IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

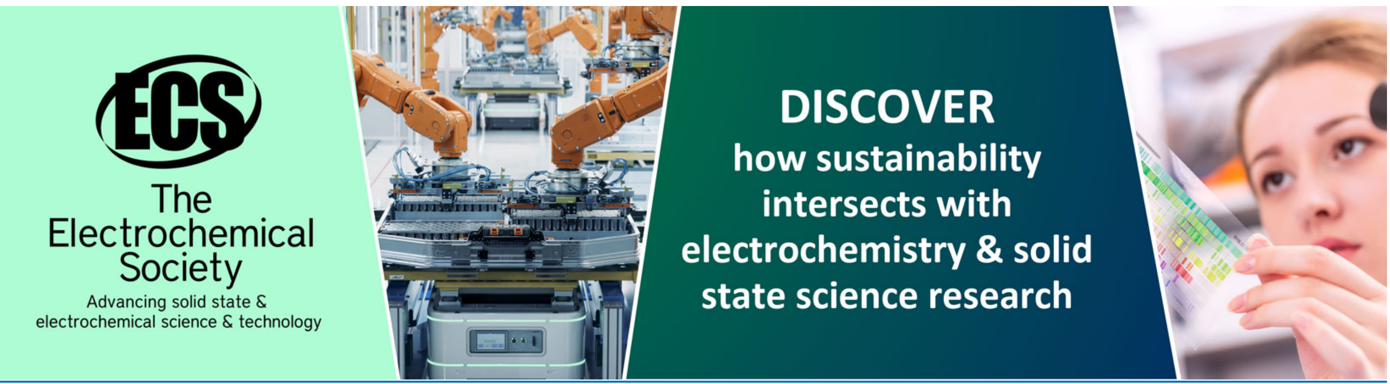
The effect of moisture content on grinding process of wheat and maize single kernel

To cite this article: M I Lupu *et al* 2016 *IOP Conf. Ser.: Mater. Sci. Eng.* **145** 022024

View the article online for updates and enhancements.

You may also like

- Yield- and protein-neutral reduction in fertilizer rate for wheat, maize and rice can reduce the release of reactive nitrogen and greenhouse gas emissions in China
  Changlu Hu, Victor O Sadras, Zhaodong Wang et al.
- Global cultivation of wheat crops induces considerable shifts in the range and niche of species relative to their wild progenitors
  Yang Rujing, Gong Xiang, Hu Xiaokang et al.
- Coupling agricultural system models with machine learning to facilitate regional predictions of management practices and crop production
  Liujun Xiao, Guocheng Wang, Hangxin Zhou et al.



This content was downloaded from IP address 3.138.114.132 on 12/05/2024 at 04:29

The effect of moisture content on grinding process of wheat and maize single kernel

M I Lupu, V Pădureanu, C M Canja, A Măzărel
Transilvania University of Brasov, Food and Tourism Faculty, Engineering and Management in Food and Tourism Department, 148 Castelului Street, 500014, Brasov, Romania

E-mail: lupu.mirabela@unitbv.ro

Abstract. The mechanical properties and the resistance of grains are key characteristics that enhance grinding behaviour of wheat and maize and are dependent on the moisture content of the grains. These properties were defined in the single-kernel compression test, and it seems that the qualities expressing the relations resulting during mechanical loads like mechanical and rheological properties are significant. The aim of the study reported here is to show the influence of moisture content on grinding process of wheat and maize single kernel. To show this influence it is necessary to study the physical and mechanical properties of wheat and maize single kernel at different moisture content 10%, 12%, 14%, 16%, 18% and 20%. The measurement results showed significant relationship between the cereal type, its resistance characteristics and the moisture content in the grinding process.

