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# THE EFFECT OF TWO TYPES OF MOISTURE TREATMENT OF WHEAT GRAIN ON ENDOSPERM DAMAGE

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A b s t r a c t. Wheat grain of low moisture content cracks when it absorbs water or moisture from the environment. The resulting endosperm damage is detected by X-ray method. Grain samples of spring wheat cv. Henika of 10 % moisture content of different endosperm types - vitreous and mealy, were subjected to the process of moistening: in water, and in a controlled-climate chamber.

The resulting internal damage was described by means of digital indexes. Analysis of results indicates that the extent of the damage is affected by both the method of moistening and the type of endosperm.

K e y w o r d s: wheat grain, internal damage, moisture gradient, X-ray detection

## INTRODUCTION

Cereal grain is subject to damage due to the action of the working elements of machinery in the course of harvest and transport. It is also subject to damage as a result of internal stress caused by high gradients of moisture occurring in the processes of heat and mass exchange during the pre-harvest period as well as during post-harvesting processing [7,9,15,16].

Mechanical damage of grain, understood as a disruption of the natural continuity of tissues, can appear in the form of cracks in the involucre, extending into the endosperm (external damage), or in the form of cracks within the endosperm, without affecting the aleurone layer (internal damage). Internal damage is not observable by the naked eye but results in unfavourable effects, physical as well as biological. A decrease in the germination capacity is observed, an increased growth of microflora, greater losses of dry mass in the process of storage, and after sowing - a lowered productivity of the plant. Damaged kernels absorb moisture from the air at a greater rate, and their rate of respiration is also increased [2]. They have a lower mechanical strength and crumble more easily during post-harvest processing than is the case with undamaged kernels [3,4].

There are also practical aspects to the problem, as it is possible to improve the grain grinding characteristics through a process of artificial seasoning prior to the grinding. This yields wheat grain with cracks, wheat which has gone through a process of moistening and drying. The resulting drop in grain hardness causes that the process of diminution requires less energy [10].

Internal damage, frequently caused by a combination of thermal, moisture and mechanical stresses, is not easy to detect. Currently, internal damage detection is performed using the latest techniques - scanning microscopy [3,6,19], NMR - nuclear magnetic resonance [13,16], laser optical method [5]. The X-ray method, whose major advantage is the possibility of conducting non-destructive tests, proved to be highly useful and much less costly [10, 17,20]. The X-ray detection technique permits the determination of the location, extent and character of damage, and thus allows for an assessment of the condition of the endosperm of a kernel subjected to the effect of a variety of destructive factors.

This paper presents an assessment of the effect of two methods of moistening of grain of low moisture content on the status of internal damage detected by means of the X-ray technique.

## MATERIALS AND METHODS

Out of a sample of grain of spring wheat cv. Henika of a moisture content of 10 %, the author selected kernels without internal damage, with typical vitreous and mealy endosperm. The kernels were placed on test trays, 100 kernels per tray, groove down, and wetted to various moisture contents, recording their image on X-ray film. Internal damage was detected using a Russian X-ray apparatus, type ELEKTRONIKA 25, according to a present procedure [17]. The apparatus produced images of various degrees of magnification (from x2 to x10).

The application of X-ray technique permitted the detection of internal damage of grain, occurring in the process of absorption of water and water vapour. Intensive moistening in water, at room temperature, lasted for 1, 3 and 6 h, which produced grain samples of moisture content levels of 16, 21 and 26 %, respectively. Intensive moistening in a controlled-climate chamber (t=15 °C and RH=98 %) lasted for 48 h and permitted an assessment of the status of internal damage for kernels of the following moisture content levels: 13, 15, 18, 21, and 26 %. Moisture content of grain was approximated by measuring weight increase during wetting.

The cracks detected were described by means of binary indexes BI based on an adopted division of kernel image and on a digital notation of the system of its damage [11,12]. Figure 1 presents eight damage patterns with kernel image division into three zones - lower (with the germ), middle, and upper, and the corresponding values of damage indexes BI.

