Acta Agrophysica, 2007, 9(1), 91-97

INFLUENCE OF MOISTURE ON RHEOLOGICAL CHARACTERISTICS OF THE KERNEL OF WHEAT

Grzegorz Łysiak

Department of Machine Operation and Maintenance in the Food Industry, Agricultural University
ul. Doświadczalna 44, 20-236 Lublin
e-mail: Grzegorz.Lysiak@ar.lublin.pl

A b s t r a c t . The paper presents results of studies on the influence of moisture on the relaxation characteristics obtained during uniaxial compression of single wheat kernels. The Polish wheat cv. Kobra, at six different moisture levels, i.e. 10, 12 14, 16, 18, and 20%, was used in the research. The experiments were made with the help of a Zwick Z020 universal machine. Individual wheat kernels were compressed with constant load value of 50 N between two flat plates. Relaxation time was equal to 5 minutes. Values of the relaxation parameter *Y(t)* were established for the determined relaxation time. Parameters k_1 and k_2 for a model presented by Peleg and Normand were also calculated. Increase of kernels moisture caused the load at relaxation time as well as the relaxation parameter *Y(t)* to decrease. Coefficients k_1 and k_2 decreased with the moisture rise. A linear relation between the two model coefficients was observed. The influence of kernel moisture on the analysed parameters was described in the form of regression equations.

K e y w o r d s : wheat, rheological characteristics, relaxation, moisture

INTRODUCTION

Stress relaxation represents the decrease in the value of stress necessary to maintain the strain in a material at a constant level. At the same time, it is an effect of loaded material tendency to change its entropy. Therefore, it constitutes an important feature that may be used to explain or describe a material reaction to external loads (Vincent 1982). The way that the material reacts to the above is closely related to its structure, hence studies of rheological phenomena, used to be more frequently done with the help of relaxation tests, are very helpful for identification of its state and behaviour changes during preservation and processing (Brujić *et al.* 2005, Lewicki and Jakubczyk 2004, Lewicki and Łukaszuk 2000, Telis-Romero *et al.* 2004) and for material quality assessment, including interactions to textural and sensory attributes (Bhattacharya *et al*. 2006, Lewicki and Spiess 1995, Lewicki and Wolf 1995).

In the case of biological materials, as generally viscoelastic bodies, their rheological characteristics depend on a lot of features, as for example the level and rate of deformation, temperature, moisture and others (Bargale *et al.* 1995, Khazaei and Mann 2004, Lewicki 2004, Lewicki and Wolf 1995). Many rheological experiments are being done for small strain levels (Karim *et al.* 2000), however in real possessing conditions large deformations (beyond the linear elastic region) take place, leading to expected material fracture or structural changes. Peleg and Normand (Steffe 1996) demonstrate that a material subjected to large deformations usually exhibits non-linear viscoelastic behavior, therefore a different analysis than in the range of linear elastic deformations is necessary. To overcome this, they suggest stress data be calculated as normalized stress (normalized force is also acceptable).

Knowledge of the rate of stress relaxation and of the ways in which this process takes place may be also advantageous in studies on the fragmentation process. A material ability to change its stress pattern, or an energetic state when the process is regarded from the energetic perspective, affects the absolute stress value or energy available for crack initiation and propagation (Ebba *et al.* 2001, Vincent 1982). The research undertaken by author constitutes a part of studies on the interfaces between material properties and their grinding susceptibility. This paper focuses on the influence of wheat kernels moisture on their rheological characteristics.

MATERIAL AND METHODS

Polish wheat cv. Kobra was used in the experiments. Six varied levels of kernel moisture content, i.e.: 10, 12, 14, 16, 18, and 20% (wet basis) were applied in the experimental plan. The above levels of moisture were attained by the addition of necessary amount of water to samples for which the initial moisture and weight were pre-determined. These required water amounts were calculated according to simple mass balance equations. The watered samples were then stored over 48 hours before mechanical testing.

