ANALYSIS OF VOLUME CHANGES OF SELECTED CEREAL GROUND GRAIN IN RESULT OF LOADING*

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Abstract. The work presents results of investigations on the effect of vertical pressure, species and moisture of ground grain on changes of its volume in results of loading. It was stated that the changes of ground grain volume in effect of loading are significantly affected by cereal species of which it was produced and its moisture, whereas earlier applied vertical pressure had no effect. Moreover, a high correlation between changes of ground grain volume and grain mass were registered.

Keywords: ground grain, grain, species, moisture, vertical pressure, change of volume

Introduction

Active airing has a crucial influence upon the course of cereal grain and ground grain conservation. At forced air movement, flow resistance occurs connected with material porosity. Therefore, the understanding of air flow resistance during this process is important. Increasing dimensions of a silo and a long time of storage cause considerable loading of the lower layers of grain and ground grain. Flow resistance through cereal grain and seeds is affected by the following factors: thickness of the layer, porosity, density, moisture of the material, size and shape of particles and degree of material density, but also storage time and the method of silo filling [Kusińska, Kizun 2006, Horabik 2001]. During cereal and seed storage in silos the lower layers of material are subjected to vertical pressure and undergo characteristic deformation connected with the properties of grain mass [Kolowca 2006]. The problem is particularly important during storing friable materials in silos of huge dimensions. At considerable material density air flow resistance through its layer may increase several-fold [Stephens and Foster 1976]. Literature of the subject lacks results of research on air flow resistance through cereal ground grain, characterized by small bulk density and porosity and becoming considerably compacted under the influence of its own weight [Kusińska et al. 2011]. For these reasons ground grain should not be stored in silos too long because a suspension of materials may occur which will cause problems with the container emptying. The analysis of available publications reveals that ground grain behaviour under the influence of loadings occurring in large-size containers has not been adequately studied.

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Aim and scope of work

The aim of presented paper was determining, under laboratory conditions, the range of changes of volume of ground grain obtained from selected cereal species in effect of assumed loading. Vertical pressure of the values registered in large-size containers, ground grain moisture and cereal grain of which it was produced were assumed as factors which may significantly affect the changes of ground grain volume.

Methods

The research was conducted in the laboratory of the Department of Engineering and Food Machinery, University of Life Sciences in Lublin. Tested was ground grain obtained from winter wheat, Tonacja c.v, winter rye, Słowiańskie c.v., oats, Sławko c.v., triticale, Pawo c.v. and spring barley Stratus, c.v. Grain initial moisture was c.a. 13%. Grain was moistened in containers according to the procedure presented in the work [Kobus et al. 2010]. In result two levels of moisture14%±0.2% and 18±0.2% were obtained. Grain moisture was determined following the standard No. PN79/R-69950. Subsequently the grains were crushed by means of beater crusher with stiff beaters equipped with sieves with 3 mm mash. The ground grain was poured into containers, 100m in diameter and 150 mm high, equipped with a removable cover enabling to obtain the assumed loading by means of four springs arrangement. The ground grain was loaded to achieve a constant vertical pressure of 35; 52 and 70 kPa and subsequently stored at the temperature of 22°C for 8 days. When the loading was removed, a ground grain sample of ~30 cm^3 was loosely poured into a container with an internal diameter of 50 mm and 60 mm high. The contained was placed in the Instron 4302 tensile tester and subsequently ground grain was loaded with a constant velocity of 0.83 $mm \cdot min^{-1}$using a cylindrical piston until the force of F_n=1.5 kN was obtained and then the measurement was stopped. In result of ground grain loading a change of its volume occurred in effect of compacting and deformation of the material.

Changes of ground grain volume under the influence of loading were determined according to the following formula:

$$Z_{mz} = \frac{(V_p - V_k) \cdot 100}{V_p} \tag{1}$$

where:

Z_{ms} – change of ground grain volume [%],
V_k – final volume of ground grain [cm^3],
V_p – initial volume of ground grain [cm^3].