1. Introduction

Cereal grains are an important energy source throughout the world. The agricultural revolution some 10.000 years ago made grains the major food raw material for humans, rice, wheat and maize providing about half of the energy of the mankind. Grain-based foods provide the majority of the carbohydrate and dietary fibre intakes in many countries. In Europe, the average annual consumption of cereal grains is 131 kg per capita, wheat making up the majority of it (108 kg/capita/year), whereas in Asia, about half of the annual cereal consumption is rice [28]. Wheat and rice are the most important cereals globally with respect to human nutrition, whereas maize is important especially in Central and South America, and sorghum and millets in Africa [10][24].

Consumption of grain products and particularly those made from wholegrain are associated with various health benefits [26]. These benefits can be achieved either by consuming wholegrain products or alternatively can be derived from changing the composition of the grain to include more beneficial components [23].

Cereals such as wheat, barley, oat, rye, and maize are staple foods for the population of Western countries, contributing about 50% of dietary fibre intake [30].

In the milling industry, it is necessary that the raw materials or intermediate products to be grind to accelerate the technological phase, to obtain a product from raw materials or even only for commercialization the products [15].

Grinding is very important in wheat processing and decides on the degree of fineness and particle size distribution. These parameters influence on the properties of the final products such as bread,

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

pasta, and other foods made from wheat grains. The wheat flour milling is a gradual reduction process [6].

Milling is applied to achieve the physical disentanglement of individual components while air classification or sieving fractionates the millings on the basis of particle density and/or particle size into enriched fractions. However, especially when particles differ little in density and/or particle size, the final purity that can be achieved towards a specific component is limited [29][31].

Cereal grain is a granular material and as such exhibits mechanical behaviour different to liquids and solids. The mechanical properties of grain settling depend on the properties of the single grain, friction between particles, inter-particle contact geometry and load history. Grain as a material of biological origin reveals the strong dependence [20] of its stress-strain behaviour on the moisture content affecting the properties of the seed coat as well as of the endosperm of single grain [20].

European Standard Eurocode 1 [9] and Polish Standard [4] recommends the determination of properties under load conditions similar to operating loads. Some properties are to be determined using the shear test (Jenike tester or triaxial compression [20] test) others, using the uniaxial compression test. Knowledge of cereals mechanical properties will improve the processes involving these materials within the food industry [20].

Studies concerning the relation between the wheat and maize kernels properties and the milling properties have been carried out since the beginning of the cereal processing industry.

2. Materials and methods

Investigations were carried out on one type of wheat Apache s and one type of maize Olt Fao 430, bout cereal kernels were collected in the year 2014. Apache wheat is a superior wheat used in bakery industry and has the next mean values of the samples: moisture content 13.1%, hectoliter mass 70.1 kg/hl, total ash 1.5%. The maize seeds have the next mean values of the samples: moisture content 12.3%, hectoliter mass 82.3 kg/hl, total ash 1.7 %.

Moisture, hectoliter mass, and ash contents of wheat and maize kernels were determined according to approved methods of ASAE [1].

The wheat and maize kernels were prepared starting from the storage moisture content like 13.1% (d.b.) at wheat and 14.2% (d.b.) at maize. From the storage moisture content the cereals kernels were brought at 10 %, 12 %, 14 %, 16 %, 18 % and 20% (± 0.2%) moisture content using a WK 11 600 climatic chambers. The kernels were put into the climatic chamber and kept their 4 days for wheat grains and 5 days for maize kernels for each moisture content. After 4 or 5 days the grain moisture content was determined using a standard oven-drying method by drying triplicate samples of wheat at 130º C for 19 h and for maize at 130º C and 21 h [1] and if required, the conditioning process was repeated to ensure that the conditioned samples were at 10%, 12%, 14%, 16%, 18% and 20% moisture contents (d. b.). All the physical and mechanical properties of wheat and maize seeds were investigated at 10%, 12%, 14%, 16%, 18% and 20% moisture levels (d.b.). The entire test was repeated twenty times to determine mean values.

