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Geometric characteristics of triticale grain stored under silo pressure

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Summary. The aim of this work was to present methodology and results of research on triticale grain (cv Pawo) subjected to storage under silo pressure. The pressure was simulated by the strain of spring-assisted device, which developed 35, 52 and 70 kPa of stress. The aim of this experiment was to detect geometric changes after storing the commodity at heightened moisture (14, 16, 18, 20, 22, 24%) while the temperature of storage was 6 and 20° C. The measurements were taken after stress relaxation by the use of Svistmet computer vision system. The results showed that geometric changes of grain characteristics were detected after storage in high-moisture and high-pressure conditions (20-24% and 52-70 kPa). The most responsible factor of these changes was moisture content of the grain.

Key words: triticale, silo, storage, geometric characteristics, image analysis.

INTRODUCTION

The raise of air flow resistance through the silo is strictly connected with deformations of grain mass and decrease of its porosity [18]. The airflow resistance should be known due to choosing the best solution of air conditioning of the silo [8]. The most important factors that are responsible for airflow resistance are: moisture content, density, porosity, grain shape and friction coefficient [9, 10]. The shape and grain size are dependent on climate conditions, agriculture, variety factors and growth conditions [16]. The volume-to-area ratio is one of the most important factors that influences on airflow resistance of shaken grain layers [11, 12]. Deformations that occurs after silo stress change airflow conditions [3, 8], as well as biological activity and market value of grain [4, 7]. The judgment of external changes in commodity as well as its injuries in an objective way is extremely difficult [13, 14]. The use of up-to-date computer systems is convenient in the judgment of complex processing expressed by colour changes [1, 20]. Sorting of tomatoes [6] or superficial alterations of citrus fruits [2] are an examples of using modern thermo-vision systems. The new measurement systems (computer image analyzers), allows to calculate more complicated biological object parameters such as area, perimeter or colour dispersion [5, 15]. The next example of research with the use of computer vision is assessment of technological value of grain [17], evaluating ingredients quantities [21] or comparison grains of many varieties to specific production applications [19]. The basic application of computer visual systems by means of grain is its morphometric description [22]. This is very important aid to judge of commodity as quality criterion in industrial applications or characterize of various grain varieties [23].

MATERIALS AND METHODS

Triticale grains (cv. Pawo) 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 have a specially designed stress-developing mechanism (Fig. 1).

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 commonly met in the industry plants. The grain was placed also to non-stressed vessels as reference material. The storage of commodity lased to 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).

