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INVESTIGATIONS REGARDING SOME FACTORS THAT AFFECT THE FRACTURE BEHAVIOR OF HARD AND SOFT GRAIN ENDOSPERM

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Abstract: *The paper presents a bibliographic study concerning the effect of some factors such as the loading-unloading bending test, the microwave drying and conditioning on the fracture behavior of wheat grains.*

Key words: *Wheat endosperm, compressive properties, fracture toughness, fracture properties, milling: SKCS, conditioning, wheat.*

1. INTRODUCTION

Fracture behavior is one of the most important characteristics of grains seeds and it determines how they are milled.

Milling is essentially a physical process, which involves the fracture and the separation of bran from endosperm, it seems logical to characterise the fracture mode of the wheat endosperm in terms of an analytical method [12].

Previous researchers ([2], [5]) have studied the compression and the hardness of wheat endosperm. They have found that hard and soft wheat endosperms have very different mechanical properties which can be attributed to the physico-chemical composition and morphology of the individual components [6].

Other reserchers have tried to find a way to predict the milling behavior of grain seeds using different types of methods. For exemple, in the paper [7] it was used the single-kernel characterization system (SKCS). The single-kernel characterization system SKCS 4100 was developed for the objective determination of admixtures of hard and soft wheat.

The SKCS 4100 system provides rapid measurements of wheat physical properties that are important to the miller. In addition, these measurements, or the raw data from which they

are derived, have been shown to be applicable to the direct prediction of processing quality.

Justification for extrapolation of the rheological properties of individual grains to those of corresponding bulk samples was provided by experiments which confirmed that wheat grains mill independently, i.e., without interaction [1].

In order to predict the milling behavior of grain seeds, some studies have been made in order to determin the way in wich the type of drying process affects the milling behavior of the grains [9].

In the food and animals industry, before grains milling are used different types of drying techniques including microwave drying method [8].

Microwave drying is especially advantageous if the subsequent step is grinding. It results in less consumption of grinding energy ([10], [11]).

The objective of the present work is to carry out a bibliographic studie that will get together a number of factors that affect the milling behavior of grain seeds.

2. METHODS

There are many reserchers that had investigated the effect of some factors on the fracture mode of the grains seeds.

a. Wang [12] tried to develop methods of measuring the fracture toughness of hard and

soft wheat endosperm in order to investigate the fracture mode of wheat endosperm during milling. For this he used the loading-unloading bending test.

He used a graphical method (fig. 1) to estimate crack length of the fracture. He applied this method to determine specific breakage energy from the loading-unloading force-displacement curves for the hard and soft wheat endosperm. By using this method, specific breakage energy, Γ , and the irreversible energy, Φ_{ir} , can be separated from fracture toughness, R .

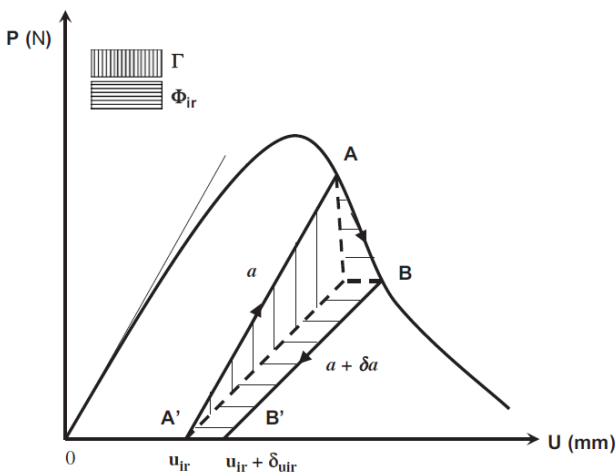


Fig. 1. A force-displacement ($P-u$) curve for linear non-elastic material during loading-unloading stable crack growth. $A0A$ and AB are loading traces and $BB0$ is an unloading trace. From A to B , there is a crack extension. Γ and Φ_{ir} represent elastic energy and irreversible energy, respectively u_{ir} is the irreversible displacement and δu_{ir} is the microincrease in irreversible displacement.

Prior to measuring the fracture toughness, it was necessary to know the crack length during the loading-unloading bending test. There were two methods used for estimating the crack length:

(1) The crack lengths were measured using an optical microscope, together with transmitted light from the side or from the back of the specimen. As shown in figure 2, the crack extensions a_1, a_2, a_3, a_4 were measured by using optical microscopy *in situ*, then the crack length was obtained from:

$$\Delta a = a_i - a_{i-1}, i = 1, 2, 3, \dots \quad (1)$$

(2) Also the crack length can be estimated from the compliance, which is calculated from force-displacement ($P-u$) curves of the loading-unloading bending test for the endosperm:

$$C = \frac{u - u_{ir}}{P}, \quad (2)$$

where: C is compliance, u is displacement in mm, u_{ir} is the irreversible displacement in mm and P is the force loaded on the crack. The force P can be gained from a force-time curve of the corresponding three-point bending test of the hard and soft wheat endosperm pieces.