To determine the average size of the seed, the length (L), width (w) and the thickness (T) of the seeds were measured using a digital calliper with an accuracy of 0.01 mm. The diameter and the surface area (S) of the wheat and maize seeds were calculated from the three principal dimensions [2]. 1000 seeds mass was measured by counting a 1000 seeds randomly and weighing on electronic balance (0.001 g accuracy, Radwag PS 1000.R2). The mechanical properties of grains have been investigated by a number of researchers [24] but the researches have been carried out mainly on wheat seeds. There are many methods for the determination of wheat mechanical properties, and these methods are very often determined as wheat hardness [11][21][5]. Some authors define hardness as the mechanical property of the individual wheat kernel [5][19] or fragments of endosperm [5][14], or the resistance to deformation or crushing [5][11], whilst others define hardness as the property of a mass of kernels [12][32]. The mechanical properties of individual parts of the kernel (germ, bran layer, endosperm) are also different and these properties also strongly depend on the water content [4][18][5]. We can find in the literature many methods of measure the wheat hardness and they are different from those used for the evaluation of the hardness of constructional materials such as metals. Those methods are correlated one with other and they are used in the milling industry for classify the wheat cultivars according to the desirability of their milling and bread making properties [5].

Wheat hardness has the greatest influence on the milling process and this parameter should be determined before milling. Kernel texture influences power consumption during milling. Hard wheat cultivars require more power to grind the kernels than do soft wheat cultivars [8]. The moisture content has a different influence on endosperm and bran layer properties. A study showed that, when a wheat grain was subjected to uniaxial compression, it behaved as an elastic-plastic-viscous body exhibiting creep, stress relaxation and elastic after effects [25][20]. Glenn et al. [13] showed that as the moisture content of wheat endosperm increased, the compressive strength, elasticity and energy to compressive failure decreased, with hard wheat's giving greater decreases. The hard wheat endosperm is more elastic and compact than soft wheat endosperm [5]. By contrast, the elasticity and plasticity of the bran layers increase with increasing moisture content [18].

The mechanical properties of wheat and maize kernels have been determinate on individual kernels with the Zwick Roell/5kN universal testing machine using a parallel plate loading device. Stress strain curves developed from the force-deformation curves were examined for characterizing the mechanical properties of wheat and maize. The mechanical properties of wheat and maize at different moisture content investigated in this study were: yield point YP, energy at yield point, maximum force of compression Fmax which is the same value with the rupture force, work W (energy consumptions) at the end of the rupture, deformation d, modulus of elasticity E.

A Zwick Roell universal testing machine (model 5kN) was used to measure the kernel responses to compressive loadings by using parallel plates [16]. All of the test kernels were checked for stress cracks and before loading, the thickness and length of each kernel was determined with a digital calliper. The individual kernels were put in to the middle of the bottom plate with germ side down. In mechanical properties test, each kernel, from each moisture, was loaded until rupture occurred and the resultant load-deformation behaviour and the work were recorded [17]. A constant test speed of 50 mm/ min was used in all tests. Unloading took place with the same deformation speed until to 0 kPa of the stress level was reached. Twenty kernels were tested for each experimental condition. Results and discussion

To highlight the influence of wheat moisture content on grinding process, it was carried out the processing data of experimental research, that were obtained from compressing individual wheat kernels with a constant speed of 50 mm/ min, until a constant distance of 0,4 mm between the two parallel plates was achieved.

The model equation is based on the elastic-plastic approach. During loading both reversible (elastic) and irreversible (plastic) strains develop in the sample.

Results of the physical and mechanical properties of wheat are presented in table 1. Values of material constants were found dependent on species and on moisture contents of the material.

For all samples the energy, the force, the yield point and modulus of elasticity decreased with an increase of seeds moisture content. The highest value of modulus of elasticity was found at 10% moisture content, 16.55 MPa.

