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THE INFLUENCE OF MOISTURE ON PHYSICAL PROPERTIES OF WHEAT AND MAIZE KERNELS, SOYBEANS AND RAPESEED

UTJECAJ VLAŽNOSTI NA FIZIKALNA SVOJSTVA ZRNA KUKURUZA, PŠENICE, SOJE I ULJNE REPICE

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SUMMARY

This paper deals with the influence of moisture on the physical properties (angle of slide, angle of repose, 1000 kernel weight, test weight and breakage of kernels) of maize and wheat kernels, soybeans and rapeseed.

The initial moisture of maize was 29.50%. At this moisture, the mean value for the 1000 kernel weight was 362.3 g, for the test weight it was 65.9 kg, the angle of repose was 40.9°, whereas the angle of slide was 15.25° at the beginning, 26.48° for the bulk and 37.30° in the end. At the above mentioned moisture, the average percentage of kernels was 97.40%. The same physical properties of maize kernels were tested at the moisture of 25.0%, 20.5%, 16.5% and 13.5%.

In the beginning the moisture of wheat was 20.50%. At this moisture, the mean value for the 1000 kernel weight was 44.82 g, for the test weight it was 70.26 kg, the angle of repose was 34.30°, whereas the angle of slide was 15.70° at the beginning of sliding, 25.25° for the bulk and 29.50° in the end. After the passage through a cylindrical drum there were no broken kernels. The same properties were tested at the moisture of 16.5.% and 13.5%.

At the initial moisture of soybeans of 20.50%, the mean value for the 1000 kernel weight was 190.44 g, while the test weight was 67.26 kg. The angle of repose was 27.50°, whereas the angle of slide was 5.95° at the beginning of outflow, 11.10° for the bulk and 18.03° in the end. The average percentage of kernels was 91.40%. The same properties were tested at the moisture of 16.5%; 13.5% and 8.0%.

The initial moisture of rapeseed was 13.50% and at this moisture the mean value for the 1000 kernel weight was 5.02 g, with the test weight of 65.82 kg. The angle of repose was 26.54°, while the angle of slide was 5.03° at the beginning of sliding, 14.55° for the bulk and 22.20° in the end. The same properties were tested at the moisture of 12.0% and 8.0%.

In the end, all the values were statistically analyzed and mathematically expressed.

Keywords: Angle of Repose, Angle of Slide, Test Weight, 1000 Kernel Weight, Breakage of Kernels, Maize, Wheat, Soybean and Rapeseed.

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INTRODUCTION

The physical properties of weight are especially important for transport, as well as for drying and storage of weight. They also, play an important role in the choice of the best final processing stage for the same weight. The most important are the bulk of the material marked by the angle of repore and the angle of slide, as well as the test weight, the 1000 kernel weight and the mechanical properties of kernels more commonly called breakage of kernels. These properties depend a great deal on the moisture of the material. Thus, for instance, the bulk of the material ist in inverse proportion to the moisture. By increasing the bulk of the material we also increase the capacity of all the transport equipment, as well as the capacity of the kernel cleaning machines. In addition, the kernel weight of a greater bulk fills up the storage facilities much better, thus increasing their holding capacity. As opposed to the bulk weight, the 1000 kernel weight, test weight and consistece are in proportion to moisture. These physical properties point to the quality of a kernel, as well as to the estimates referring to the processes of drying and storage. According to some bibliographical references, the moisture of a kernel can reduce the test weight by 20% (Žeželj, 1989). Breakage of kernels is different an different crops. Thus, for example, the lowest breakage in maize is at the moisture between 24 and 26%, whereas moister and drier kernels break more frequently (Katić, 1985; Pliestić, 1989).

REFERENCES

By definition, the angle of repose is the space between a pile of kernels and a horizontal surface (Katić, 1992). The same author defines the angle of slide as an angle at which kernels start sliding. He looks into both problems by analyzing wheat, maize, soybean and sunflower at different levels of moisture of kernels, and comes up with a conclusion that there is a great deal of correlation between the angle of repose and the angle of slide with regard to the moisture of kernels.