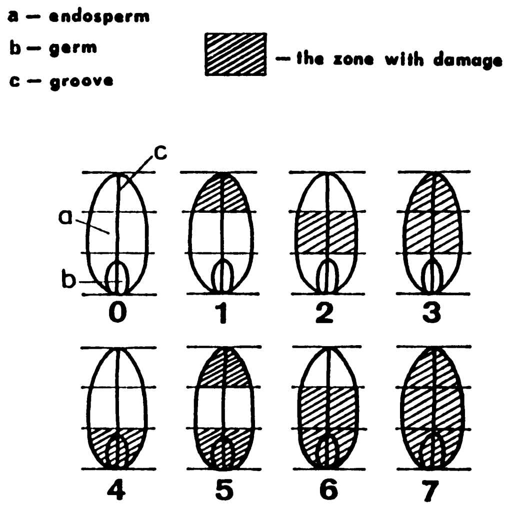


Fig. 1. All the possible patterns of cracks locations in the three zones of kernel and the binary index (BI) assigned to them.

## RESULTS AND DISCUSSION

The study showed that wetting grain of low moisture content causes internal damage to the endosperm which, in X-ray images, take the form of characteristic lateral cracks (Photo 1).

An analysis of results showed that the percentage of kernels damaged in water increased rapidly with increasing grain moisture content within the range from 10 to 21 %. Already at the initial stage of wetting, from 10 to 16 %, internal damage occurred in 50 % of kernels of mealy endosperm, and in as much as 90 % of kernels of vitreous endosperm (Fig. 2a). At 21 % moisture content, 100 % of vitreous kernels were damaged, while the damage of mealy kernels was not much lower. In the case of grain wetting in the controlled-climate chamber the percentage of damaged kernels initially increased with increasing moisture content from 10 to 15 %, and then decreased within the range from 18 to 26 %. In samples of mealy kernels 81 % of cracked kernels were recorded, the value for vitreous kernels being 88 % - a maximum at 15 % moisture content (Fig. 2b).

The extent of damage to endosperm was assessed by means of binary indexes BI. Table 1

