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CHANGES OF GEOMETRIC CHARACTERISTICS OF STORED BARLEY IN ACCORDANCE WITH SIMULATED LOADS SUBSISTING IN SILO

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Summary. The paper presents methodology and results of geometric characteristics measurements of grain stored in silo-stress simulated conditions. The subject of the study was barley grains (cv. Stratus). The silo-like stress was developed by specially designed cylinders. The values of stress were 35, 52 and 70 kPa, which is commonly met in industry-scale silos. The aim of this work was to search the course of geometric changes in grains, developed by variable conditions of storage (14, 16, 18, 20, 22, 24% of moisture and 6°C and 20°C of temperature). The measurements of geometric characteristics were taken by SVISTMET system and software. The results showed that the changes of geometric characteristics were not statistically significant. Slight changes appeared only at extremely high stress (70 kPa) and at higher temperature (20°C) and moisture content (over 20%).

Key words: barley, silo, storage, geometric characteristics, image analysis

INTRODUCTION

Active ventilation in the silo enables to maintain proper conditions of grain during storage [Kamiński i in. 1978; Haque i in. 1982; Jayas, Muir 1991]. The reaction to air conditioning is flow resistance, which is estimated so far by many researchers [Al-Yahya, Moghazi 1998; Agullo i in. 2005; Molenda i in. 2005]. Grain elevators that are used in today's industry have become increasingly higher and bigger, that means the bulk resistance is still a non-solved problem [Pabis 1978; Sacilik 2004; Kusińska 2006]. The raised bulk density and low porosity of grain with the time of storage and height of grain loaded in the silo cumulates high resistance to airflow [Giner, Denisienia 1996; Łukaszuk 2005].

The keeping of grain quality is strictly determined by its moisture, temperature, and time of storage [Łuszczewski 1985; Tyburcy1997; Ciećko 2003]. Ventilation by active multiple atmosphere exchange made the intergrain space accessible to fresh air thus diminishing physiological activity of grain [Bujak 1972; Kusińska *2008]. The flow resistance of air should be known at the initial phase of conditioner construction [*Sokhansanj i in. 1990; Dziki, Laskowski 2004]. The most effectual factors of air-flow resistance are: bulk density, moisture content, porosity, shape and size of grain as well as internal friction of grain [Bekasov 1952; Giner, Denisienia 1996]. The shape and size of grain are strictly influenced by a variety of properties as well as climate and conditions of growth [Jankowski 1988]. There is a strong relationship between shape and size of grain. The shape of grain may be spherical, egg-like, oval or wedge-shaped. It may sometimes exist as the ridge side, the abdominal side or basis and top of the particular grain. Shaken mass of grain cumulates flow-resistance which is strongly influenced by volume-to-area ratio [Lityński 1982; Grzesiuk, Górecki 1994]. Almost every grain has its length (a), thickness (b) and width (c). All these characteristics change with the moisture content in the grain. The shape of the grain may be illustrated by spherical coefficient, K1=c/a, K2=b/a.

The use of modern visual technology (digital image analysis systems) enables to calculate more complex image parameters existing in biological objects. They are based on area measurements, edge lines distance or substituted diameters [Guz 2009]. The description of phenomena and its effect on the stored material is now more specific and accurate. This is especially important in description of grain stored in high-volume silo, where the porosity is significantly diminishing [Bekasov, Denisov 1952]. The volume of intergrain spaces has a decisive influence on air-flow resistance [Bujak 1972].

Germination capacity is the most common factor studied after storage. Higher values of germination have grains of higher springness and resistance to stress, impact and thrust [Lityński 1982]. The susceptibility to deformation of grain after stress is higher due to its higher plasticity caused by high moisture content. At the low level of moisture the grains loose their plasticity and are+ very susceptible to internal break [Kolowca 1979]. Grain shape changes are by so far one of the most important factors that creates its quality and influences the conditions of ventilation process in silos [Waszkiewicz, Nowakowski, Sznajder 1999].

MATERIALS AND METHODS

Barley grains (cv Stratus) at initial moisture content of 14% were moistened to 16, 18, 20, 22 and 24% of moisture. The grain then was placed to cylindrical shaped vessels of 2l capacity. Vessels had a specially designed stress-developing mechanism (Fig. 1).

