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MECHANICAL STRENGTH OF VITREOUS AND MEALY VARIETIES OF CANADIAN AND POLISH WHEATS

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A b s t r a c t. Structural differences between market classes and varieties of wheat will have a marked influence on their mechanical properties. An analysis of the mechanical properties of mealy and vitreous grains was conducted on hard, vitreous durum wheat, variety Wascana from Canada and two Polish varieties: Delta (Soft White Winter) and Jara (Soft White Spring), which exhibited mealy and intermediate grain characteristics. Simple quasi-static compression tests were performed to measure the force, deformation and initial irreversible deformation, based on the compression curve. The results showed that mealy grains were less resistant to external loads than vitreous grains. But mealy grains were more elastic, and withstood greater deformation, than vitreous grains which exhibited greater maximal force but were 'brittle'.

K e y w o r d s: wheat, mechanical strength, mealy and vitreous grains

INTRODUCTION

Mechanical damage to wheat occurs each time grains are handled. Initially, internal fractures may appear during grain maturation [1]. Harvesting can intend internal fractures and some new tissue incontinuity can be observed, even as broken parts of grains in extreme cases. The next operations after harvesting increase mechanical damage of grains, what is a very important problem in grading, processing and storage due to increased susceptibility to moulds and insects.

Variability of wheat grains in resistance to mechanical damage depends on wheat variety, moisture content, growing conditions, type of load, kernel size, etc. Also type of grain structure - mealy and vitreous, affects the mechanical parameters, which characterize the damage resistance of grains.

The following investigations were conducted in order to compare the strength characteristics of durum wheat grains from Canada and selected wheat varieties, bred in Poland, with the majority of mealy or vitreous type of grain endosperm, of the Soft White Winter and Spring market class.

MATERIAL AND METHODS

Three varieties of wheat: Delta, Jara and Wascana were selected for the study. The Delta variety was chosen as a typical mealy variety bred in Poland. The majority of vitreous type of endosperm characterized Jara, which is also commonly grown in Poland. Both Polish varieties were obtained from experimental farms, where growing conditions of plants were recommended. Wascana, Canadian durum wheat variety, came from the experimental farm of the University of Saskatchewan. The endosperm of all grains of this variety was vitreous.

Grains of all varieties had an equal moisture content during the test of 7 %. The static compression test was performed on an INSTRON testing machine connected through analog-digital converter to a personal computer. Compression curves (Fig. 1) were recorded in force-deformation coordinate

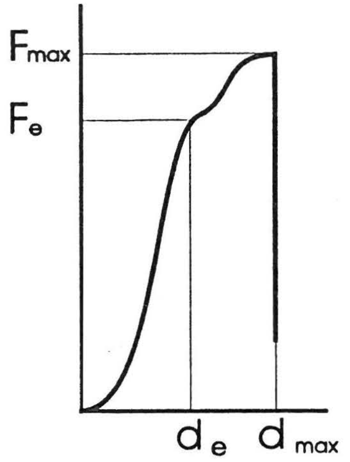

Fig. 1. Characteristic parameters derived from the compression curve.

system. Grains, with the grooves oriented horizontally, were compressed between two parallel plates at a constant rate of 10 mm/min. Maximal force and deformation were read from the curves obtained, then force and deformation from the linear part of the curve (untill the first crack) was read as well. These second values were considered as limits of elasticity. Energy required to damage the grain was also derived from the compression curve.

Every test consisted of 50 replications. The analysis of variance was made in order to estimate differences between varieties and significance of these differences.

RESULTS

The range in endosperm structure, which characterized the three varieties of wheat influenced the behaviour of their compressed grains. Not only the values of investigated parameters were significantly different but also the shape of the compression curves differed according to variety.

A distinct first peak in the compression curve of Wascana wheat was observed (Fig. 2). This peak was less clear and sharp for other varieties, where this place was marked only by non-linearity of curve or shoulder. Also the place of the curve, where the bend oc-

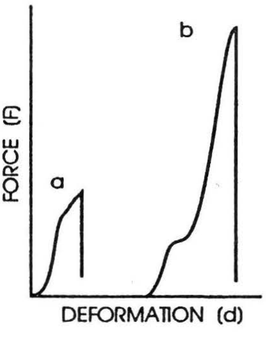

Fig. 2. Typical compression curves of mealy grain (a) and vitreous grain (b).

curred, was different. It was close to the maximal peak (above two third of curve height) for Polish varieties Delta and Jara, while for Canadian Wascana it was very early (the lower third of curve height).

