# IMPACT OF STORAGE CONDITIONS ON GEOMETRICAL PARAMETERS OF TRITICALE GRAIN

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**Summary**. The work presents results of research on the geometrical parameters of triticale grain length, width, contour and area of horizontal projection in relation to moisture content and storage time. An enlargement of all geometrical parameters and grain temperature was observed, as a result of the natural processes of grain respiration. The statistical analysis of results showed that the storage time and moisture content have a crucial impact on grain geometrical parameters. For this survey suitable regression equations were written.

Key words: grain, moisture content, storage, geometrical parameters

### INTRODUCTION

Geometrical parameters describing size and shape of grain belong to a very important group of grain physical features. Having knowledge about them is indispensable in order to construct different machines (e.g. used for pneumatic transport and storage bins), as well as in making right choices in selecting the proper working parameters. The new technique of interior transport, both mechanic and pneumatic, technique of preparing the grain for milling must include physical parameters for obtaining the right effects [Jankowski 1988]. With geometrical features mechanical strength and Young modulus [Koper and Kukiełka 1989] are also connected.

Moisture content has a crucial impact on the physical and mechanical parameters [Mohsenin 1978, Grzesiuk and Kulka 1981, Waszkiewicz 1988, Molenda *et al.* 1995] and so has storage time, during which self-heating [Kusińska 2001a, b], as a natural result of grain respiration, may occur. Carbon dioxide, water and warmth are released as a result of this respiration. If water is absorbed by grain, than an increase of moisture content will occur as well as a change of all its parameters, including dimensions.

Till recent times, the grain dimensions were described using just typical measurement devices. Now, visual systems are a modern technique of measurement of the length, width and thickness of grain, but also the area of horizontal projection and the contour of horizontal projection [Liao *et al.* 1994, Tylek 1995, Guz 2000, Panasiewicz *et al.* 2002]. Many dependencies between geometrical parameters and other features may be described by regression equations. Janiak *et al.* [1993] and Dziki *et al.* [2002] as well as Szczepanik *et al.* [2004] used simple regression equations in order to describe separately dependencies between the mass of corn grain, with different moisture contents and particular dimensions.

The aim of this work is to prove that an important impact on the dimensions of triticale grain, stored in isolation, is exerted by moisture content and the storage time with which a temperature of self-heating is inseparably connected. The work presents the determination of the length, width and thickness of triticale grain as well as grain contour and its area in relation to moisture content and storage conditions.

#### MATERIAL AND METHODS

The Presto triticale from the 2003 harvest period, bought in The Grain Storage Centre in Lublin, Poland, was used in the research. Material without broken grains was sorted out using a flat sieve with holes of 2.7 mm in size. Initial moisture content for 20 samples chosen randomly from the total material was between  $0.132-0.143 \text{ kg}(\text{kg d.b.})^{-1}$ . After a careful mixing of the grains, their moisture content was  $0.136 \text{ kg}(\text{kg d.b.})^{-1}$ . For testing, this material and grains were wetted with distilled water to the following moisture levels: 0.163; 0.19; 0.22; 0.25 and  $0.282 \text{ kg}(\text{kg d.b.})^{-1}$  were used. The samples were cooled to initial temperature of  $15^{\circ}$ C. Amount of water to be added was calculated according to the following equation:

 $W = M \frac{u - u_z}{1 + u}$ 

where:

W – mass of added water, kg

M – mass of watering grains, kg

u – required moisture content, kg(kg d.b.)<sup>-1</sup>

 $u_z$  - initial moisture content, kg(kg d.b.)<sup>-1</sup>.

The grain samples were stored in properly closed jars of 5 dm<sup>3</sup> capacity. The jars were placed in polystyrene foam boxes. The time of tempering was minimum 48 hours. The content of the jars was mixed every 12 hours in order to moisturize the whole sample material equally. After the opening, moisture content was controlled and the temperature of grain was checked using alcoholic thermometer with the range of 0-100°C. For every single sample, obtained in this way, the length, width and thickness of grains were described as well as their contour and area of horizontal projection using the computer visualisation method Super VIST v.1 with a module for mofromethic marking SVISTMET (according to the ASAE Paper N°911751). SVIST system was installed on PC computer. The image came from a CCD camera distinguishing 256 of grays and was projected on the color monitor NEC, joined to a graphic card VESA Local Bus. A single grain was put on a table in the view if the camera with its groove upside down or it was glued on its side part. It was lit with dissipated light with a help of four lamps in order to eliminate shadows. The image from the camera, projected on the screen was saved as

(1)

a bitmap. After system calibration, procedures enabled reading of obligatory parameters of SVISTMET program were run. Every testing was repeated 300 times. The first measurement was done just after obtaining the tested material (noted as day 0). Maximum storage time was 10 days.

The grain sphericity was calculated according to the following Mohsenin equation [1978]:

$$sf = \frac{\sqrt[3]{abc}}{a} \tag{2}$$

where:

*sf* – grain sphericity

a - length of grain, mm

b – width of grain, mm

c – thickness of grain, mm.

#### RESULTS

The results of studies are shown in Fig. 1-6. Every single geometrical parameter rises with an increase of moisture content as well as of the storage time. It should be noticed that the temperature of triticale grain was also rising. The highest value of  $42^{\circ}$ C was obtained after 10 days of storage and at 0.282 kg(kg d.b.)<sup>-1</sup>moisture content. The grains with moisture content of 0.136 kg(kg d.b.)<sup>-1</sup> had the temperature around 16°C.