Fig. 1. Specially designed silo-stress simulator vessel

The stress values were 35,52 and 70 kPa accordingly to the stress simulation in silo conditions. Such a tension is equal to the thrust of over ten meters high bed of grain, which is common in industry plants. The grain was placed also to non-stressed vessels as reference material. The storage of commodity lasted until the stoppage of relaxation in the stressed layer. After storage 3 parts of volume of 30 ml were randomly taken from the vessel and mixed together. Every measurement was taken out with the participation of 100 grains taken from the mixture. Objects of the study were placed on specimen table that was illuminated with backlight to emboss the grain silhouette. Every measurement was taken 10 times with 10 grains which were placed on limited area to improve the measurement precision. Images taken digitally were stored for further analysis. After storage the images were digitally filtered to dual-color (binary image) (Fig. 2) which was the basis of measurements (SVISTMET).

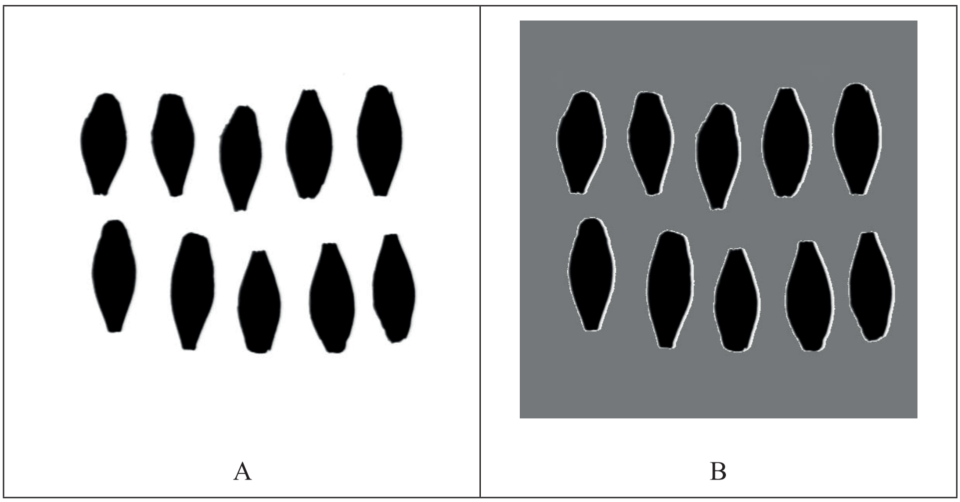

Fig. 2. Barley grain measurement images: A- digital primary image, B – binary digital image with edge line

The following data were measured: length, width, area of horizontal projection and shape coefficients:

$$K1=\frac{L}{S}$$

$$K2=\frac{4A}{PR}$$

where:
L – length of grain,
S- width of grain,
A – area of horizontal projection,
P – perimeter of grain,
R – radius of equivalent area.

RESULTS

The courses of horizontal projection area in dependence on pressure and storage temperature were shown in Fig 3 and 4. The area of grain changed insignificantly.

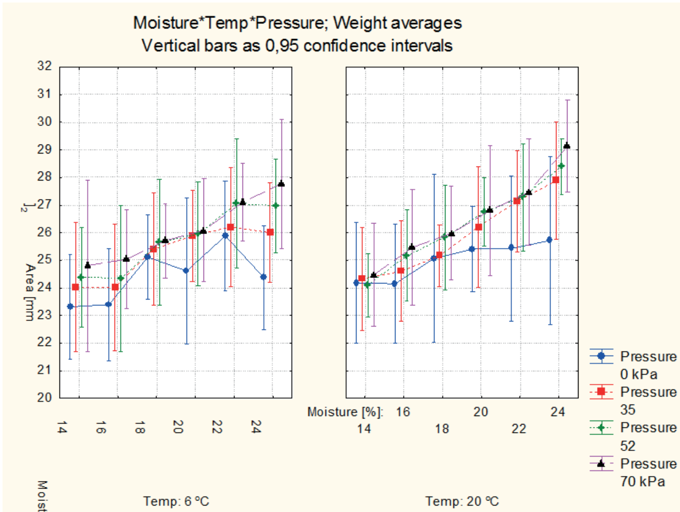

Fig. 3. Area of horizontal projection in dependence on silo pressure

The least changes were noticed for non-stressed grains. Those changes were not statistically significant. Although the commodity was a strictly selected sewing material and its dimensions were specified by sieve, there was still a problem with detecting slight deviations in grain dimension.