Values of force and deformation up to the initial peak were considered as the conventional limits of elasticity, beyond this point arose the first irreversible deformations. Total destruction of a grain structure was observed at maximal peak.

Grains of durum wheat underwent first failure during compression earlier than the two other wheat classes (Fig. 3a). Average elastic force varied from 16.1 N for Wascana to 58.6 N for Jara and 45.7 N for Delta. So the Polish varieties, with superiority of mealy type of grains, withstood five times higher loads than Canadian wheat Wascana. The differences among classes and varieties were statistically significant.

The opposite situation occurred with respect to maximal damage force (Fig. 3b), which was three times higher for Wascana than for Delta or Jara. Average damage force of durum wheat was 197.3 N, while Delta withstood loads of only 70.9 N and Jara 85.6 N. The differences in this parameter between Delta and Jara were insignificant, but were significant among Wascana and the other two varieties. The value of maximal force with respect to elastic force of durum variety was ten times greater, while this proportion for the other two varieties was about 1.5.

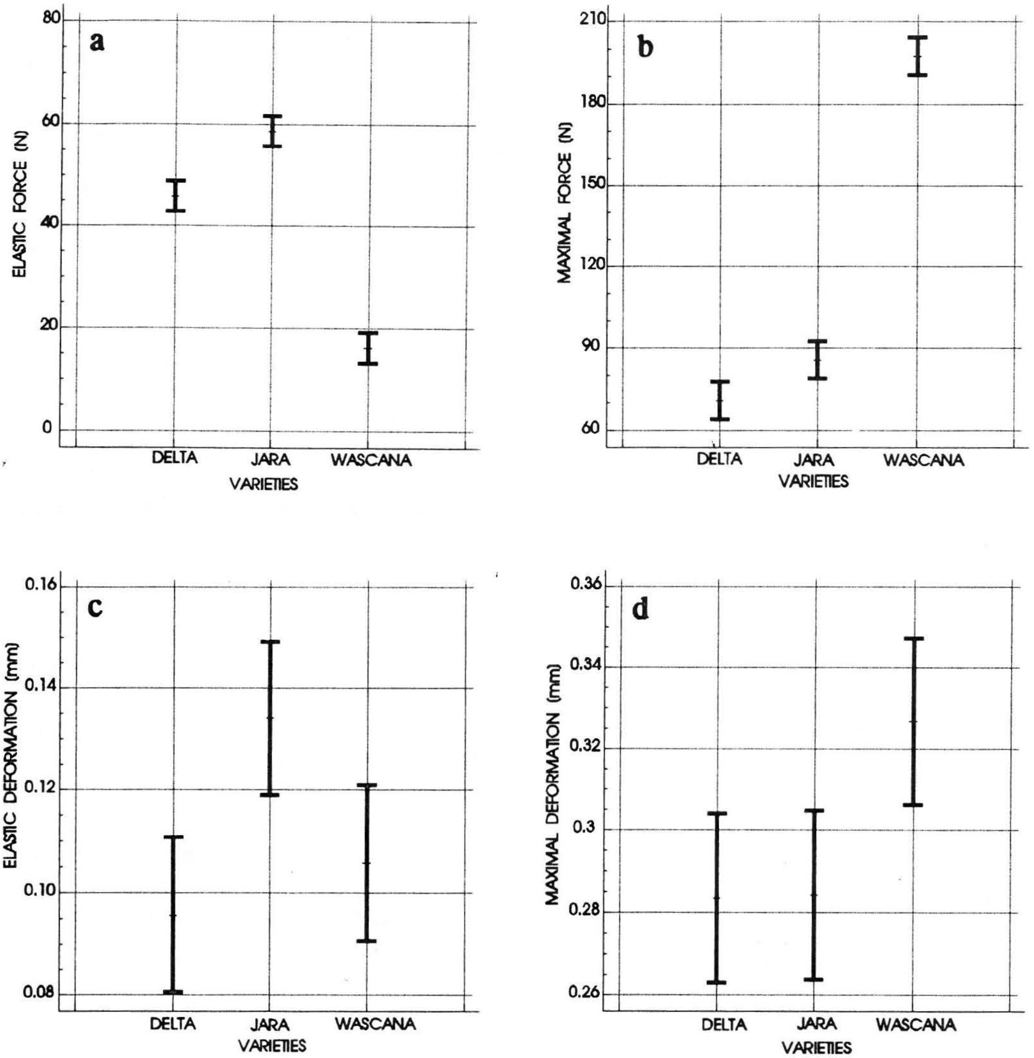

Fig. 3. Mean values with confidence intervals of: elastic force (a), damaging force (b), elastic deformation (c), and damaging deformation (d).

The smallest elastic deformations occurred for grains of Delta (Fig. 3c), average 0.10 mm, and the largest elastic deformation occurred for Jara, average 0.14 mm. There were significant differences between these varieties, but the differences were insignificant between Wascana and both Polish varieties. The average elastic deformation for Wascana was 0.11 mm.

Maximal deformation of grains of tested varieties showed a different pattern (Fig. 3d). Grains of Wascana were the most deformed and the average damage deformation was 0.33 mm. This value differed significantly from the corresponding values of the other two varieties, for which damage deformations were equal on average and had similar confidence intervals. The damage deformations of Delta and Jara were 0.28 mm. The proportions between elastic and maximal deformations were different compared to the first failure, similar to Delta, while Jara stood about two times greater deformations until damage compared to first failure.