Statistical analysis was conducted by means of Statistica 6 programme of Statsoft, Inc, [StaSoft Inc. 2003]. The assessment of variables (species, vertical pressure and moisture) effect on changes of ground grain volume Z_{ms} was conducted using ANOVA module.

Results

Changes of ground grain volume Z_{ms} for the analyzed cereal species in effect of F_n loading depending on the moisture were presented on charts (Fig. 1-5). For comparison the charts show changes of grain mass volume under the influence of loading for individual cereal species obtained in previous research [Nadulski et al. 2011]. Conducted statistical analysis revealed that changes of ground grain volume depend significantly on the cereal species of which it was produced. Among the analyzed cereals the greatest change of volume Z_{mz} for ground grain with 14% moisture was obtained for oats – 48.3% , which is connected with specific structure of kernels and in result also structure of ground grain. On the other hand the smallest change of ground grain volume, 27.2% was obtained for barley. In case of the other cereal species changes in ground grain volume were from 29.4% for triticale ground grain to 33.5% for rye ground grain.

Statistical analysis revealed a significant effect of moisture on the range of changes of ground grain volume Z_{mz} in effect of loading. For ground grain with 18% moisture the highest value of changes in effect of Z_{mz} loading – 50.6% was obtained also for oats, whereas the lowest for barley – 29.5%.

Statistical analysis revealed a high correlation between changes of grain mass volume in effect of loading and changes of volume of its ground grain. Obtained values of correlation coefficients range from 0.89 to 0.96. A comparison of the change of ground grain volume and volume of grain from which it was made shows the highest values for rye (Fig. 3) and the lowest for oats (Fig. 2). The investigations point to a diversified range of changes of volume for the analyzed samples of cereal species and ground grain in result of loading.

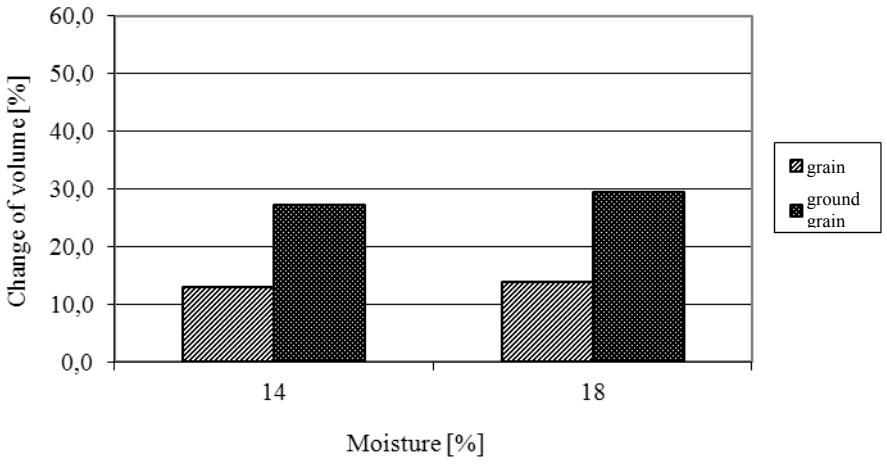

Fig. 1. Change of volume Z_{mz} of barley ground grain and grain mass in effect of loading depending on its moisture

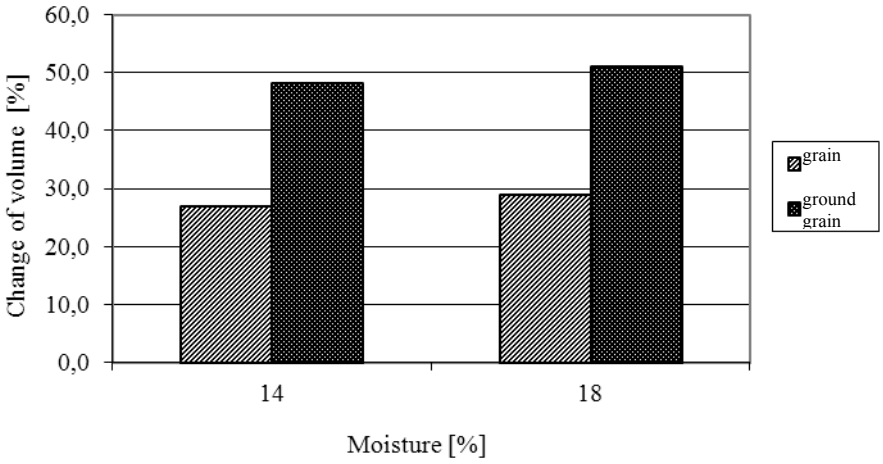

Fig. 2. Change of volume Z_{mz} of oat ground grain and grain mass in effect of loading depending on its moisture