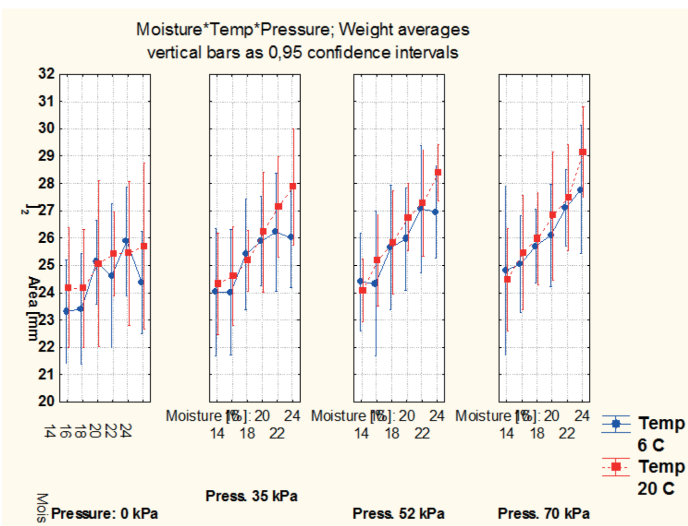

Fig. 4. Area of horizontal projection in dependence on storage temperature

The next factor analyzed in the storage was process temperature. The growth of grain plasticity after moistening at ambient storage temperature resulted in grain growth (Fig. 4). The course of area changes showed that moistening had a significant influence on grain size.

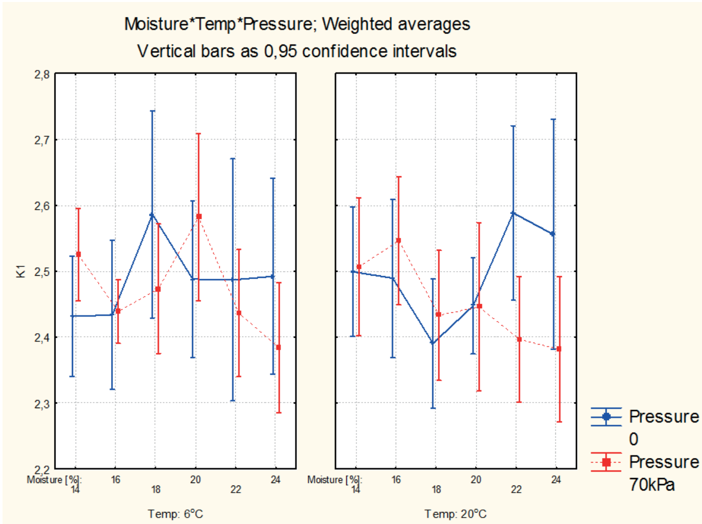

Fig. 5. The comparison of K1 changes caused by storage pressure

The pressure in the silo is not a significant factor of size changes in barley grains. The uniform pressure values were not the influent factor forming the grain size in the temperature range used in the experiment.

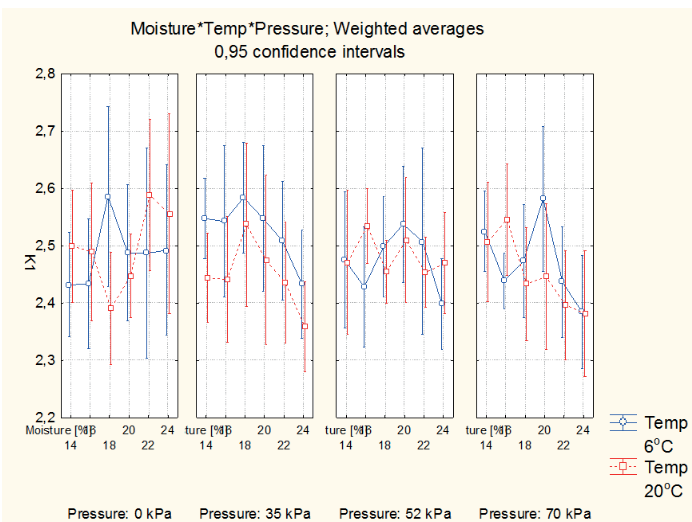

Fig. 6. The temperature course of K1 coefficient

The K1 coefficient changes were similar to the course which was independent of the silo pressure. The temperature taken into account as a factor forming the shape of barley grains was not influential to K1 slight deviations (Fig. 5) The K2 values represented stable, unchangeable factor through the whole pressure and moisture range values used in the experiment (Fig 7).