The fact that the modulus of elasticity decreases with the increase of moisture content may be due to the fact that at higher moisture content, the grain is less elastic and more viscous in nature. Higher moisture also plasticizes and causes a transformation from brittle-elastic (at moisture contents up to 12%) to an elastic-plastic (moisture content 12-15%) and finally into a viscous-plastic state (moisture content >15%) [3][26]. Furthermore, an increase in moisture content causes a reduction in the friction coefficient of the system thereby causing deformation to increase and module to decrease as the pressure is applied.

Table 1. Effect of moisture content on physical and mechanical properties of wheat (mean ± std. dev.).

Properties	Moisture content, (%, d.b.)					
	10	12	14	16	18	20
Length (mm)	6.81±0.2	6.82±0.3	6.82±0.3	6.91±0.2	6.92±0.2	6.92±0.3
Width (mm)	2.91±0.2	2.97±0.2	3.0±0.1	3.02±0.2	3.03±0.2	3.03±0.2
Thickness (mm)	2.98±0.2	3.01±0.3	3.03±0.2	3.04±0.1	3.05±0.2	3.06±0.3
Mass of 1000 kernels (g)	39.19±0.3	39.83±0.3	39.95±0.2	40.12±0.3	42.33±0.2	43.61±0.2
Surface area (mm^2)	54.28±5.0	54.47±6.3	55.56±5.4	58.76±4.6	59.34±5.3	59.89±6.5
Yield point (N)	144.97±10.2	117.0±5.4	113.80±8.4	101.61±9.01	100.29±10.3	99.73±5.7
Energy at YP (J)	93.49±8.9	71.73±4.8	69.35±9.1	39.36±8.2	11.85±9.7	11.02±5.5
Rupture force (N)	1041.97±3.4	1030.73±8.5	1028.62±7.7	1024.05±6.9	1015.91±5.8	1011.16±9.1
Rupture energy (J)	684.15±6.1	657.52±6.3	598.60±7.2	579.75±8.1	673.63±3.7	556.13±8.1
Deformation (mm)	1.22±0.1	1.30±0.1	1.31±0.2	1.31±0.2	1.32±0.2	1.33±0.1
Modulus of elasticity (MPa)	16.55±3.7	14.56±4.3	13.93±4.7	13.43±5.4	12.92±6.3	12.87±6.9

Regarding the stress- strain curve evolution it can be notice a failure tests brittle accompanied by an audible cracking sound up to 18% moisture content. At hire moisture content the cracks were neither audible nor could be obtained from the force-deformation curve [3].

Analyzing the force-deformation curves at six different moisture contents of maize kernels it can be observed that the relationships of vertical stress and total vertical strain for loading - unloading cycles for maize are similar with the wheat results.

A significant difference is noticed at the elastic –plastic curve behaviour. At the maize, the elastic plastic properties are more pronounced due to the high content of starch. The most visible is at the lower moisture content.

Also it can be notice that at maize, in comparison with wheat kernels, the first kernel crack is done at higher force.

In table 2, where is highlighted the effect of moisture content on physical and mechanical properties of maize, it can be noticed that like at the wheat individual kernels compression, the yield point, the force, the energy and modulus of elasticity decreased with an increase in the content of the moisture in the seeds. Only the surface area and the kernel deformation are increasing with the increase of moisture content.

Table 2. Effect of moisture content on physical and mechanical properties of maize (mean ± std. dev.).