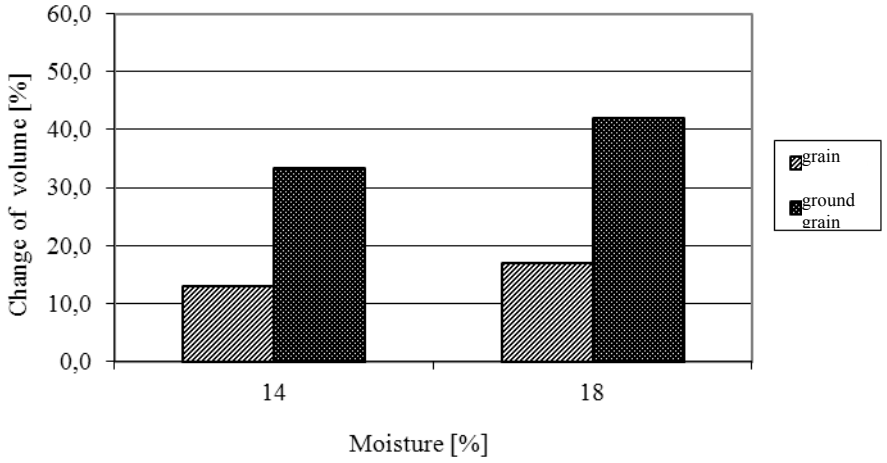

Fig. 3. Change of volume Z_{mz} of rye ground grain and grain mass in effect of loading depending on its moisture

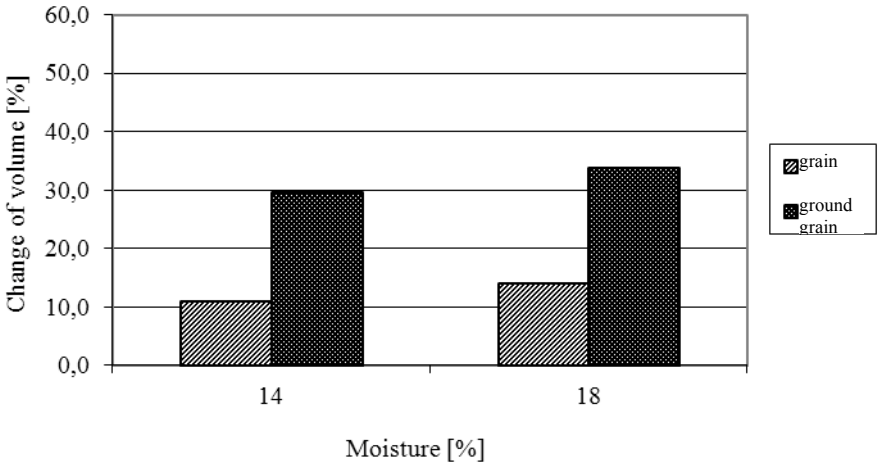

Fig. 4. Change of volume Z_{mz} of wheat ground grain and grain mass in effect of loading depending on its moisture

