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ATTEMPT TO APPLICATION OF IMAGE PROCESSING TO EVALUATION OF CHANGES IN INTERNAL STRUCTURE OF WHEAT GRAIN*

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A b s t r a c t. Test experiments have been carried out concerning the application of computer analysis of X-ray images for the assessment of the changes in inner structure of wheat grain subjected to the process of wetting and then low drying to the initial moisture content. After each stage of the process established, which ensured sufficiently high differentiation in grain moisture content, the images of the same kernels have been registered on X-ray photographic plates. The X-ray images have been entered to the system of computer image analysis using a CCD monochromatic camera. Both kernels images (source and processed) and corresponding distributions of grey levels have been appropriately stored and constituted the basis for further analyses. The computer analysis of X-ray images of wheat grain appeared to be a very subtle tool for the investigation of the changes in grain inner structure. Although it has been possible to notice the differences in grey levels of the images being the results of different level of grain moistening, it has been stated that more careful preparation of the experiment is indispensable. Improvement of X-ray images quality and application of a scanner for image transfer into computer would allow for the elimination of factors which disturb drawing conclusion, which will be accounted for in futher investigations.

K e y w o r d s: wheat grain, weray detection, image analysis

INTRODUCTION

The processes of wheat kernels obtainment may cause different damage formation in this raw material. Deterioration of its reproductive and consumptive quality is the consequence of these processes [2]. For that reason, there is a need for a method, which allows for a new precise and quantitative determination of kernel damage state in laboratory examinations. Knowledge of this state enables, e.g., choice of optimum crop and drying parameters, etc. from the point of view of damage minimization or estimating their effects.

Almost half a century, soft X-radiation has been applied to detect internal damages in cereal kernels and other seeds. X-ray photography performs precise display of the internal kernel structure changes (these originate from different destructive factors), and therefore allows for a wide damage class identification. Moreover, it is much cheaper than, e.g., the nuclear magnetic resonance (NMR), scanning microscopy or laser technology. Besides, it is a non-destructive detecting technique (NDT).

Various classifications are applied to estimate kernel damages detected by X-ray photography. However, such estimation causes problems with assigning kernels to certain classes. Then, the effective, quantitative, statistical methods cannot be used for damage analysis. Next, the estimation based on counting the damage is deceptive due to their form varieties [6].

Considering the fact that damages occur on the so called 'continuous scale', to begin

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with the tinniest slit through bigger cracks, decrements to a total kernel destruction, an idea came out to apply a measure adequate to the damage state estimation [1]. In many works, it was implied so as such a measure could also include kernel damages location because of possible damage effects. With regard to these postulates, Niewczas has put forward a simple method determining such measures. They are called fault detectors. The previous experiments proved that this method can be applied for damage estimation caused by different factors [3,5,7].

The internal endosperm slits are the first noticeable damage symptoms on X-ray photographs. It is the effect of internal stresses that arose in kernels, e.g., as a result of moisture gradient. Drying experiments show that not only slits and cracks may have an influence on kernels properties after drying. For example, numerous kernels which did not sprout and were without cracks but with the clearly darker germ or/and endosperm background. Most probably, the germ, as more hydrated and of greater protein amount, may become denatured before the endosperm cracks. Therefore, it is important to include the endosperm changes of the germ and endosperm background in the researches on the internal kernel structure.

The identification and estimation of many changes of the internal kernel structure (especially the endosperm cracks) is very simple while using the mentioned method even with help of X-ray photographs eye survey. But detection and estimation of the web-eye or germ background diversification may become very difficult, especially, during mild kernels treatment, i.e., without greater damages in their internal structures. This paper is an attempt of overcoming these difficulties with an image processing method and image analysis.