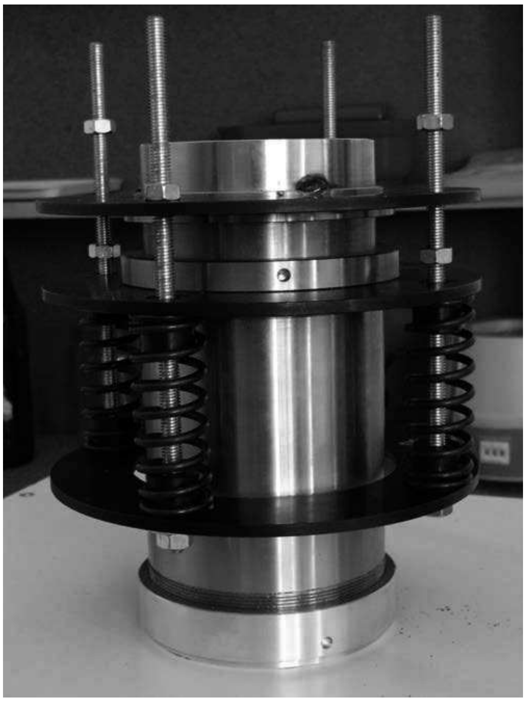

Fig. 1. Specially designed silo-stress simulator vessel

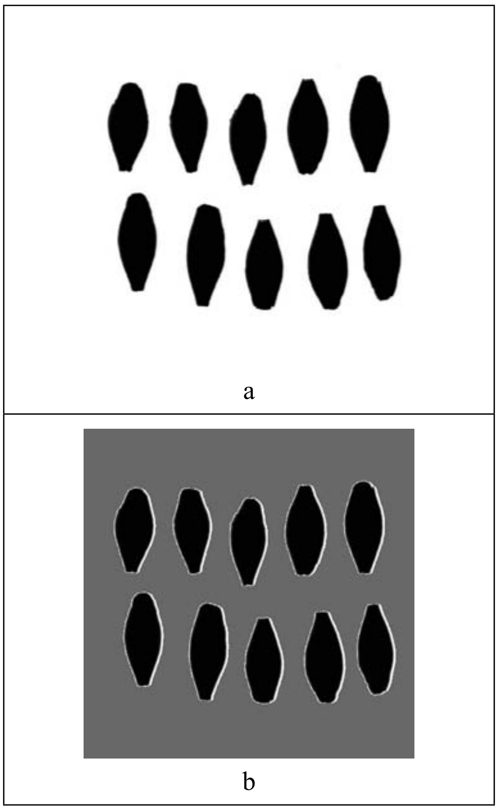

Fig. 2. Triticale grain measurement images: a- digital primary image, b – binary digital image with edge line

