Table 2.** Forces $F_1$ and $F_2$ in relation to wheat kernel debranning ratio and moisture content

| Force (N) | Kernel moisture content (%) | Debranning ratio (%) | | |
|---|---|---|---|---|
| | | 0 | 49 | 73 |
| $F_1$ | 12 | $123^{Aa}$ | $74^{Ba}$ | $77^{Ba}$ |
| | 14 | $93^{Ab}$ | $66^{Ba}$ | $67^{Ba}$ |
| | 16 | $91^{Ab}$ | $70^{Ba}$ | $64^{Ba}$ |
| $F_2$ | 12 | $1466^{Aa}$ | $790^{Ba}$ | $503^{Ca}$ |
| | 14 | $1453^{Aa}$ | $780^{Ba}$ | $562^{Ca}$ |
| | 16 | $1573^{Aa}$ | $897^{Ba}$ | $589^{Ca}$ |

* values designated by different capital letters in the lines of the Table are significantly different ($\alpha = 0.05$).
**values designated by different small letters in the columns of the Table are significantly different ($\alpha = 0.05$).

Laskowski *et al.* [5,6] found a positive correlation between the rapture force and grinding energy of cereal kernels.

The results showed that debranning had a significant influence on the force at the end of compression. As the debranning ratio increased, the values of $F_2$ decreased and for the kernel after the second stage of debranning were almost three times lower than for the undebranned kernel. The wheat moisture content (range of 12-16%) had no statistically significant influence on this force (Tab. 2).

The changes of force $F_2$ were described by the use of a linear regression equation, where the kernel ash content ($z_p$) and mass of the individual kernel ($m$) were taken as independent variables:

$$F_2 = 626.8\, z_p + 18990.6\, m - 633.4 \quad R^2 = 0.914 \qquad (2)$$

where: $F_2$ – force at the end of the kernel compression (N), $z_p$ – the kernel ash content (%), $m$ – the mass o the individual kernel (g).

Predicted values as related to observed values are presented in Figure 2. It should be noted that equation (2) is proper only for the Turnia wheat. The future investigations will be extended onto other wheat cultivars. The results showed that both the moisture content and the debranning ratio had a significant influence on the deformation work up to the kernel rapture point ($L_1$). For all samples, as the moisture of kernel increased the $L_1$ decreased. Debranning caused a decrease of this work, the highest when the kernel moisture content was 12% (about 300%).

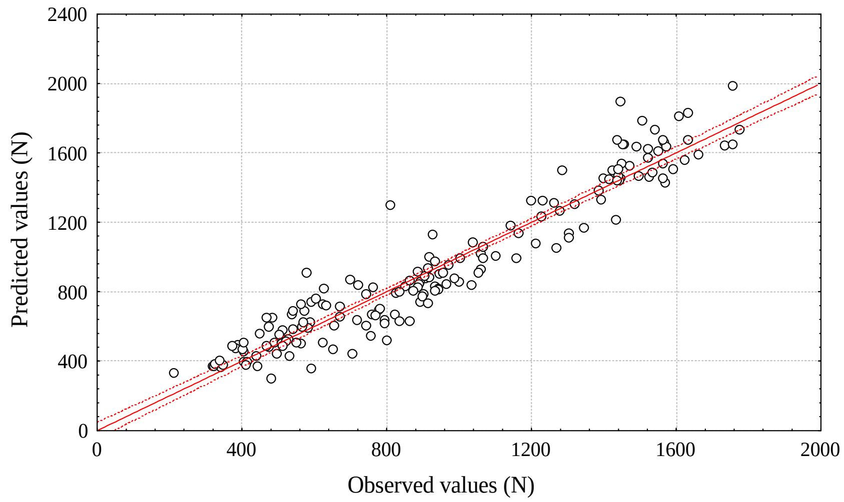


**Fig. 2.** Predicted values of $F_2$ versus observed values

However the differences between $L_1$ obtained for kernels after the first and the second stage of debranning were not statistically significant (Tab. 3). Other relations were observed for the deformation work up to the end of the kernel compression ($L_2$). The moisture content had no statistically significant influence on the values of this work for the debranned kernels. But for undebranned kernels the highest values of $L_2$ were obtained when the kernel moisture content was 16%. Romański and Niemiec [11] showed nonlinear dependency between the wheat moisture content and crushing energy of kernel by the use of corrugated rolls. They obtained the highest crushing energy when the kernel moisture content was 16-17%.