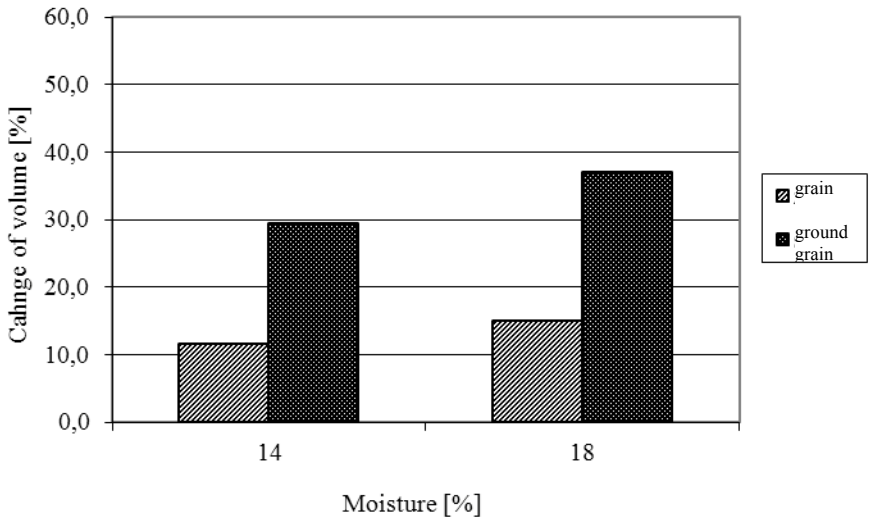

Fig. 5. Change of volume Z_{mz} of triticale ground grain and grain mass in effect of loading depending on its moisture

Conclusions

Conducted investigations allow to formulate the following conclusions:

1. Changes of ground grain volume under the influence of loading depend significantly on cereal species from which it was prepared.
2. Ground grain moisture crucially affects the course of its volume changes in result of loading, however the range of these changes depends on cereal species.
3. The highest dynamics of changes with increasing moisture was observed for rye and triticale ground grain.
4. A change of ground grain volume in effect of loading does not depend on the vertical pressure to which it was subjected before compacting.
5. There is a high correlation between changes of grain mass volume in result of loading and ground grain volume.

References

Horabik J. 2001 Charakterystyka właściwości fizycznych roślinnych materiałów sypkich istotnych w procesie składowania. Acta Agrophysica. 54. Lublin.

Kobus Z., Guz T., Kusińska E., Nadulski R., Oszczak Z. 2010. Wpływ wilgotności na wybrane właściwości fizyczne pszenżyta odmiany Pawo. Inżynieria Rolnicza. Nr 3(121). pp. 61–67.

Kolowca J. 2006. Wpływ wielokrotnych obciążeń statycznych na stopień zagęszczenia i właściwości reologiczne masy ziarna. Inżynieria Rolnicza. Nr 13(88). pp. 193–199.

Kusińska E., Kizun V. 2006 Wpływ zagęszczenia ziarna owsa I prędkości przepływu powietrza na opór hydrauliczny. Inżynieria Rolnicza. Nr 5(80). pp. 403–410.

Kusińska E., Nadulski R., Kobus Z., Guz T. 2011. Opory przepływu powietrza podczas wietrzenia śruty pszennej.Inżynieria Rolnicza. Nr 4(129). pp. 159–165.

Nadulski R., Kusińska E., Kobus Z., Guz T., Oszczak Z. 2011. Analiza zmian objętości masy ziarnowej wybranych gatunków zbóż pod wpływem obciążenia. Inżynieria Rolnicza. Nr 4(129). pp. 237–242.

StatSoft, Inc. 2003: STATISTICA (data analysis software system). Version 6. http://www.statsoft.com. Polska Norma PN79/R-69950.

ANALIZA ZMIAN OBJĘTOŚCI ŚRUTY WYBRANYCH GATUNKÓW ZBÓŻ POD WPŁYWEM OBCIĄŻENIA

Streszczenie. W pracy przedstawiono wyniki badań dotyczące wpływu nacisku pionowego, gatunku i wilgotności śruty na zmianę jej objętości pod wpływem obciążenia. Stwierdzono, że na zmiany objętości śruty pod wpływem obciążenia istotny wpływ ma gatunek zboża, z którego została wykonana i jej wilgotność, natomiast nie wpływa nacisk pionowy, któremu była poddana przed wcześniej. Ponadto stwierdzono wysoką korelacja pomiędzy zmianami objętości śruty i masy ziarnowej.

Słowa kluczowe: śruta, ziarno, gatunek, wilgotność, nacisk pionowy, zmiana objętości

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