RITZ (1992) defines the angle of repose between the diameter of a base and the height of a cone as it falls into shape while the kernnel weight is pouring down a flat horizontal surface. The author defines the angle of slide of slide as an angle at which kernels (kernnel weight) begin sliding down any sort of surface. He looks into both problems in wheat and finds out that at kernel moistures of 15.3% up to 35.0% the angle of repose is from 30.0° to 38.0°, whereas the angle of slide is 35°. No data on the moisture of kernels is given.

WIERZBICKI (1984) provides a mathematical pattern for quantitative and qualitative cleaning of kernels in a rotary cylinder trieur. To find the proper position for the pattern, the author considers the angle of repose to be one of the basic standard criteria, besides the rotation speed and the passage of kernels through the cylinder.

DANIEWSKI (1984) explores the angle of slide as a standard criterium to be applied for cleaning potatoes of impurities. On the basis of his research the author considers the vibration amplitudes as the most appropriate for cleaning and giving the best results.

HONG et al. (1986) built a plant for extruding and drying/cooling cereal bran. They took the angle of slide as the basic standard for the construction of one part of the plant which is used for drying/cooling the product after extruding. On the basis of the values gained in this way the authors obtained the values of vibrations that are necessary for the sliding of pelletes in the dryer/cooler.

SARIĆ (1979), after doing some research on the angle of repose with feed meal, reaches the conclusion that the angle is 42.70° at the moisture of 10.88%.

TIC (1967) gives a definition of the angle of repose and its dependence on the moisture, shape and size of a particle; according to him, this angle varies depending on whether the particle is at the stage of repose or activity, as well as on vibrations.

KOJIĆ (1970) carries out research on the angle of slide in wheat and maize kernels. He claims that angle for wheat is from 30° to 38°, while for maize it is from 28° to 32°. The author does not provide any data on the moisture of samples.

BOLTJANSKIJ (1976) gives the angle of slide for soybeans and sunflower kernels. He claims that the angle of slide for soybeans is 25°, whereas for sunflower kernels it is from 31° to 45°. The author does not mention the moisture values of kernels.

BRAKE et al. (1992) conduct some research into chemical and physical properties of hardwood bark when it is used as stable litter for chickens instead of pine sawdust. Apart from other advantages of using hardwood bark, they mention the bulk of the material which is far more balanced and thus more easily stored.

UJEVIĆ (1988) presents the dependence of the angle of slide for wheat and soybean kernels on moisture. The angle of slide for wheat kernels is from 17° to 35° at the moistures from 13% to 35%, whereas for soybean kernels it is from 6° to 26° at the moistures between 13% and 35%.

AHMED (1990) follows storage and the problems of maize storage in Malavsia. He divides the process of storage into the period of storage of up to 30 days and the period of over 30 days. He mentions that in the process of fungiciding of kernels and during the transport (because of increased temperatures), big problems arise due to the inadequate storage and the inappropriate selection of silo cells (funnels).

TAJANA KRIČKA i Šarić (1995) analysed the angle of repose for rapeseed at the moisture up to 4.8% and 10.8%. In the former the angle of repose was 26.2°, whereas in the latter it was 27.5°.

UJEVIĆ (1988) claims that a decrease in the moisture of kernels leads to an increase in the test weight., providing as a proof the data (by HOPF) according to which the test weight is 78 kg if the water content is 16%, whereas the test weight increases to 80 kg if the water content is reduced to 12%. The test weight can also be increased due to the way the analysis is carried out. The same author mentions that the 1000 kernel weight increased at milk stage from 12 to 28 g, and the content of moisture fell from 69 to 46%, wheereas at soft dough stage the 1000 kernel weight rose again up to 32 g at the reduced, moistures of up to 36% and then it fell to 30 g when the level of moisture decreased to 32%.

PLIESTIĆ (1989) find that if the moisture of maize kernels is reduced or increased outside the intervals of 18-22%, the mechanical damage of kernels rises.

PARANOS (1990) follows the 1000 kernel weight of maize at different levels of moisture and finds out that there is a big correlation between the two of them. He also finds that the temperatures of drying (110° and 130°) do not affect breakage of kernels considerably.