Energy required to damage grain (Fig. 4) was more than two times greater for durum wheat than for the other two wheat classes. Average damage energy of Wascana grains was 30.08 mJ, while of Jara grains was 14.2 mJ and of Delta 12.6 mJ. The differences were statistically significant between Wascana and both Polish varieties, between which the differences were not significant.

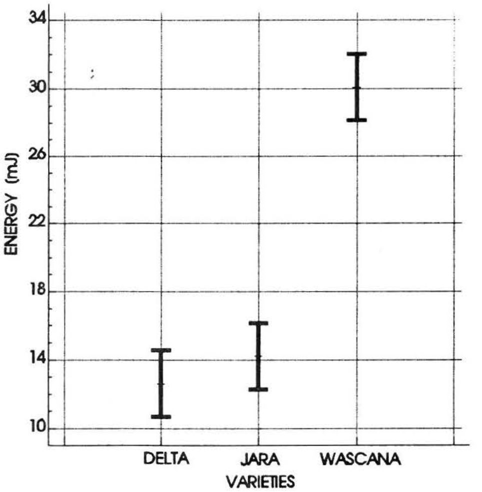

Fig. 4. Mean values and confidence intervals of damaging energy of grains.

DISCUSSION

Investigations showed that the structure of wheat grain had a fundamental effect on its mechanical characteristics. Significant differences occurred mainly between parameters of durum type of wheat and other wheats. Within studied wheats Jara had more vitreous type of grains than Delta, the latter variety withstood lower loads until first cracking, which was in contradiction with the lowest level of elastic force of the all-vitreous grains of Wascana.

Completely different proportions of elastic and damaging forces could be born by structure of endosperm and its properties under compression. There would be other reasons for differences between Delta and Jara. Some of these could be solved by special investigations, made only on samples cut from endosperm (to eliminate the influence of grain shape, dimensions and discontinuous born by a groove).

Generally durum wheat was hard and brittle - underwent earlier rupture of grain structure, but withstood much higher maximal loads, causing total damage of grain. Polish market class wheats were elastic but their structures were weak - did not support so high loads but, at the same time, first rupture of grain structure occurred under higher loads comparing to durum wheat.

The high damaging energy of Wascana durum wheat indicated that the milling process of this type of wheat should be much more energy-consuming than milling of mealy types of wheat.

CONCLUSIONS

1. Considerable influence of type of grain structure on mechanical strength was demonstrated. The differences between parameters obtained for mealy and vitreous grains were statistically significant.

2. Maximal force causing grain damage was much greater for durum wheat than for other wheats. Similarly deformations corresponded to maximal force was greater for Wascana than for Jara or Delta.

3. Force causing initial rupture was differentiated for these wheats and the greatest was for Jara, while for Delta and Wascana this force was not significantly different.

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