The results of the research were subjected to the analysis of variance. Crucial impact of moisture content and time of storage on the geometrical parameters was shown. Regression analysis taken in the next stage let to obtain relations between grain geometrical parameters and its moisture content  $u \, [kg(kg \, d.b.)^{-1}]$  as well as storage time  $\tau \, [day]$ .

The grain length increased from 8.54 to 9.12 mm, i.e. by 6.79% (Fig. 1). This dependence may be expressed by the equation:

$$a = 10.045 + 0.768 \ln u + 0.00708\tau$$
(3)  
R<sup>2</sup> = 0.984,  $\alpha \le 0.01$ 

The grain width was changing from 3.17 to 3.86 (Fig. 2) and the change was described by the following equation:

$$b = 4.56 + 0.337 \ln u + 0.02\tau$$
(4)  
R<sup>2</sup> = 0.967,  $\alpha \le 0.01$ 

The growth was relatively high at the level of 5.99%.



Fig. 1. Influence of moisture content and storage time on triticale grain length



Fig. 2. Influence of moisture content and storage time on triticale grain width

The length and width of grain are logarithmically dependant on moisture content and linearly on storage time.

The grain thickness was rising (by 35.27%) from 2.75 to 3.52 mm (Fig. 3). This was described by the linear equation:

$$c = 2.071 + 4.128u + 0.0242\tau \tag{5}$$

$$R^2 = 0.96, \alpha \le 0.01$$



Fig. 3. Influence of moisture content and storage time on triticale grain thickness

Dependence of grain sphericity on moisture content as well as storage time was shown in Fig. 4. The sphericity ranged from 0.492 to 0.546, and depended logarithmically both on moisture and storage time. Its changes were described by the following equation:

$$sf = 0.585 + 0.055\ln u + 0.095\ln \tau \tag{6}$$

$$R^2 = 0.935, \alpha \le 0.01$$

Dependence of grain contour (Fig. 5) on moisture content and storage time can be presented as:

$$O = 33.61 + 7.1 \ln u + 0.151\tau$$
(7)  
R<sup>2</sup> = 0.964,  $\alpha \le 0.01$ 



Fig. 4. Influence of moisture content and storage time on triticale grain sphericity



Fig. 5. Triticale grain horizontal projection of contour as a function of its moisture content and storage time

For the research conditions the contour of horizontal projection of grain was rising from 20.54 to 26.42 mm, while the area was increasing from 21.95 to 28.46 mm (Fig. 6). The changes in the projected area values were described as:

$$S = 38.155 + 8.59 \ln u + 0.149\tau$$
(8)  

$$R^2 = 0.979, \quad \alpha \le 0.01$$

The contour and area of horizontal projection were also logarithmically dependant on the moisture content and linearly on the storage time.



Fig. 6. Triticale grain horizontal projection of area as a function of its moisture content and storage time

For the equations (3) to (8) there is a high correlation between dependent and independent variables. Correlation coefficient between measured parameters and particular parts of the equations containing function of moisture content are 0.95-0.98. Correlation coefficient between measured features of parts of equations containing time of storage are smaller (0.638-0.86). On this basis we may conclude, that the obtained results are more influenced by moisture content than storage time.

Nonlinear estimation analysis was applied to the description of the contour and area of grain using ellipse formulae because it is closest to the shape of the grain projection. It was found, that the determination coefficient for these equations was very small, about 0.33. Following, a mathematical model was used for the description of the grain projected area:

$$O = k \left(\frac{a+b}{2}\right)^n \tag{9}$$

It was found that the determination coefficient for this equation was 0.993 with k = 0.238 and n = 2.51. The area may be also expressed by:

$$S = k_1 a b \tag{10}$$

In this case a high determination coefficient ( $R^2 = 0.97$ ) was also obtained, for  $k_1 = 0.823$ .

Fig. 7 presents a view of the same grain with 0.136 kg(kg d.b.)<sup>-1</sup> moisture content before storage and after 10 days storage time – moisture content of 0.282 kg(kg d.b.)<sup>-1</sup>.



Fig. 7. View of triticale grain of moisture content  $0.136 \text{ kg} \cdot (\text{kg d.b.})^{-1}$  before storage (on the left) and grain of moisture content  $0.282 \text{ kg} \cdot (\text{kg d.b.})^{-1}$  after 10 days storage (on the right)

Difference in grain size is remarkably apparent.

The observed and described differences in values of geometrical parameters were caused by direct watering as well as by process of water migration dependent on storing conditions (high moisture content, too high temperature, no ventilation).

#### CONCLUSIONS

1. Moisture content and the storage time have important influence on the geometrical parameters of triticale grain. Their increase, in controlled conditions, caused enlargement of all the measured features i.e. length, width, thickness, sphericity, contour and area of horizontal projection. The highest growth was observed for the grain thickness.

2. The length, width, thickness, contour and area of horizontal projection of grain were logarithmically dependant on moisture content and linearly on storage time.

The thickness of grain was linearly dependent on both the parameters, while the sphericity was logarithmically dependent on them.

3. Moisture content had a greater impact on grain geometrical parameters than storage time.

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