MATERIAL AND METHODS

During the experiment we applied 5 wheat kernels of Begra variety of the same size and initial moisture content (11.2 % w.b.). The kernels were placed on paper cassettes in a stable position (groove down), and exposed to X-ray detection. Next, four of them were moistened in the distilled water of room temperature for 0.5, 3 and 6 h in succession to obtain material fairly diversified in respect of moisture content. After each moistening stage kernels were placed in the same container and the X-ray photography was applied including the fifth, dry, the so called, control kernel. During the next experimental stages, the moistened kernels were slowly dried in the room temperature. Just as before, after each drying stage (6, 18, 24, and 42 h), kernels - including the control kernel - were exposed to X-ray detection.

By this way, eight X-ray photographs of the same five kernels were made at the scale of 5:1. The first visual X-ray photograph analysis did not allow to formulate the results of endosperm and germ background diversification in the examined kernels. By the monochromatic CCD camera, the image corresponding with an X-ray photograph was inserted into computer image analysis system. The images were converted into digital images consisting of 262144 pixels arranged in 512 lines, each line consisting 512 pixels, where every point (pixel) is a number from the range of <0; 255>. This number represents grey level, where 0 corresponds to black, and 255 to white. Here after the images were transformed to a common scale to remove the differences among individual X-ray photographs resulting from processing of photographic plate or unevenness of lighting. After this, fragments containing individual kernels were selected from each image. Both the images (original and converted), and frequency distributions of grey levels occurrences in the kernel were recorded on discs. The images were recorded as binary files of TIFF 5.0 format, whereas, the distributions in ASCII text files. These records were the basis for further analysis.

RESULTS AND DISCUSSION

On the computer monitor, the gray images of kernels there was no loss of information to observe in relation to a photographic plate. However, the visual analysis of these images