Mechanical tests were done with the help of a universal machine Zwick Z020. An individual kernel was placed with the ventral side on the bottom machine plate and then loaded axially up to 50 N – the constant force value. The corresponding kernel deformation was held constant for 5-minute period. The constant compression rate during the loading at 1.25 $mm \cdot min^{-1}$ was adjusted. For each individual kernel force-time characteristics were registered with the help of TestXpert software by Zwick. The experiments were done in 10 replications for each of the moisture levels. On the basis of the force decrease during tests, the decay parameter $Y(t)$

was determined according to the following equation (Bhattacharya *et al.* 2006, Lewicki and Spiess 1995, Lewicki and Wolf 1995)

$$Y(t) = \frac{F_o}{F_o - F(t)} \tag{1}$$

where: F_o – initial force at time t = 0 (N), $F(t)$ – force at relaxation time t (N), t – time of relaxation (s)
For the model presented by Peleg and Normand and presented in the formula 2 (Steffe 1996) constants k_1 and k_2 were also determined.

$$\frac{F_o t}{F_o - F(t)} = k_1 + k_2 t \tag{2}$$

The reciprocal of k_1 determines the initial decay rate and k_2 is the hypothetical value of the asymptotic normalized force (Bhattacharya *et al.* 2006, Steffe 1996). The constants were obtained from the intercept and slope of the relaxation curves by applying Excel software. Statistical analyses were done with the help of Statistica by Statsoft.

RESULTS

Examples of rheological characteristics of wheat at the different water content levels are presented in Figure 1.

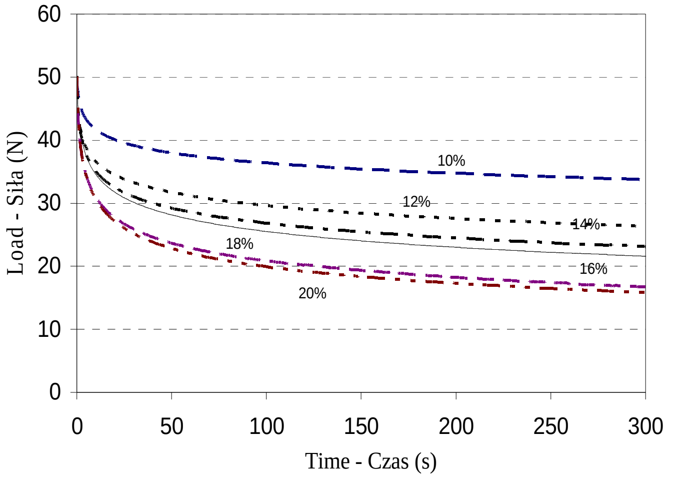

Fig. 1. Examples of relaxation characteristics for wheat at different moisture content

A change in the kernel moisture caused the force relaxed at the initial stage of the test to change significantly as well. This speed of force relaxation increased with the rise in moisture. The moisture increase induced a significant decrease in average values of loads at the end of the experiments (after 5 minutes). For the studied range the average values of this residual force decreased from 31.4 (±1.21) to 16.2 N (±0.62). A higher decrease was observed for the 10-16% moisture domain.

Values of the decaying parameter *Y(t)* decreased with the increase in kernel moisture from 2.68 to 1.48 (Fig. 2). The significance of the level of grain moistening at $\alpha = 0.05$ was confirmed by the statistical analyses applying Tukey tests. The observed relation between the decay parameter *Y(t)* and the kernel moisture was described by means of a square polynomial equation at a very high determination coefficient $R^2 = 0.996$.

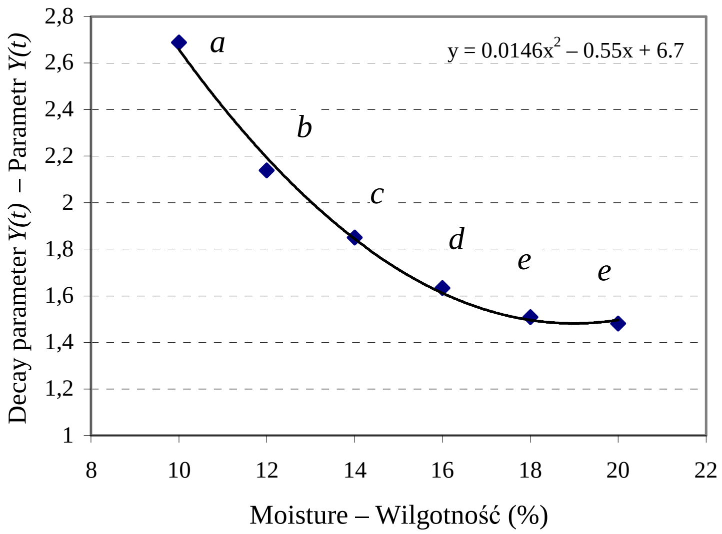

Fig. 2. Relation of the relaxation parameter *Y(t)* to wheat kernel moisture content: a-e – homogeneous groups at $\alpha = 0.05$