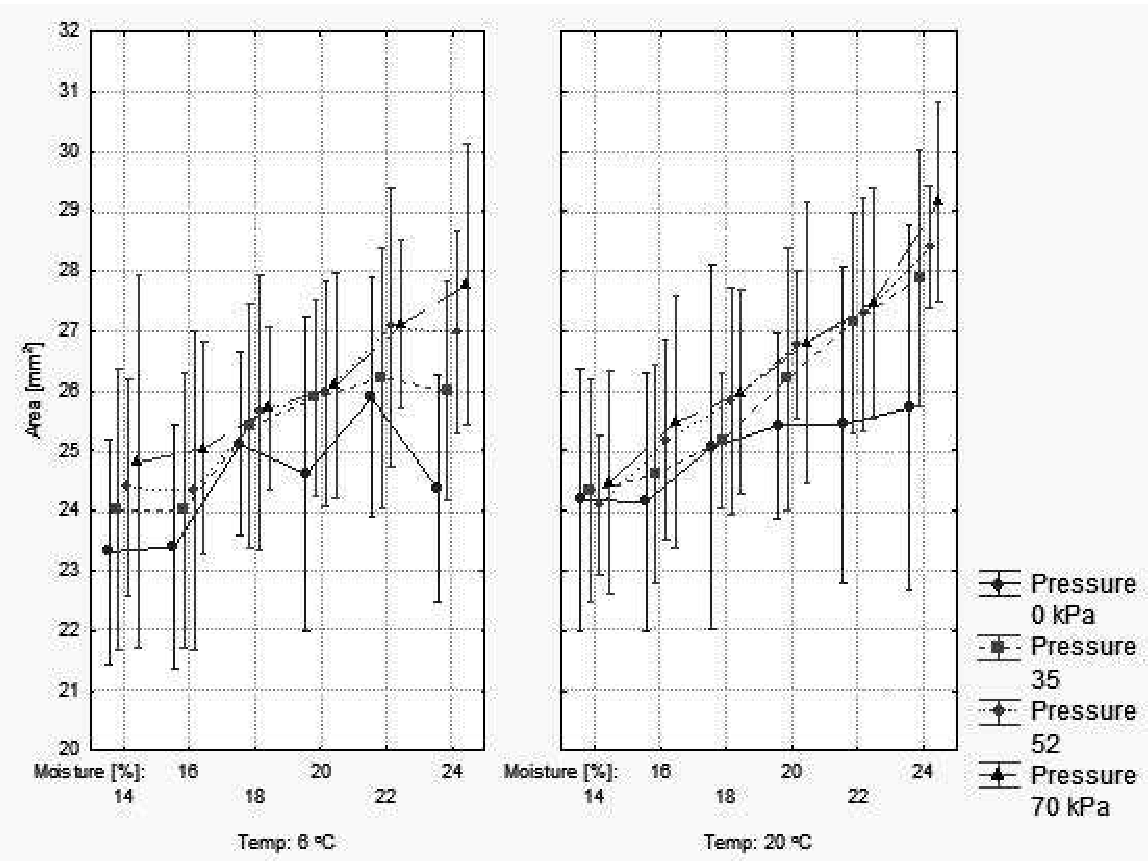

Fig. 3. Area of horizontal projection in dependence of silo pressure

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

$$K1 = \frac{L}{S}, \tag{1}$$

$$K2 = \frac{4A}{PR}, \tag{2}$$

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

RESULTS

Triticale grains were analyzed by the detection of its geometric alterations caused by tension formed in the experiment. Moisture content, temperature of storage and stress were taken into account during data analyzing. This procedure is common in this kind of research. The measurements of projected area and accompanying shape coefficients K1 and K2 were taken on 100 grain samples from stress cylinders. Grain extension, expressed by K1 coefficient and K2 coefficient, which defines perimeter to area ratio was presented in Figures 5-8, whereas changes of projected area were explained in Figures 3-4.

The curve shape of projected area changes were similar in accordance to all pressure values applied in cylinders. Slight increase of projected area caused by moisture changes was observed. Neither the value of external load nor temperature of storage influenced significantly the projected area changes (Fig. 3 and 4). Analysis by comparison of the pair of values corresponding to 22% of moisture only 70 kPa of external pressure caused significant extension of grain. This phenomenon was observed for grain stored at 6 °C as well as at 20 °C.

The K1 coefficient for triticale (this is description for grain extension) was stable. Mean values during experiments, taking into account all the experimental factors were at 2,45 to 2, 72 values level, which is standard for non-loaded grain. Temperature and moisture content changes did not influence K1 values for particular value of load (Fig. 5

This is probably associated with strong influence of stress caused by silo as opposed to other factors (i. e. moisture and temperature). The grain subjected to extreme load (70 kPa of stress) keeps constant length-to-width ratio. Slight decrease for higher grain moisture values was observed (Fig. 6).

The values of K2 coefficient stayed resist for non-loaded grain during experiment (Fig. 7). There were no evident changes of this parameter. Higher values of K2 coefficient were obtained at loads over 35 kPa and 20 deg. C storage temperature. This is explained by higher plasticity of grain that occurs in these storage conditions.