**Table 3.** Works $L_1$ and $L_2$ in relation to wheat kernel debranning ratio and moisture content

| Work (mJ) | Kernel moisture content (%) | Debranning ratio (%) | | |
|---|---|---|---|---|
| | | 0 | 49 | 73 |
| $L_1$ | 12 | $17.2^{Aa}$ | $5.6^{Ba}$ | $7.7^{Ba}$ |
| | 14 | $19.0^{Aa}$ | $9.1^{Bb}$ | $10.3^{Bb}$ |
| | 16 | $29.7^{Ab}$ | $15.6^{Bc}$ | $16.6^{Bc}$ |
| $L_2$ | 12 | $729^{Aa}$ | $392^{Ba}$ | $252^{Ca}$ |
| | 14 | $706^{Aa}$ | $364^{Ba}$ | $278^{Ca}$ |
| | 16 | $796^{Ab}$ | $421^{Ba}$ | $243^{Ca}$ |

* values designated by different capital letters in the lines of the Table are significantly different (α = 0.05).
** values designated by different small letters in the columns of the Table are significantly different (α = 0.05).

Debranning caused a high decrease of $L_2$; average of about 190 and 280% after the first and the second stage of debranning, respectively (Tab. 3).

The results showed that the mechanical properties of debranned kernel were significantly different from the properties of undebranned kernel. The future study should be extended onto other wheat cultivars and should be conducted for mechanical properties of kernel with higher range of debranning ratio.

## CONCLUSIONS

1. Debranning caused a decrease of deformation of kernel up to the rapture point. However, the differences between this deformation obtained for kernels after the first and the second stage of debranning were not statistically significant. The kernel moisture content also had an influence on this deformation, as the moisture content increased the deformation increased too.

2. Debranning also caused a decrease of rapture force and the force at the end of compression (by an average of about 43 and 230% respectively). The moisture of kernel had no significant influence on these forces. Only for undebranned kernel the increase of moisture from 12 to 14% caused a decrease of rapture force.

3. The changes of the kernel loading force at the end of compression were described by a linear regression equation, where the kernel ash content (positive correlation) and mass of kernel (positive correlation) were taken as independent variables ($R^2$ = 0,914).

4. The results showed that both the debranning ratio and the kernel moisture content had a significant influence on the kernel mechanical properties. The future studies should be extended onto other wheat cultivars.

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## WPŁYW STOPNIA OBŁUSKANIA I WILGOTNOŚCI ZIARNA NA WŁAŚCIWOŚCI MECHANICZNE PSZENICY

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Streszczenie. Przedstawiono wyniki badań dotyczące cech mechanicznych ziarna pszenicy otrzymanych na podstawie testu jednoosiowego ściskania. Stwierdzono, że zarówno stopień obłuskania, jak i wilgotność ziarna miały istotny wpływ na określane cechy. Obłuskanie spowodowało spadek odkształcenia ziarna do momentu jego pęknięcia. Wraz ze wzrostem wilgotności wartości tego odkształcenia zwiększały się. Obłuskanie wpłynęło również na spadek siły powodującej pęknięcie ziarna oraz siły na końcu procesu zgniatania (odpowiednio średnio o 43 i 230%). Wilgotność ziarna nie miała istotnego wpływu na wartości tych sił. Jedynie w odniesieniu do ziarna nieobłuskanego stwierdzono, że wzrost wilgotności z 12 do 14% spowodował spadek siły powodującej pęknięcie ziarna. Zmiany siły obciążającej ziarno na końcu proces zgniatania opisano równaniem regresji, w którym jako zmienne niezależne uwzględniono zawartość popiołu w ziarnie i masę pojedynczych ziarniaków ($R^2$ = 0,914).

Słowa kluczowe: pszenica, właściwości mechaniczne, obłuskiwanie, wilgotność