Increase in the kernel moisture caused the Normand and Peleg model parameters k_1 and k_2 to decrease from 48.05 to 21.38 s, and from 2.61 to 1.43 s, respectively. The post-hoc analysis applying Tukey tests ($\alpha = 0.05$) confirmed differences between the average values of the two coefficients in relation to the kernel moisture. The differences were mostly observed for the lower moisture levels and for the k_2 coefficient, for which five homogeneous groups were identified (Fig. 4). For the k_1 coefficient three homogeneous groups were observed, i.e. for water content levels of 10%, 12 and 14%, as well as for 16, 18 and 20% (Fig. 3). For both coefficients, their relation to kernel moisture was described by a second degree equation at high determination coefficients equal to 0.982 for k_1, and 0.994 for k_2. Higher values of the k_1 parameter point also to the lower force relaxation rate for kernels at lower moisture contents.

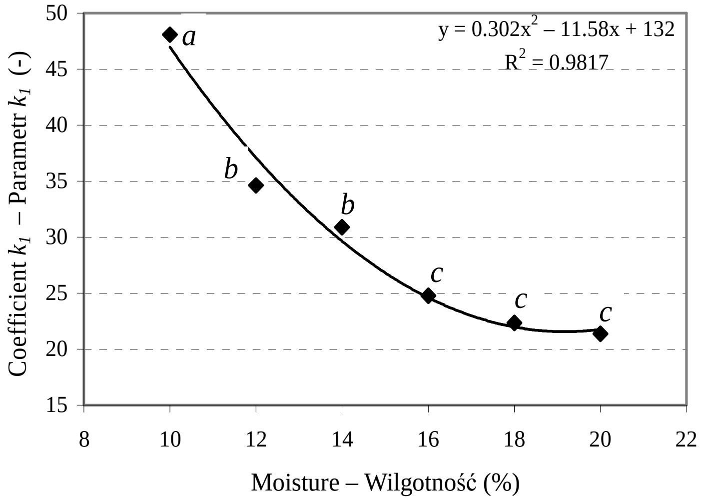

Fig. 3. Relation of the relaxation parameter k_1 to wheat kernel moisture content: a-c – homogeneous groups at $\alpha = 0.05$

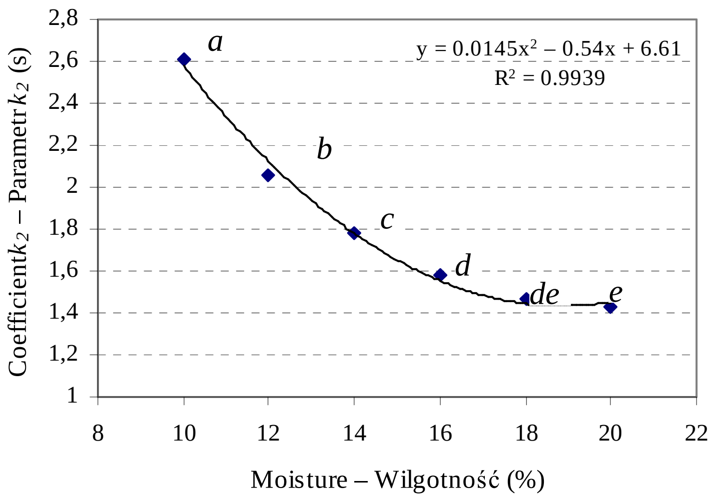

Fig. 4. Relation of the relaxation parameter k_2 to wheat kernel moisture content: a-e – homogeneous groups at $\alpha = 0.05$

CONCLUSIONS

1. It was noticed that increase in wheat kernel moisture content caused the average value of residual force (not relaxed) to decrease. Higher increase in the force values was observed in the 10-16% moisture range. Lower values of the force and smaller relaxation time may be related to the higher plasticity of moist kernels.

2. Increase in wheat moisture caused the coefficients k_1 and k_2 of the model presented by Peleg and Normand to decrease. Their relations to the level of kernel watering were described in the form of regression equations of second degree at high determination levels. This points to the statement that the model used in the analysis allowed the rheological characteristics of wheat kernel to be well described.