TAJANA KRIČKA (1993) finds that the breakage of perforated kernels is bigger than the breakage of unperforated ones. However, while analysing the hybrids separately, the author finds that seven hybrids display a bigger breakage in perforated kernels than in unperforated ones, whereas in three hybrids it is opposite.

TAJANA KRIČKA et al. (1996) analyse the impact of moisture on the angle of repose and the angle of slide in wheat and soybean feed meal and they reach the conclusion that the moisture of meal has an effect upon the mentioned physical properties. They present both properties with simple mathematical equations to facilitate calculating the necessary values the construction of a funnel.

METHODOLOGY

All the researches have been carried out on maize and wheat kernels, as well as on soybeans and rapeseed, at different temperatures as follows:

- maize kernels (w) – 29.50%; 25.00%; 20.50%; 16.50%; 13.50%.
- wheat kernels (w) – 20.50%; 16.50%; 13.50%.
- soybeans (w) – 20.50%; 16.50%; 13.50%; 8.0%.
- rapeseed (w) – 13.50%; 12.50%; 8.0%.

The angle of repose was measured with a measuring sound for each separate moisture of kernels (seed). The number of repetitions was 35 for

each moisture and each sort, and the values obtained were statistically processed.

After the angle of repose had been determined, the samples were tested again with a mobile aluminium surface of inclination to establish the angle of slide. The procedure was repeated 35 times for each sample and during each repetition the following three properties were measured:

– initial sliding of the grains
– bulk sliding of the grains
– sliding of the remaining part grains

The values obtaine were statistically processed. The test weight and the 1000 kernel weight were measured five times with standard methods for each sort and at each separate moisture.

A centrifugal drum was used during the examination of the dynamic resistance of kernels the above mentioned grains in laboratories. While passing through a drum a kernel follows the laws of mechanics for relative motion.

The procedure was repeated five times for all the grains except rapeseed.

RESULTS

Table 1. Physical properties of maize kernels
Tablica 1. Fizikalna svojstva zrna kukuruza

Moisture Vlaga	Angle of Slide Kut klizanja	Angle of Repose (°) Kut mirovanja			1000 Kernel Weight Težina 1000 zrna	Test Weight Težina	Breakage of kernels Lom zrna
(%)	(°)	Beginning Početak	The greater pace Najveća brzina	The end Kraj	(g)	(kg)	(%)
29,50	40,90	15,25	26,48	37,30	362,30	65,93	2,6
25,00	32,74	15,70	26,75	32,53	338,88	73,60	2,6
20,50	21,16	15,10	24,05	28,74	318,40	77,36	10,4
16,50	21,38	15,08	24,10	27,17	306,72	78,00	19,0
13,50	20,00	14,02	16,12	19,80	292,96	78,33	38,0

Equations:

Angle of slide	y = 1,34x – 1,000	r = 0,94
Angle of repose – beginning	y = 0,11x +12,850	r = 0,94
- the greater pace	y = 0,55x +11,970	r = 0,82
- the end	y = 0,98x + 8,490	r = 0,97
- 1000 Kernel weight	y = 4,23x +23,496	r = 0,99
- The weight	y = 6,87x +88,673	r = 0,89
- Breakage of kernels	y = 2,08x +58,200	r = 0,91

Table 2 – Physical properties of wheat kernels
Tablica 2 – Filzikalna svojstva zrna pšenice

Moisture Vlaga	Angle of Slide Kut klizanja	Angle of Repose (°) Kut mirovanja			1000 Kernel Weight Težina 1000 zrna	Test Weight Težina	Breakage of kernels Lom zrna
(%)	(°)	Beginning Početak	The greater pace Najveća brzina	The end Kraj	(g)	(kg)	(%)
20,50	24,30	15,70	25,25	29,48	44,82	70,16	0
16,50	27,19	15,30	21,40	26,03	44,48	70,26	0,80
13,50	22,55	14,40	20,02	25,92	44,06	75,93	1,40

Equations:

- Angle of slide	y = 1,68x - 0,330	r = 1
- Angle of repose – beginning	y = 0,18x +12,090	r = 0,95
- the greater paste	y = 0,76x + 9,460	r = 0,98
- the end	y = 0,51x +18,500	r = 0,89
- 1000 Kernel weight	y = 0,25x +40,640	r = 0,81
- The weight	y = 7,65x +84,991	r = 0,81
- Breakage of kernels	y =-0,20x + 4,100	r = 1