Properties	Moisture content, (%, d.b.)					
	10	12	14	16	18	20
Length (mm)	10.23±0.7	10.23±0.4	10.24±0.3	10.25±0.4	10.26±0.7	10.27±0.4
Width (mm)	8.38±0.6	8.39±0.7	8.39±0.4	8.41±0.6	8.42±0.7	8.44±0.8
Thickness (mm)	4.28±0.3	4.31±0.4	4.31±0.1	4.32±0.4	4.33±0.2	4.33±0.3
Mass of 1000 kernels (g)	352.3±4.1	360.1±6.2	364.8±5.2	369.4±3.9	373.7±5.7	379.8±4.9
Surface area (mm^2)	183.46±23.2	184.96±16.3	185.14±23.4	186.20±21.6	187.03±24.3	187.66±22.5
Yield point (N)	487.82±18.2	420.34±16.3	379.30±17.6	338.20±19.1	228.59±17.4	209.46±18.6
Energy at YP (J)	260.47±11.2	206.03±13.7	123.63±14.9	104.3±11.7	74.43±12.6	50.89±12.9
Rupture force (N)	1033.06±23.5	1018.92±20.5	1006.25±21.4	999.81±20.9	976.44±21.8	897.15±22.3
Rupture energy (J)	1242.96±24.1	1061.48±23.4	999.19±22.9	983.18±23.1	935.38±22.7	915.08±23.5
Deformation (mm)	1.57±0.1	1.59±0.2	1.61±0.3	1.85±0.2	1.92±0.1	1.97±0.2
Modulus of elasticity (MPa)	3.58±2.7	3.46±2.1	3.37±1.5	2.9±1.9	2.65±2.3	2.42±1.1

3. Conclusions

The physical and mechanical properties of wheat and maize seeds determined in the single particle uniaxial compression test allow us to describe the moisture content role in the grinding process.

Wheat and maize grain shape and size affect the mechanical properties of seeds coats during compression tests and the milling process.

At wheat seeds and maize seeds, the yield point, the force, the energy and modulus of elasticity decreased with an increase in the content of the moisture in the seeds. Only the surface area and the kernel deformation are increasing with the increase of moisture content.

The fact that the modulus of elasticity decreases with the increase of moisture content may be due to the fact that at higher moisture content, the grain is less elastic and more viscous in nature.

References

[1] ASAE, 2000. ASAE standards 2000. St. Joseph, MI: American Society of Agricultural Engineers.
[2] Babic, L.J., Radojcin, M., Pavkov, I., Babic, M., Turan, J., Zaranovic, M., Stanisic, S., 2013. Physical properties and compression loading behavior of corn seed. International Agrophysics,27, 119-126.
[3] Bargale, P.C., Irudayaraj J., 1995. Mechanical strength and rheological behavior of barley kernels. International Journal of Food Science and Technology, 30, 609-623.
[4] Dyduch, M., Kaminski, M., Lapko, A., & Runkiewicz, L., 2000. Amendment of Polish Standard PN-89/B-03262 Concrete bens for storing granular materials and silags. XI Conference

Reinforced and prestressed concrete containers for liquids and granular materials, Swieradow Zdroj, 65-69.

[5] Dziki, D., Laskowski, J., 2005. Wheat kernel physical properties and milling process. Acta Agrophysica, 6(1), 59-71.

[6] Dziki, D., 2011. Effect of preliminary grinding of the wheat grain on the pulverizing process. Journal of Food Engineering, 104, 585–591.

[7] Dziki, D., 2004. Mechanical properties of single kernel of wheat in relation to debranning ratio and moisture content. Acta Agrophysica, 4(2), 283-290.

[8] Dziki, D., Laskowski, J., 2000. Investigation of wheat milling properties (in Polish). Inzynieria Rolnicza, 8, 63-70.

[9] Eurocode 1, 1996. Basis of design and actions on structures – Part 4: Actions in silos and tanks. European Committee for Standardization. Central Secretariat: rue de Stassart 36, B-1050 Brussels.

[10] Food and Agriculture Organisation of the United Nations, 2011.

[11] Frączek, J., Kaczorowski, J., Ślipek, Z., Horabik, J., Molenda, M., 2003. Standardization of methods for the measurements of the physico-mechanical properties of plant granular materials (in Polish). Acta Agrophysica, 92, 8-59.