REFERENCES

Bargale P. C., Irudayaraj J., Marquis B., 1995. Studies on Rheological Behaviour of Canola and Wheat. J. agric. Engng Res. 61, 267-274.

Bhattacharya S., Narasimha H.V., Bhattacharya S., 2006. Rheology of corn dough with gum arabic: Stress relaxation and two-cycle compression testing and their relationship with sensory attributes. Journal of Food Engineering, 74 (1), 89-95.

Brujić J., Johnson D., Makse H. A., Sindt O., 2005. Granular Dynamics in Compaction and Stress Relaxation. Phys. Rev. Lett, 95.

Ebba F., Piccerelle P., Prinderre P., Opota D., Joachim J., 2001. Stress relaxation studies of granules as a function of different lubricants. Eur. J. Pharm. Biopharm, 52, 211-220.

Karim A. A., Norziah M.H., Seow C.C., 2000. Methods for the study of starch retrogradation. Food Chemistry, 71, 9-36.

Khazaei J., Mann D., 2004. Effects of Temperature and Loading Characterictics on Mechanical and Stress-Relaxation Behavior of Sea Buckthorn Berries. Part 3. Relaxation Behavior. Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, VI.

Lewicki P., 2004. Water as the determinant of food engineering properties. A review. Journal of Food Engineering, 61, 4, 483-495.

Lewicki P., Jakubczyk E., 2004. Effect of hot air temperature on mechanical properties of dried apples. Journal of Food Engineering, 64, 3, 307-314.

Lewicki P., Spiess W. E. L., 1995. Rheological Properties of Raisins: Part I. Compression Test Journal of Food Engineering, 24, 3, 321-338.

Lewicki P., Wolf W., 1995. Rheological Properties of Raisins: Part II. Effect of Water Activity. Journal of Food Engineering, 26, 1, 29-43.

Lewicki P., Łukaszuk A. 2000. Effect of osmotic dewatering on rheological properties of apple subjected to convective drying Journal of Food Engineering, 45, 3, 119-126.

Steffe J.F., 1996. Rheological Methods in Food Process Engineering, Second edition. Freeman Press, East Lansing , MI , USA.

Telis-Romero J., Guizzo-Silva L. K., Telis V. R. N., Gabas A. L., 2003. Rheological Properties of Rehydrated Papaya. Braz. J. Food Technol., 6, 2, 221-227.

Telis-Romero J., Gabas A. L., Sobral P.J.A., 2004. Osmo-convective drying of mango cubes in fluidized bed and tray dryer. Drying 2004, Proceedings of the 14th International Drying Symposium, São Paulo, Brazil, C, 1868-1875.

Vincent J.F.V., 1982. Structural Biomaterials. The Macmillan Press Ltd, Hong Kong.

WPŁYW WILGOTNOŚCI NA CECHY REOLOGICZNE ZIARNA PSZENICY

Grzegorz Łysiak

Katedra Eksploatacji Maszyn Przemysłu Spożywczego, Akademia Rolnicza
ul. Doświadczalna 44, 20-236 Lublin
e-mail: Grzegorz.Lysiak@ar.lublin.pl

Streszczenie. W pracy przedstawiono wyniki badań wpływu wilgotności ziarna pszenicy na charakter krzywych relaksacji uzyskanych w teście osiowego ściskania ziarna. Do badań użyto ziarno pszenicy odmiany Kobra o wilgotności od 10 do 20%. Pomiary zrealizowano na maszynie wytrzymałościowej Zwick Z020. Pojedyncze ziarna pszenicy obciążano do stałej wartości siły 50 N, a czas relaksacji wynosił 5 minut. Wyznaczono wartości parametru *Y(t)* w przyjętym czasie relaksacji. Określono również parametry k_1 i k_2 dla modelu przedstawionego przez Pelega i Normanda. Wraz ze wzrostem wilgotności ziarna malała średnia wartość siły po pięciominutowym czasie relaksacji, zmniejszały się jednocześnie wartości parametru relaksacji *Y(t).* Ze wzrostem wilgotności pszenicy zmniejszały się również wartości parametrów k_1 i k_2. Wpływ wilgotności na analizowane parametry opisano w postaci równań regresji.

Słowa kluczowe: pszenica, charakterystyki reologiczne, relaksacja, wilgotność