Table 3. Physical properties of Soybeans
Tablica 3. Fizikalna svojstva zrna soje

Moisture Vlaga	Angle of Slide Kut klizanja	Angle of Repose (°) Kut mirovanja			1000 Kernel Weight Težina 1000 zrna	Test Weight Težina	Breakage of kernels Lom zrna
(%)	(°)	Beginning Početak	The greater pace Najveća brzina	The end Kraj	(g)	(kg)	(%)
29,50	27,50	5,95	11,10	18,95	190,44	67,26	8,6
16,50	24,53	5,88	10,90	18,02	181,14	70,57	23,8
13,50	22,50	4,68	9,75	17,67	173,66	71,53	51,4
8,00	20,54	4,65	9,38	17,12	166,00	72,17	92,4

Equations:

- Angle of slide	y = 1,56x + 15,65	r = 0,98
- Angle of repose – beginning	y = 0,12x + 3,57	r = 0,85
- the greater paste	y = 0,15x + 8,08	r = 0,94
- the end	y = 0,14x + 15,87	r = 0,97
- 1000 Kernel weight	y = 1,96x +149,09	r = 0,99
- The weight	y = 3,74x + 75,847	r = 0,90
- Breakage of kernels	y = 6,91x +145,11	r = 0,99

Table 4. Physical properties of Rapeseed
Tablica 4. Fizikalna svojstva sjemena repice

Moisture Vlaga	Angle of Slide Kut klizanja	Angle of Repose (°) Kut mirovanja			1000 Kernel Weight Težina 1000 zrna	Test Weight Težina
(%)	(°)	Beginning Početak	The greater pace Najveća brzina	The end Kraj	(g)	(kg)
13,0	26,53	5,03	14,55	22,5	5,09	65,83
12,0	24,05	4,50	11,57	22,2	4,74	66,93
8,0	23,36	3,35	10,62	19,62	4,59	68,27

Equations:

- Angle of slide	y = 0,50x +19,120	r = 0,79
- Angle of repose – beginning	y =0,32x + 0,760	r = 0,99
- the greater paste	y =0,63x + 5,310	r = 0,82
- the end	y = 0,57x +15,140	r = 0,96
- 1000 Kernel weight	y = 0,07x + 3,990	r = 0,87
- The weight	y = 4,43x +71,883	r = 0,96

Table 5. Equations of linear regressions of physical properties for the sorts unter examination
Tablica 5. Jednadžbe fizikalnih svojstvata ispitivanih vrsta

Variety Vrsta	Angle of Slide Kut klizanja	Angle of Repose (°) Kut mirovanja			1000 Kernel Weight Težina 1000 zrna	Test Weight Težina	Breakage of kernels Lom zrna
(%)	(°)	Beginning Početak	The greater pace Najveća brzina	The end Kraj	(g)	(kg/m^3) y=	(%)
Maize Kukuruz	1,34x-1,00	0,11x+12,85	0,55x+11,97	0,98x+8,49	4,23x+23,496	-6,87x+88,67	-2,08x+58,2
Wheat Pšenica	1,68x-0,33	0,18x+12,09	0,76x+9,46	0,51x+18,50	0,25x+18,50	-7,65x+84,99	-0,20x+4,1
Soybeans Soja zrno	0,56x+15,65	0,12x+3,57	0,15x+8,08	0,14x+15,87	0,14x+15,87	-3,74x+75,85	-6,91x+145,11
Repaseed Sjemenke repice	0,50x+19,12	0,32x+5,31	0,63x+5,31	0,57x+15,14	0,57x+15,14	- 4,43x+71,88	0

After analysing the research findings, it is apparent that the moisture of the material has a significant impact upon the angle of repose in maize and wheat kernels, whereas it is considerably less important for the same angle in oil plant seed.

It has also been established that angle of side for the crops (materijal) under research depends on the

amount of water they contain. However, it ist important to point out that no significant differences in the angle of slide have been noticed between the crops under examination.