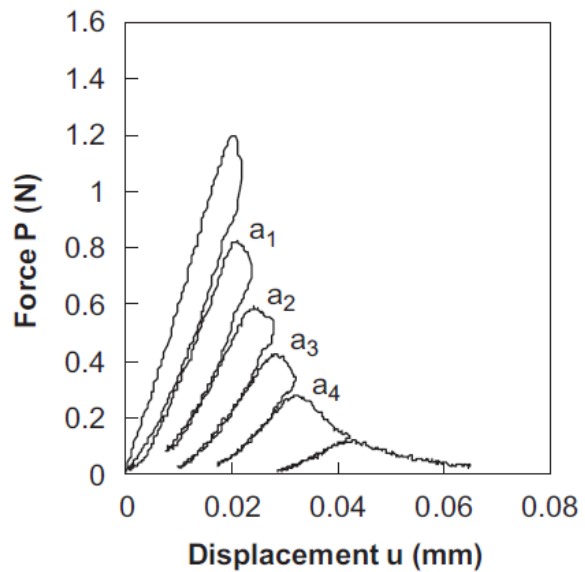


Fig. 2. A typical loading-unloading force-displacement curve recorded from the three-point bending test of a wheat endosperm piece and a_1, a_2, a_3, a_4 correspond to loading-unloading cycles 1, 2, 3 and 4.

Then a crack length was estimated from the following expression:

$$a_i = a_{i-1} + \frac{T}{2} \cdot \frac{C_{i-1} - C_i}{C_i}, \quad i = 1, 2, 3, \dots \quad (3)$$

and

$$da = a_i - a_{i-1}, \quad (4)$$

where a_i and a_{i-1} are crack extensions, and C_i and C_{i-1} are the compliance corresponding to a_i and a_{i-1} , T is the thickness of the test piece and da is the crack length.

The results of the loading-unloading bending test showed that the compressive failure strength

of the hard and soft wheat endosperms were about 70 and 20MPa, respectively; and the Young's modulus of the hard and soft wheat endosperms were 1.870.2 and 0.970.2 GPa, respectively, so that it can be seen that the hard and soft wheat endosperm were almost certainly isotropic.

As a conclusion of his studies, Wang discovered that the fracture mode of wheat endosperm, hence, is in good agreement with the milling behaviour of wheat varieties. The flour prepared from soft wheat displays finer particle size, better separation between starch and protein as well as less starch damage than the flour prepared from hard wheat.

b. Edwards [3] explore, for both hard and soft wheat, the single-kernel characterization system (SKCS) testing protocol for unconditioned whole grain to the first stage of roller milling, which includes conditioning. He tried to find out if, this two methods are close enough as result to the real milling process and in this way if it's suitable for predicting the milling behavior of grains seeds using this methods.

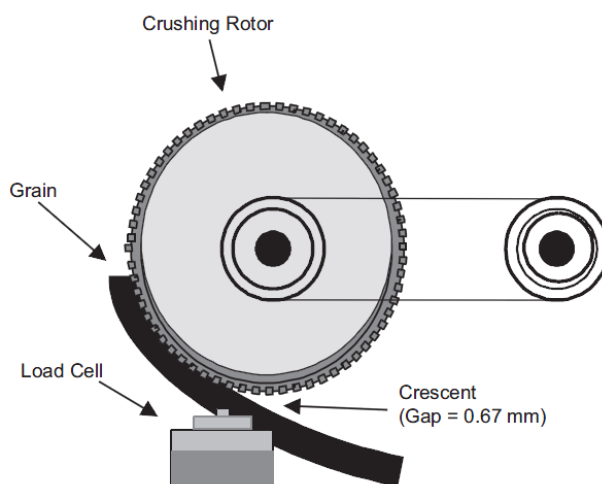


Fig. 3. The SKCS 4100 crushing mechanism.

The SKCS (fig. 3) measures predominantly the compressive strength of whole wheat grain and produces significant rupturing of central endosperm cells.

In first-break roller milling of wheat, the factors affecting breakage of grains can be broadly classified into the physicochemical properties of the wheat (size distribution, moisture content, hardness) and those related to

the design and operation of the milling equipment [1]. With the occurrence of compressive stress in the horizontal direction and shear stress in the vertical direction, a kernel tends to break along a principal tensile stress plane because the tensile strength of the endosperm is much smaller than its compressive strength [4].