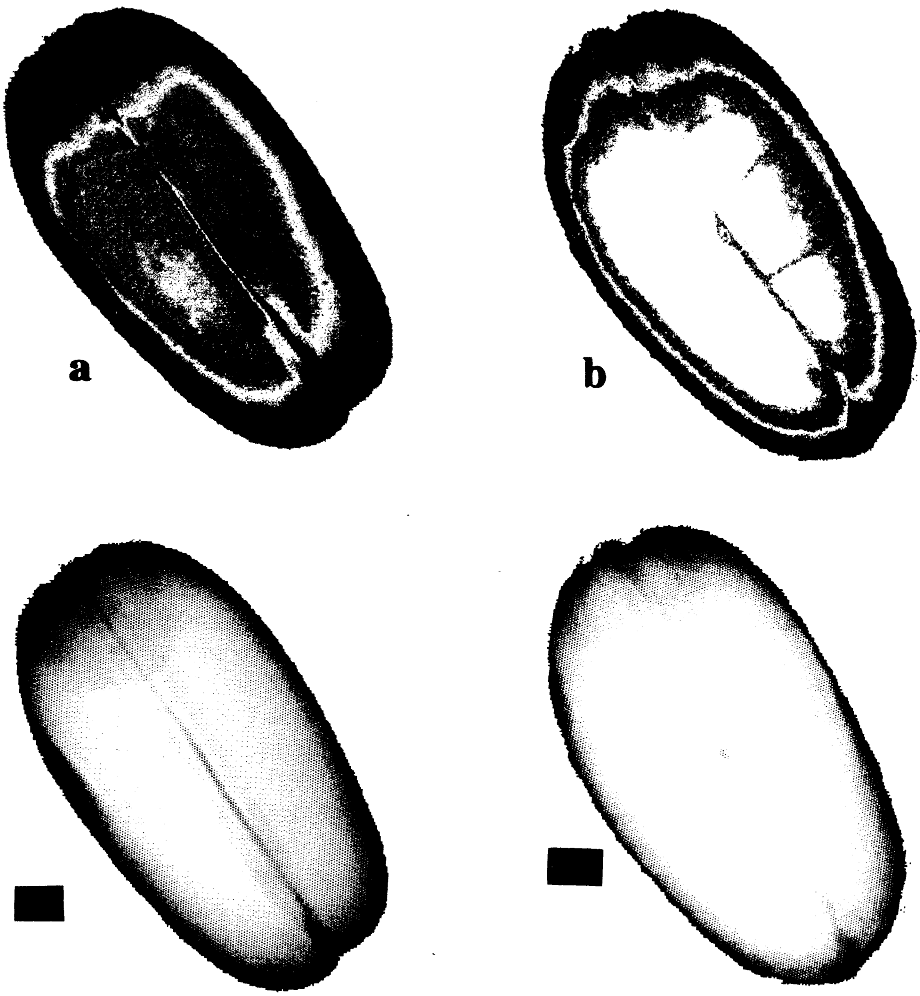

Fig. 1. Images of the same kernels in pseudocolours and grey scale: a) dry in pseudocolours, b) moistened in pseudocolours, c) dry in grey scale, d) moistened in grey scale.

was not enough to draw any conclusions about examined images diversification. Better results were achieved with an enlarged contrast application. This contrast was obtained by the image transformation to a grey scale of <0; 8>. Very interesting effects were obtained by pseudocolours image presentation. This time the diversification of an individual kernel structure and the differences between a dry kernel and the moistened kernel were visualized. However, because of different sizes of the dry and moistened kernels and therefore their different coarseness, no conclusions can be drawn before eliminating the influence on results. The most reliable conclusions can be drawn on the basic of numerical analysis. These analyses are obtained from grey levels frequency distributions. It was found that these distributions are very similar in their shapes (Fig. 2). That fact was proven by the results of homogeneity distributions examinations. This indicates, that all of the distributions are characteristic for the examined objects.

There were big differences among the middle grey levels, which were evaluated for a kernel image. The differences indicated standard deviations. It is an evidence for a considerable object diversification both within every X-ray

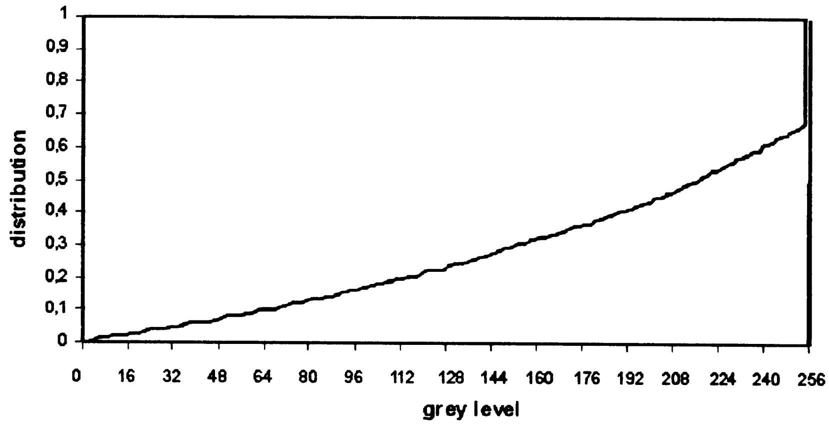

Fig. 2. Diagram of typical cumulative distribution function of the image grey levels for wheat kernel X-ray photograph.

photograph and corresponding objects on the successive X-ray photographs. Apart from the mentioned reasons, the following problems had to be considered:

1) Different kernel to the processes of drying and moistening.

2) Small differences resulting from a different position of the same kernels to the successive X-ray photograph exposition.

Due to the excessive diversification, comparisons of particular individuals were eliminated. Instead, the statistical analysis of 'averaged kernels' was applied. Therefore, the average grey level value was evaluated for every of X-ray photograph the 4 kernels. Then, the kernels were moistened and dried considering the influence of every average X-ray photograph background and average level of control kernel grey images. Average values for each X-ray photograph were put together in Table 1.

Too small representation of the examined sample, non-normality of grey level distribution and too big variance of the source results, make accurate statistical conclusions for the data impossible, on the basis of variance analysis. One may only attempt to formulate the analysis of general changes tendency.