Besides the above mentioned physical properties, the 1000 kernel weight and the test weight have also exhebited certain changes due to the changes in the moisture of the material. The 1000 karnel weight is in direct proportion to the moisture of the material, whereas the test weight is inversely proportionate to it.

The above mentioned researches point out and confirm the fact that it is highly recommended to present these physical properties together with the level of moisture in the material.

DISCUSSION

For years in silos and feed factories inappropriately built funnels have caused the appearance of "bridges" since the consistence is bigger than the tension in the raw material. In such a situation the tension has a vertical effect on the inside parts of the funnel (Katić 1982). In order to avoid this and to enable a proper construction of funnels, or make a decision about storing particular raw material in a particular silo cell, some simple mathematical equations for maize and wheat kernels, as well as for soybeans and rapeseed were obtained on the basic of our own research on the physical properties of kernels such as weight, 1000 kernel weight, test weight and their proportionate values – breakage.

CONCLUSION

On the basis of our own research into the physical properties of kernels (such as angle of repose, angle of slide, 1000 kernel weight and mechanical-dynamic properties) it can be said that:

1. The bulk expressed by means of the angle of repose and the angle of slide gets reduced if there has been a decrease in the moisture of kernels (seed).

2. The 1000 kernel weight is reduced if there has been a decrease in the moisture of kernels (seed).

3. The test weight is increased if there has been a decrease in the moisture of kernels (seed).

4. The percentage of breakage of kernels (seed) gets bigger with a decrease in the moisture of kernels (seed).

5. Physical properties can be shown by means of simple mathematical equations of a straight line.

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SAŽETAK

Tema ovog rada je utjecaj vlažnosti na fizikalna svojstva (kut trenja, kut prirodnog pokosa, masa od 1000 zrna, hektolitarska masa I lom zrna) zrna kukuruza, pšenice, soje i uljane repice.

Početna vlažnost kukuruza iznosila je 29,50%. Pri toj vlažnosti srednje vrijednosti iznosile su za masu od 1000 zrna 362,3 g, hektolitarsku masu 65,9 kg, kut prirodnog pokosa 40,9°, kut trenja, početni 15,25°, za glavninu 26,48°, a za kraj 37,30°. Pri navedenoj vlažnosti prosječan postotak cijelih zrna bio je 97,40%. Navedena fizikalna svojstva zrna kukuruza ispitivana su i za vlažnost od 25,0%, 20,5%, 16,5% i 13,5%.

Pšenica je početnu vlagu imala 20,50% I pri toj vlazi dobivene su srednje vrijednosti za masu od 1000 zrna 44,82 g, hektolitarsku 70,26 kg, kut prirodnog pokosa 34,30°, a kut trenja za početak klizanja mase iznosio je 15,70°, za glavninu 25,25° i kraj 29,50°.

Nakon prolaska kroz centrifugalni bubanj nije bilo slomljenih zrna. Navedena svojstva ispitivana su i za vlažnost od 16,5% i 13,5%.

Kod početne vlažnosti soje od 20,50%, srednja vrijednost mase od 1000 zrna bila je 190,44 g, dok je hektolitarska masa iznosila 67,26 kg. Kut prirodnog pokosa iznosio je 27,50°, a kut trenja za početak istjecanja mase 5,95°, za glavninu 11,10° i kraj 18,03°

Prosječan postotak cijelih zrna iznosio je 91,40%. Navedena svojstva ispitivana su i za vlažnost od 16,5%; 13,5% i 8,0%.

Početna vlažnost uljane repice iznosila je 13,50%. Pri toj vlažnosti, srednje vrijednosti iznosile su za masu od 1000 zrna, 5,02 g, uz hektolitarsku masu od 65,82 kg. Kut prirodnog pokosa iznosio je 26,54°. Kut trenja za početak klizanja iznosio je 5,03°, za glavninu 14,55°, a kraj 22,20°. Navedena svojstva ispitivana su i za vlažnost od 12,0% I 8,0%.

Ukupno dobivene vrijednosti statistički su obrađene i matematički modelirane.

Ključne riječI: kut trenja, kut prirodnog pokosa, masa od 1000 zrna, hektolitarska masa, lom zrna, kukuruz, pšenica, soja. repica.