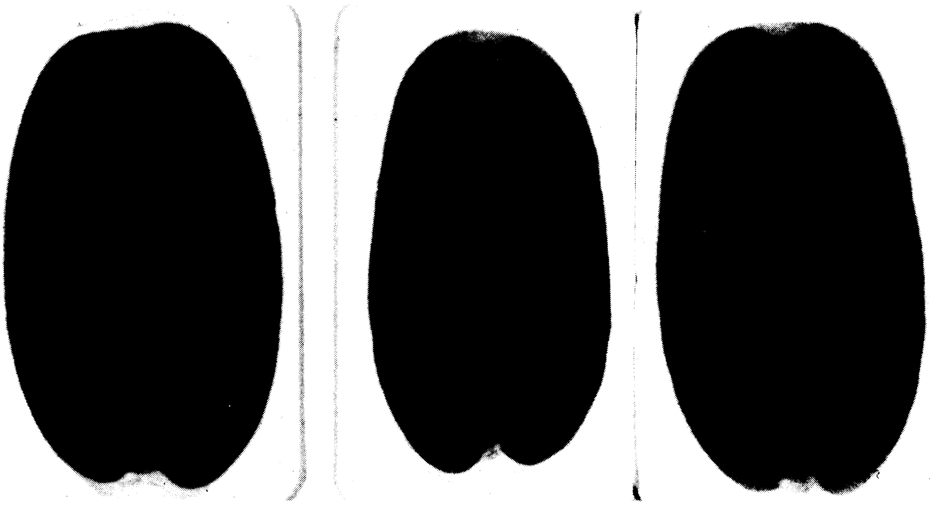

**Photo 1.** X-ray pictures of wheat kernels.

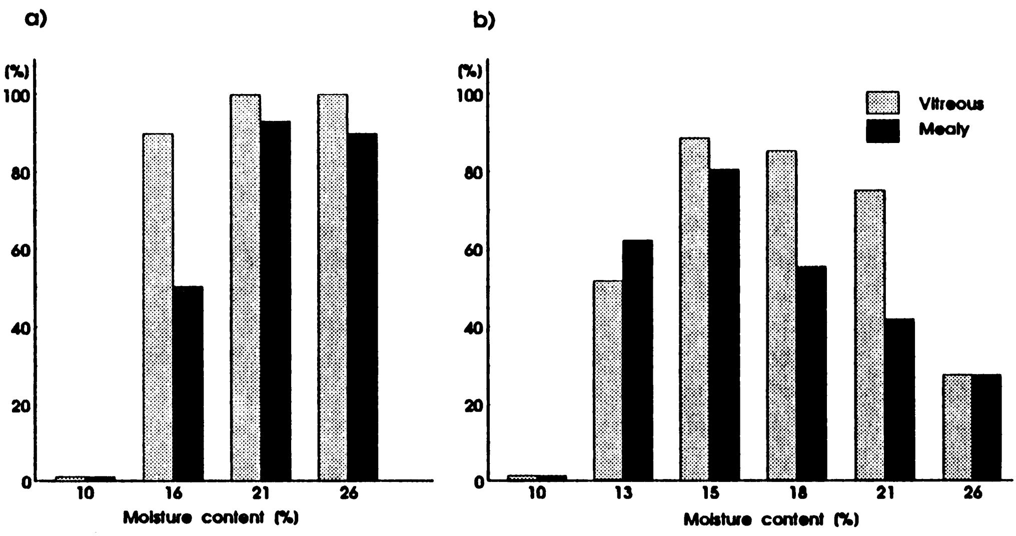


**Fig. 2.** Percentage of damage kernels in samples of vitreous and mealy grain moistened in water (a) and climatic chamber (b).

presents mean values of BI indexes for grain wetted in water and in air of high relative humidity (controlled-climate chamber). Irrespective of the type of endosperm and the method of wetting, the initial increase in grain moisture content was accompanied by an increase in the extent of internal damage. The highest increase in damage was observed after 3 h of wetting in water, i.e., at grain moisture content of 21 %, for which BI=6.2. For grain samples wetted in the controlled-climate chamber, the highest number of cracks was observed at a moisture content of about 15 % - BI=3.9. With further wetting the values of the damage indexes

**Table 1.** Mean values of binary indexes (BI) of the samples of wheat grain of cv. Henika

| Method of wetting | Moisture content (%) | Type of endosperm | | Mean values |
|---|---|---|---|---|
| | | vitreous | mealy | |
| Water | 10 | 0 | 0 | 0 |
| | 16 | 4.1 | 1.9 | 3.0 |
| | 21 | 6.7 | 5.6 | 6.2 |
| | 26 | 5.7 | 4.6 | 5.2 |
| Mean values | | 5.5 | 4.0 | 4.8 |
| Controlled-climate chamber | 10 | 0 | 0 | 0 |
| | 13 | 2.1 | 2.7 | 2.4 |
| | 15 | 3.8 | 3.9 | 3.9 |
| | 18 | 3.3 | 2.3 | 2.8 |
| | 21 | 2.6 | 1.7 | 2.2 |
| | 26 | 0.6 | 0.9 | 0.8 |
| Mean values | | 2.5 | 2.3 | 2.4 |

decreased, which indicated the disappearance of cracks formerly detected.

The frequency of occurrence of kernels with damage related to the adopted binary indexes shows that in the initial phase of wetting the most numerous group was that of kernels with cracks in the zone with the germ - BI=4 (Tables 2 and 3). Further wetting caused an increase in damage in the other zones, which is indicated by the highest percentage of kernels with indexes 2, 6 and 7. At the same time it was observed that as the grain moisture content increased, the frequency of occurrence of kernels with index 4 decreased.

Damage in the lower zone in the initial phase of wetting, followed by the appearance of cracks in the middle and upper zones, confirms that water penetrates the kernel the fastest from the direction of the germ. Internal stress, caused by moisture sorption and the resultant moisture gradient, initiate the appearance of cracks in the successive zones of the kernel. The direction of propagation of the cracks, and then the direction of disappearance of cracks formerly detected, roughly coincide with the direction of water movement within the kernel [14].

The saturation of starch granules with water causes their swelling and endosperm cracks earlier visible cannot be detected any more. In vitreous kernels disappearance of cracks is observed at higher moisture contents than in mealy kernels. The more compact structure of endosperm and the higher content