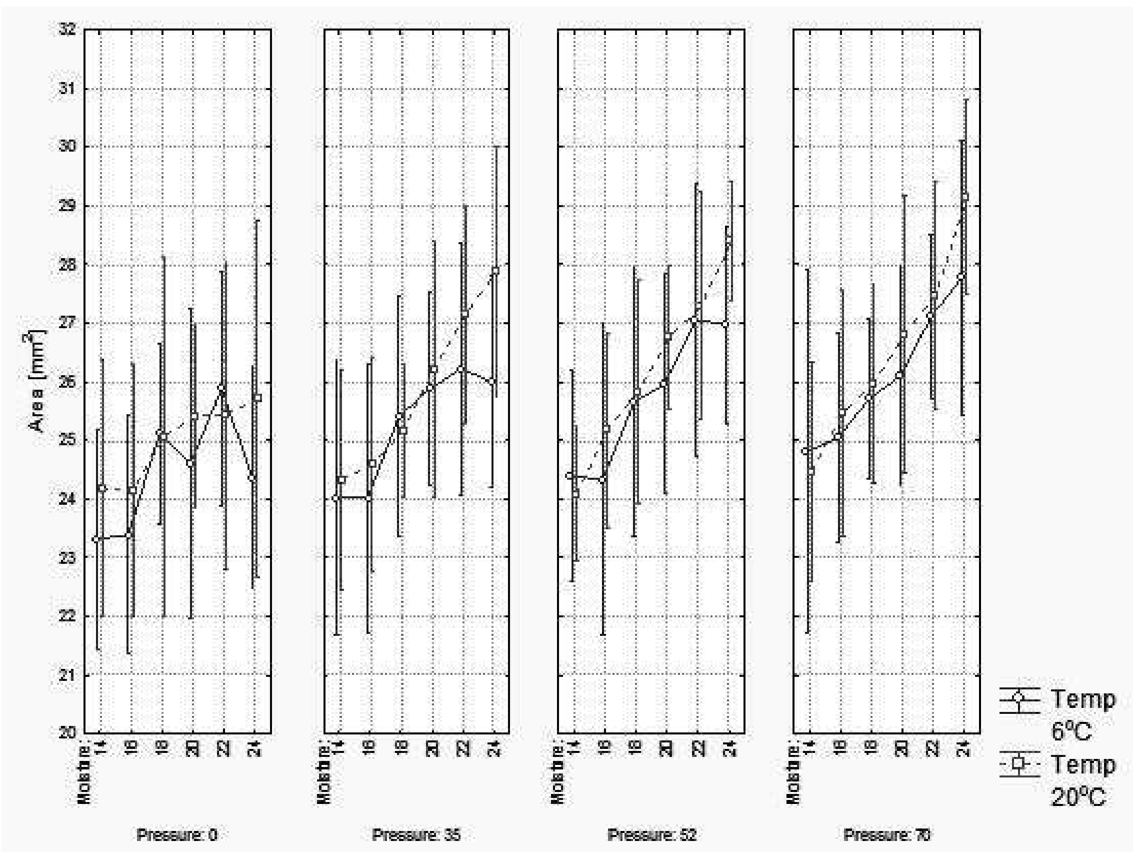

Fig. 4. Area of horizontal projection in dependence of storage temperature

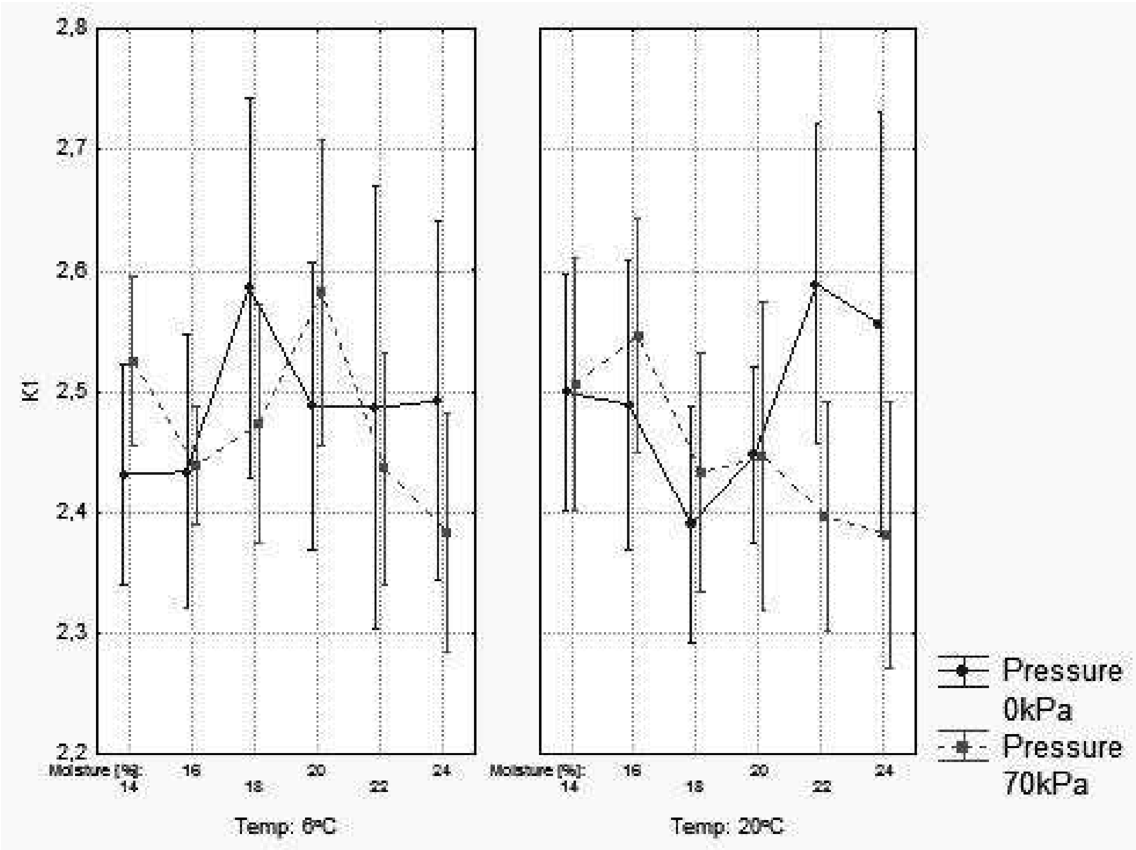

Fig. 5. The comparison of K1 changes caused by storage pressure

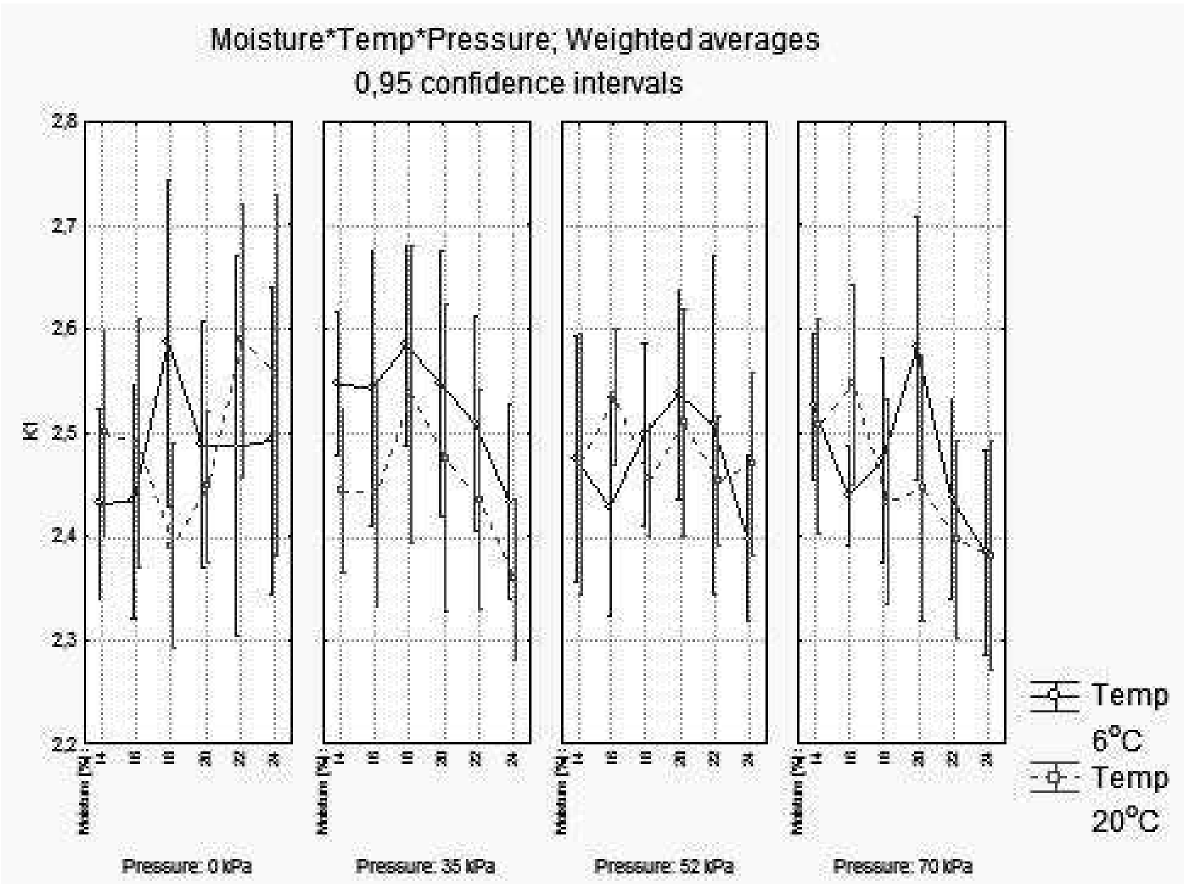

Fig. 6. The temperature course of K1 coefficient

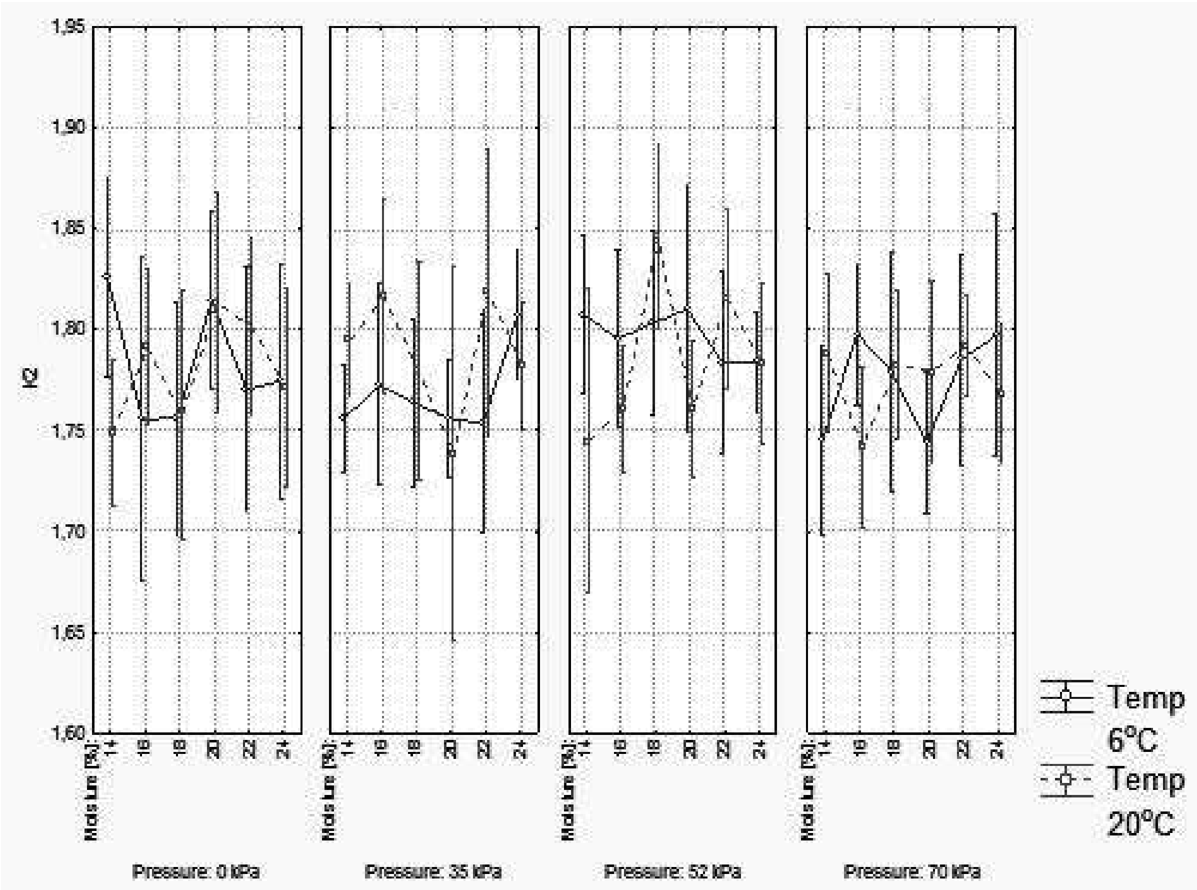