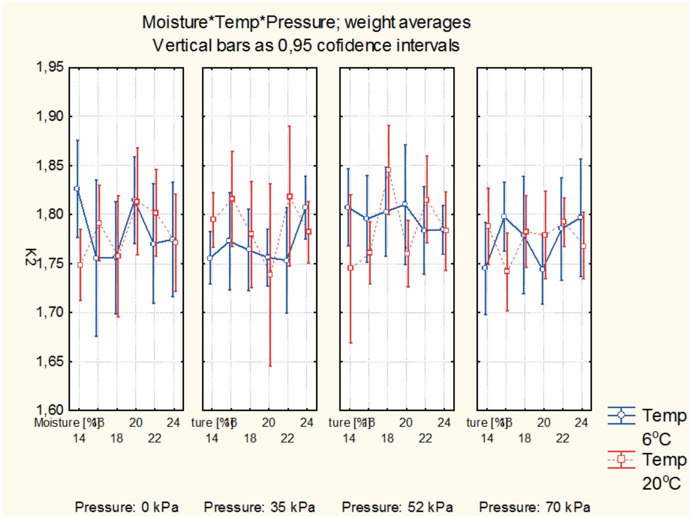

Fig. 7. The temperature course of K2 coefficient

Stability of K2 coefficient is a confirmation that the border line of the grain has a constant ratio in relation to other geometrical characteristics, taken into account during defining the K2 shape coefficient. The border line in the whole grain specimens was not distracted by deformations caused by bruises, breaks and other stable inconsistency of the grain outlines. Slight decrease of K2 value was observed only at 20°C and 52-70 kPa. (Fig. 7).

CONCLUSIONS

The experiment developed slight geometric changes of sampled barley grain caused by different factors. Among those factors moisture content, silo pressure and storage temperature were taken into account. On the basis of observations it was affirmed that moisture content and silo pressure were the most influencial factors that made these changes. The temperature of storage surprisingly wasn't the main factor significantly forming geometric parameters of barley grain measured in the experiment. Moreover, it was observed, that after storage of the commodity in silo conditions, all geometric parameters changes, expressed by shape coefficients were in aspect ratio to almost all storage conditions. This was a direct evidence that storage process was conducted without any harm to external structure of grain. This was shown by calculating the K1 and K2 shape coefficients. Only after storage at 20°C and higher pressure values a slight value drop of K2 was observed.

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ZMIANY CECH GEOMETRYCZNYCH JĘCZMIENIA PRZECHOWYWANEGO W WARUNKACH OBCIĄŻENIA PANUJĄCYCH W SILOSIE

Streszczenie. Praca przedstawia metodykę i wyniki oceny zmian cech geometrycznych ziarna jęczmienia odmiany Stratus po przechowywaniu w warunkach symulowanego laboratoryjnie obciążenia. Naprężenia o wartościach 35, 52 oraz 70 kPa były wywoływane w specjalnych cylindrach symulujących warunki przechowywania w silosie. Celem pracy było ustalenie przebiegu zmian cech geometrycznych nasion w zmiennych (wilg. 14, 16, 18 20, 22 i 24%; temp. 6°C oraz 20°C) warunkach ich przechowywania. Pomiary cech geometrycznych przeprowadzono z użyciem systemu SVISTMET. Wyniki badań wskazują, że zmiany cech geometrycznych nasion (statystycznie nieistotne) występują tylko w skrajnych warunkach przechowywania (20°C, 52 i 70 kPa) w warunkach wysokiej ich wilgotności (ponad 20%), która była głównym czynnikiem tych zmian.

Słowa kluczowe: jęczmień, silos, przechowywanie, cechy geometryczne, analiza obrazu

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