[12] Gąsiorowski, H., Kołodziejczyk, P., Obuchowski, W., 1999. Wheat hardness (in Polish). Przeg. ZboŜ.-Młyn, 7, 6-8.

[13] Glenn, G.M., Younce, F.L., Pitts, M.J., 1991. Fundamental physical properties characterizing the hardness of wheat endosperm. J. Cereal Science. 13, 179-194.

[14] Haddad, Y., Mabille, F., Mermet, A., Abecassis J., Benet, J.C., 1999. Rheological properties of wheat endosperm with a view on grinding. Powder Technology, 105, 89-94.

[15] Lupu, M.I., Pădureanu, V., 2012. Grinding cereals. Ed. Transilvania University of Brasov, 133-135.

[16] Lupu, M.I., Padureanu, V., 2013. The influence of the knife edge on the process of corn grains grinding, International Conference INMATEH – Agricultural Engineering.

[17] Lupu, M.I., Padureanu, V., Canja, C.M., 2015. The influence of speed compression on the maize grinding process. Bulletin of the Transilvania University of Braşov, Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 8(57) No.1.

[18] Mabille, F., Gril, J., Abecassis, J., 2001. Mechanical properties of wheat seed coats. Cereal Chemistry, 78, 231-235.

[19] Martin, C.R., Pousser, R., Brabec, D.L., 1993. Development of a single kernel wheat characterization system. ASAE, 22, 881-885.

[20] Molenda, M. & Stasiak, M., 2002. Determination of the elastic constants of cereal grains in a uniaxial compression test. International Agrophysiscs, 16, 61-65.

[21] Obuchowski, W., Bushuk, W., 1980. Wheat hardness comparison of methods of its evaluation. Cereal Chemistry. 57(6), 421-425.

[22] Obuchowski, W., 1985. Wheat hardness technological importance and factors influencing this property. Rozprawy naukowe, 152, 9-53.

[23] Poutanen, K., Shepherd, R., Shewry, P., Delcour, J. A., Bjorck, I., van der Kamp, J. W., 2008. Beyond whole grain the European healthgrain project aims at healthier cereal foods. Cereal Foods World, 53(1), 32-35.

[24] Poutanen, K., 2012. Past and future of cereal grains as food for health. Trends in Food Science & Technology, 25, 58-62.

[25] Singh, S.S., Finner, M.F., Rohatgi, P.K., Buelow, F.H., Schaller, M., 1991. Structure and mechanical properties of corn kernels: a hybrid composite material. Journal of Material Science, 26, 274-284.

[26] Shepherd, R., Dean, M., Lampila, P., Arvola, A., Saba, A., Vassallo, M., Claupein, E., Winkelmann, M., Lahteenmaki, L., 2012. Communicating the benefits of wholegrain and

functional grain products to European consumers. Trends in Food Science and Technology, 25, 63-69.

[27] Shpolyanskaya, A.L. 1952. Structural-mechanical properties of the wheat grain. Colloid Journal (USSR),14(1), 137-148.

[28] Slavin, J., 2003. Proceedings of the Nutrition Society 62: 129—134.

[29] Trigwell, S., Tennal, K. B., Mazumder, M. K., & Lindquist, D. A., 2003. Precombustion cleaning of coal by triboelectric separation of minerals. Particulate Science and Technology, 21(4), 353–364.

[30] Vitaglione, P., Napolitano, A., Fogliano, V., 2008. Cereal dietary fibre: a natural functional ingredient to deliver phenolic compounds into the gut. Journal Trends in Food Science & Technology, 19 (9), 451-463.

[31] Wang, J., Maarten, M., Schutyser, A.I., Boom, R. M., 2014. Analysis of electrostatic powder charging for fractionation of foods. Innovative Food Science and Emerging Technologies, 26, 360-365.

[32] Williams, P., Sobering, D.C. 1986. Attempts at standardization of hardness testing of wheat. Cereal Foods World, 31(5), 359-364.