Fig. 7. The temperature course of K2 coefficient

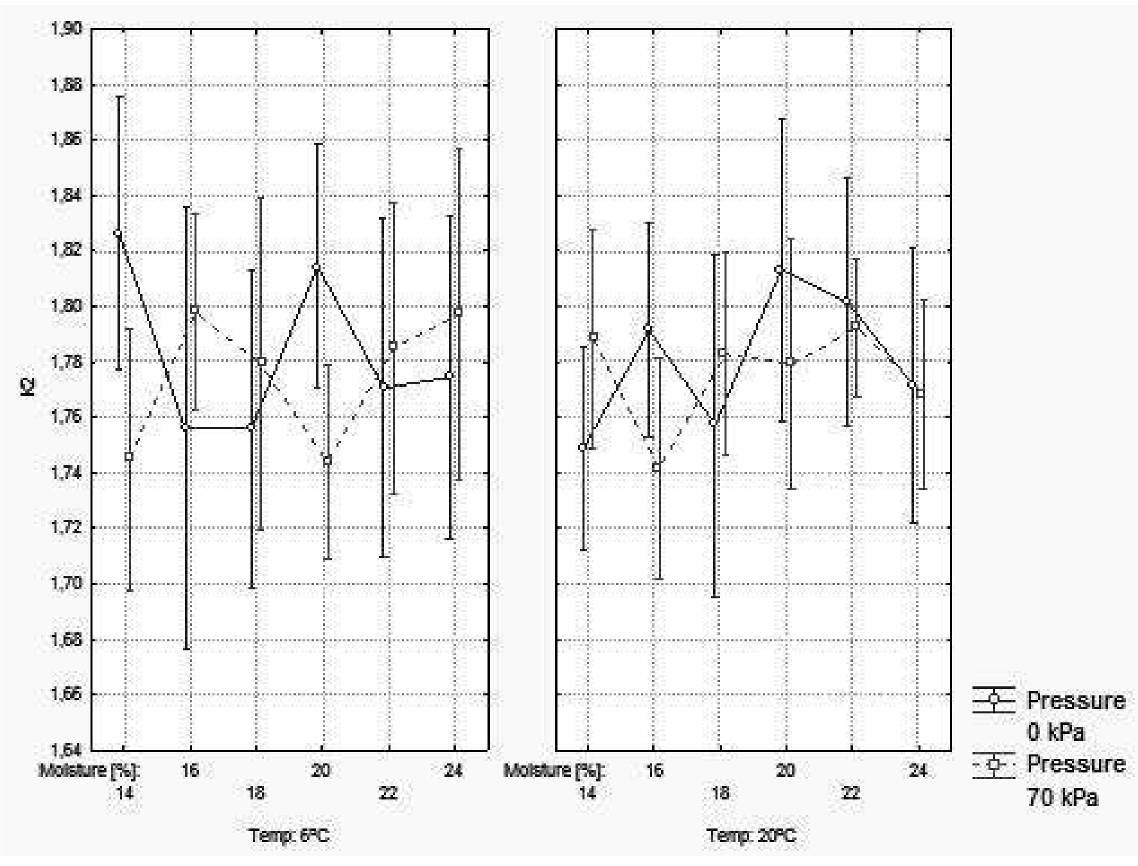

Fig. 8. The pressure course of K2 coefficient

Commodity is less susceptible to damage, which is referred to boundary line changes. Additionally, at higher pressure values the K2 course is disordered doing difficult or impossible to interpret. There was no evidence of pressure control on K2 values curves after storage in the range of 6 to 20 deg. C (Fig. 8).

CONCLUSIONS

1. Temperature of storage had no influence to area changes values during experiment.
2. All shape changes that occurred after storage were constant, being performed without stable damages or breaks, which was proved by K1 and K2 calculations.
3. Slight K2 changes were observed only after high-pressure and high-moisture storage of grain at 20 deg. C.
4. The results of the experiment proved that all grain geometric changes may occur at extreme storage conditions (20 deg. C, 52, and 70 kPa) for grain being moistened at least to 20%. Higher moisture values were the main factor responsible for these variations.