He concluded that the fragmentation patterns of both hard and soft wheat that result from crushing in the SKCS 4100 and in the first break stage of roller milling show that SKCS analysis of unconditioned wheat (the standard practice) is a suitable predictor of the milling performance of conditioned wheat.

c. Velu [9] in his study carried out, wanted to evaluate the the effect of drying (both microwave and convective) on the grinding characteristics and fracture behavior of maize.

For drying in microwave, samples of maize at different initial moisture contents weighing 200 g were dried in the microwave oven at 390 W level for 3–16 min time periods with intermittent mixing.

In the case of flow drying procedure, A sample of 200 g was dried at 65, 75 and 90 °C with an air velocity of 0.6 m/s (at conditions of room temperature) in a through flow drier.

After the drying procedure, the samples where milled. The grinding of the maize grains was carried out in a hammer mill keeping the amperage constant for the mill by adjusting the feed rate. The microwave-dried samples were ground for different timings.

The conclusions of his study where that the microwave dried samples of maize consumed less grinding energy during dry milling which was indicated by lower Bond's work Indices.

3. CONCLUSION

1. The fracture mode of wheat endosperm, hence, is in good agreement with the milling behaviour of wheat varieties.
2. The fragmentation patterns of both hard and soft wheat that result from crushing in the SKCS 4100 and in the first break stage of roller milling show that SKCS analysis of unconditioned wheat (the standard practice) is a

suitable predictor of the milling performance of conditioned wheat.

3. The microwave dried samples of maize consumed less grinding energy during dry milling which was indicated by lower Bond's work Indices.

4. REFERENCES

- [1] Campbell, G.M., Webb, C., "On predicting roller milling performance, Part I: The breakage equation", Powder Technology 115, 234–242, 2001.
- [2] Dobraszczyk, B.J., Whitworth, M.B., Vincent, J.F.V., Khan, A.A., "Single kernel wheat hardness and fracture properties in relation to density and the modelling of fracture in wheat endosperm", Journal of Cereal Science 35, 245–263, 2002.
- [3] Edwards, M.A., Osborne, B.G., Henry, R.J., "Investigation of the effect of conditioning on the fracture of hard and soft wheat grain by the single-kernel characterization system: A comparison with roller milling", Journal of Cereal Science 46, 64–74, 2007.
- [4] Fang, C.Y., Campbell, G.M., "Stress–strain analysis and visual observation of wheat kernel breakage during roller milling using fluted rolls", Cereal Chemistry 79, 511–517, 2002.
- [5] Glenn, G.M., Johnston, R.K., "Mechanical properties of starch, protein and endosperm and their relationship to hardness in wheat", Food Structure 11, 187–199, 1991.
- [6] Haddad, Y., Mabilie, F., Mermet, A., Abecassis, J., Benet, J.C., "Rheological properties of wheat endosperm with a view on grinding behaviour", Powder Technology 105, 89–94, 1999.
- [7] Osborne, B.G., Anderssen, R.S., "Single-kernel characterization principles and applications", Cereal Chemistry 80, 613–622, 2003.
- [8] Shivhare, U. S., Raghavan, G. S. V., Bosisio, R. G., "Microwave drying of corn II. Constant power, continuous operation", American Society of Agricultural Engineers, 35(3), 951–957, 1992.
- [9] Velu, V., Nagender, A., Prabhakara Rao, P.G., Rao, D.G., "Dry milling characteristics of microwave dried maize grains", Journal of Food Engineering 74, 30–36, 2006.
- [10] Walde, S. G., Balswamy, K., Shivaswamy, R., Chakkaravarthi, A., Rao, D. G., "Microwave drying and grinding characteristics of Gum karaya (*Sterculia urens*)", Journal of Food Engineering, 31(3), 305–313, 1997.
- [11] Walde, S. G., Balswamy, K., Velu, V., & Rao, D. G., "Microwave drying and grinding characteristics of wheat (*Triticum aestivum*)", Journal of Food Engineering, 55, 271–276.
- [12] Wang, L., Jeronimidis, G., "Investigation of the fracture mode for hard and soft wheat endosperm using the loading-unloading bending test", Journal of Cereal Science 48, 193–202, 2008.

Investigații peivind câțiva factori care afectează procesul de distrugere a semințelor de cereale

Rezumat: În această lucrare este prezentat un studiu privind efectul pe care o serie de factori îl au asupra procesului de distrugere a semințelor de cereale.

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