Table 1 reveals that the brightest kernel images came from X-ray photograph number 1 (control kernels). After the moistening process (X-ray photograph number 2), the kernel images faded and their average grey level dropped about 10 units. The occurrence of cracks within endosperm could be a probable reason here. Further moistening had an adverse effect, i.e., a small increase of grey level. This might be caused by the apparent disappearance or rather stricking of the cracks within the endosperm because of excessive moisture. The X-ray photograph number 5 refers to the beginning of the kernel drying process, whereas unexpectedly average value of the kernel grey level increased about 4 units. This might imply that the process of water distribution in starch and so sticking successive slits, was still going on. The decrease of grey level occurred only after 18h of drying. Then the renewed process of kernel cracking began because of moisture loss. The achieved average grey level (about 20 units) did not change to the end of the experiment.

In Table 1, relatively big standard deviations and coefficients of variation corresponding to

Table 1. Average grey levels, standard deviations and coefficient of variation evaluated for the n=4 sample kernels after successive stages of moistening and drying

Number of X-ray photograph	Average grey level	Standard deviation	Coeff. of variation (%)
1	25.5	1.6	6.2
2	15.6	2.0	12.6
3	17.8	1.6	9.0
4	19.9	1.8	9.0
5	24.2	4.5	18.4
6	19.7	2.5	12.7
7	20.2	1.5	7.3
8	18.9	1.3	6.8

the X-ray photographs numbers 5 and 6 (initial drying stages), also 2 (initial moistening stage) draw our attention. They testify to extensive, individual differences in kernels performance at the beginning of processes. As a result of further drying, dispersion of results decreased considerably.

Very similar results were obtained by the applicaton of image decimal-to-binary conversion on the level of 127, that is assigning 0 value to <0;127> grey level, and value 1 to the levels of <128; 255> using at the same time, the average ranking method for source results.

CONCLUSIONS

Preliminary investigations of the changes in the inner structure of wheat grain on the basis of its X-ray image analysis allow to draw the following conclusions:

- There is a possibility to apply computer analysis for the assessment of the changes in grain endosperm.

- The observation of the images in full grey scale <0;255> does not cause noticeable information loss as compared with X-ray photographic plates. However, presentation of images in pesudocolours has clearly shown the differentiation between test control (dry) kernels and moistened kernels.

- Changes in mean grey levels of kernels images in subsequent stages of moistening and drying have been noticed.

- Computer analysis of wheat grain X-ray images appeared to be a very subtle tool for the investigation of the changes in grain inner structure. However, it is indispensable to prepare experiments very carefully, improve the quality of X-ray images and use a scanner to transfer the images to a computer.

REFERENCES

1. **Chowdhury M.H**: Methods for determining grain damage (Mechanical). Proc. 4-th Int. Conf. on Mechanization of Field Experiments, Iowa, 216-228, 1976.
2. **Grzesiuk S., Kulka K.**: Biology of Corn Grains (in Polish). PWN, Warszawa 1988.
3. **Kudra T., Niewczas J., Szot B., Raghavan G. S. V.**: Stress Cracking in High-intensity Drying: Identification and Quantification. IDS' 94 Drying 94, ed. V. Rudolph, R. B. Key, 809-815, 1994.
4. **Niewczas J.**: The method of determination of the index of mechanical damage of single kernel by means of X-ray detection. Zesz. Probl. Post. Nauk Roln., 389, 89-95, 1991.
5. **Niewczas J.**: Assessment of Mechanical Damage to Wheat Grain Detected Using X-ray Technique (in Polish). Acta Agrophysica 2, 1994.
6. **Niewczas J.**: Internal damage indices of wheat grain and the possibilities of application in labolatory investigations (in Polish). VIII Drying Simp. Conf. Materials, Vol.I, 137-148. SGGW-AR, Warszawa 1994.
7. **Woźniak W., Styk W.**: Internal damage to wheat grain as a results of wetting and drying. Drying Technology (in press).