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REFERENCES

1. **Fernandez L., Castillero C., AguileraJ.M. 2005:** An application of image analysis to dehydration of apple discs. Journal of Food Engineering 67, p. 185-193.
2. **Fito P.J., Ortol, M.D, De los Reyes R., Fito P., De los Reyes E. 2004:** Control of citrus surface drying by image analysis of infrared thermography. Journal of Food Engineering 61, p. 287-290.
3. **Grundas S., Szot B., Woźniak W. 1978:** Variability of the porosity of cereal grain layer under the influence of static loading. Zeszyty Problemowe Postępów Nauk Rolniczych, z. 203, p. 33-39.
4. **Grzesiuk S., Kulka K. 1988:** Biologia ziarniaków zbóż. PWN Warszawa, ISBN 83-01068647.
5. **Guz T. 2009:** The use of image analysis to estimate harvest ripeness of apples. TEKA Kom. Mot. i Energ. Roln. 9, p. 61-68.
6. **Jahns G., Møller Nielsen H., Paul W. 2001:** Measuring image analysis attributes and modelling fuzzy consumer aspects for tomato quality grading. Computers and Electronics in Agriculture 31, p. 17-29.
7. **Kostecki Z. 2003:** Zapewnianie jakości ziarna w okresie jego przechowywania. Przegląd Zbożowo-Młynarski 7, p. 28-29.
8. **Kusińska E. 2006:** Horizontal pressure on the wall of a model silo in relation to the moisture content of oats. TEKA Kom. Mot. i Energ. Roln. 6A, p. 115-122.
9. **Kusińska E. 2008:** Hydraulic resistance of air flow through wheat grain in bulk. *TEKA Kom. Mot. i Energ. Roln. 8*, p. 121-127.
10. **Laskowski J., Skonecki S. 2001:** Pomiar współczynnika tarcia wewnętrznego pszenicy o różnej wilgotności i stopniu rozdrobnienia. Acta Agrophysica 46, p. 95-104.
11. **Łukaszuk J., Stasiak M., Rusinek R., Horabik J. 2001:** Wpływ wilgotności na kąt tarcia wewnętrznego ziarna zbóż. Acta Agrophysica 46, p. 105-113.
12. **Molenda M., Łukaszuk J., Horabik J. 2005:** Airflow resistance of wheat as affected by grain density and moisture content. Electronic Journal of Polish Agricultural Universities, Vol 8, Issue 4, p. 67-77.
13. **Paulus I., De Busscher R.,Schrevens E. 1997:** Use of image analysis to investigate human quality classification of apples. Journal of Agricultural Engineering Research 68, p. 341-353.
14. **Paulus I., Schrevens E. 1999:** Evaluating and modelling the size classification of apples. Journal of Agricultural Engineering Research 74, p. 411-419.
15. **Puchalski C., Gorzelany J.*, Zaguła G., Brusewitz G. 2008:** Image analysis for apple defect detection. TEKA Kom. Mot. i Energ. Roln. 8, p. 197-205.
16. **Szot B. 1983:** Czynniki kształtujące odporność ziarna pszenicy na obciążenia. Zeszyty problemowe Postępów Nauk Rolniczych 258, p. 437-447.
17. **Szulc M., Kahl J., Busscher N., Mergardt G., Doesburg P., Ploeger A. 2010:** Discrimination between organically and conventionally grown winter wheat farm pair samples using the copper chloride crystallisation method in combination with computerised image analysis. Computers and Electronics in Agriculture 74, p. 218-222.
18. **Szwed G., Łukaszuk J. 2003:** Ocena oporu przepływu powietrza przez warstwę nasion rzepaku. Acta Agrophysica 2, p. 645-650.
19. **Venora G., Grillo O., Saccone R. 2009:** Quality assessment of durum wheat storage centres in Sicily: Evaluation of vitreous, starchy and shrunken kernels using an image analysis system Journal of Cereal Science 49, p. 429-440.
20. **Zaguła G., Gorzelany J., Sosnowski S., Puchalski C., Brusewitz G. 2010:** Colour inspection of apple with machine vision. TEKA Kom. Mot. i Energ. Roln. 10, p. 527-537.
21. **Zaguła G., Gorzelany J., Sosnowski S., Puchalski C., Brusewitz G. 2010:** Sugar content determination using computer vision system. TEKA Kom. Mot. i Energ. Roln. 10, p. 538-547.
22. **Zapotoczny P., Zielinska M., Nita Z. 2008:** Application of image analysis for the varietal classification of barley: Morphological features. Journal of Cereal Science 48, p. 104-110.
23. **Zapotoczny P. 2011:** Discrimination of wheat grain varieties using image analysis and neural networks. Part I. Single kernel texture. Journal of Cereal Science 54, p. 60-68.

WPŁYW NACISKÓW W SILOSIE NA ZMIANY CECH GEOMETRYCZNYCH PSZENŻYTA

S t r e s z c z e n i e. Praca przedstawia metodykę i wyniki oceny zmian cech geometrycznych ziarna pszenżyta odmiany Pawo 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 ziaren (statystycznie nieistotne) występują tylko w skrajnych warunkach przechowywania (20°C, 52 i 70 kPa) w warunkach wysokiej wilgotności, która była głównym czynnikiem tych zmian.

Słowa kluczowe: pszenżyto, silos, przechowywanie, cechy geometryczne, analiza obrazu.