**Table 2.** Frequency of occurrence of kernels with assumed values of binary index (%) - for samples wetted in water

| Binary index | Moisture content (%) | | | | | |
|---|---|---|---|---|---|---|
| | 16 | 21 | 26 | 16 | 21 | 26 |
| | mealy | | | vitreous | | |
| 0 | 52.2 | 7.0 | 11.5 | 10.0 | 0.0 | 0.0 |
| 1 | 1.5 | 0.2 | 1.0 | 1.8 | 0.3 | 0.5 |
| 2 | 5.2 | 6.0 | 15.3 | 1.3 | 0.3 | 4.0 |
| 3 | 0.7 | 2.2 | 10.8 | 1.0 | 0.5 | 22.3 |
| 4 | 32.7 | 6.2 | 5.8 | 57.3 | 1.8 | 0.2 |
| 5 | 2.0 | 1.2 | 1.0 | 12.0 | 3.3 | 2.8 |
| 6 | 4.2 | 23.5 | 14.3 | 6.5 | 12.8 | 11.5 |
| 7 | 1.2 | 53.5 | 40.5 | 10.2 | 81.3 | 58.8 |

**Table 3.** Frequency of occurrence of kernels with assumed values of binary index (%) - for samples wetted in controlled-climate chamber

| Binary index | Moisture content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 15 | 18 | 21 | 26 | 13 | 15 | 18 | 21 | 26 |
| | mealy | | | | | vitreous | | | | |
| 0 | 37.5 | 19.1 | 45.6 | 58.4 | 73.1 | 49.0 | 12.4 | 15.0 | 25.4 | 73.6 |
| 1 | 1.4 | 1.1 | 0.8 | 1.4 | 1.4 | 0.3 | 1.0 | 0.6 | 1.0 | 0.6 |
| 2 | 10.8 | 14.6 | 16.1 | 13.0 | 10.4 | 2.4 | 26.4 | 43.1 | 34.9 | 20.0 |
| 3 | 1.3 | 5.0 | 3.1 | 3.8 | 3.1 | 0.0 | 2.9 | 6.5 | 5.5 | 1.9 |
| 4 | 25.4 | 14.9 | 11.1 | 9.0 | 5.9 | 42.0 | 13.0 | 10.9 | 12.5 | 2.5 |
| 5 | 2.0 | 2.5 | 1.4 | 0.4 | 1.0 | 0.0 | 1.1 | 1.5 | 0.8 | 0.1 |
| 6 | 16.4 | 25.8 | 14.9 | 8.5 | 3.4 | 5.9 | 37.8 | 26.0 | 17.4 | 1.1 |
| 7 | 5.5 | 17.0 | 7.0 | 5.6 | 1.8 | 0.5 | 4.6 | 5.4 | 2.6 | 0.1 |

of protein [1] cause that the protein film absorbs water first, and then water gets into the starch granules causing their swelling. Mealy kernels, due to their less compact structure and lower content of protein, need less moisture for cracks detected at lower moisture contents to disappear.

The heterogeneity of composition and the irregularity of shape of grain make the analysis of diffusion a complex problem. Water diffusion is not identical for the various components of grain. Moisture penetrates the kernel through its whole surface, but the process is the fastest from the direction of the germ [13]. The germ zone, therefore, has a relatively higher moisture content than the other zones of the kernel. An increase in moisture content at the surface causes swelling, and therefore compressive stress in the affected areas. The interior of the kernel is still dry and close to the initial value of moisture content. The compressive stress on the surface or close to the surface of the kernel cause stretching stress within the endosperm. When the stretching limit is exceeded, the kernel gets damaged, which is manifested by cracks within the endosperm [14].

Vitreous endosperm extends the process of wetting in time, as compared to mealy kernels. The non-homogeneity of water absorption is caused by starch degradation and the resultant decrease in its viscosity. The specific mechanism of moisture sorption by the various components of wheat grain is not sufficiently well known so far. It is known, however, that the initial moisture content of grain has a significant effect on the rate of water absorption, and that is related with the formation of internal stresses leading to damage to endosperm [7-9,13,16,18,19].

## CONCLUSIONS

1. The process of wheat grain wetting within the range of grain moisture content from 10 % to 26 % is accompanied by the appearance, and then disappearance, of endosperm cracks.

2. More kernels get damaged in the course of wetting grain in water than in a controlled-climate chamber.

3. The extent of damage to endosperm due to contact of grain with water, described by the binary index, is greater than the extent of damage due to absorption of water vapour in the controlled-climate chamber. Therefore, a higher rate of wetting results in a greater degree of damage to endosperm.

4. In the case of grain wetting with water the maximum of cracking occurs at a grain moisture content of about 21 %, while in the case of grain wetting in the controlled-climate chamber at about 16 %.

5. Vitreous kernels are more susceptible to damage than mealy kernels, irrespective of the method of wetting.

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