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DEPENDENT OF MOISTURE CONTENT SOYBEAN SEED ON PHYSICAL PROPERTIES

UTICAJ VLAŽNOSTI NA FIZIČKE OSOBINE SEMENA SOJE

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ABSTARACT

The main aim of this research is to establish the effects of moisture content on some physical properties of soybean seeds. Testing was performed for the Balkan and Sava varieties. The following physical properties were measured: dimensions, equivalent diameter, sphericity, grain density, apparent density, coefficient of friction, dynamic angle of repose, grain volume and mechanical properties. Moisture content of soybean seeds ranged from 8 to 20%. This paper presents the preliminary results from the first year of research. It was noted that most of the ***soybean*** *physical properties depends on the humidity in the measured range. It is known from science literature that soya seed (grain) deforming, may cause two cases. The final outcome of dry seeds is grinded grain, and in case of wet grains they may be crushed . This research presents preliminary values of rupture force in the case of grinding grain and analyze the change of modulus of elasticity.*

Key words*: physical properties of soybean, mechanical properties of grain, grain density, modulus of elasticity.*

REZIME

Cilj istraživanja je utvrđivanje zavisnosti fizičkih osobina od vlažnosti semena soje. Ispitivanje je obavljeno za sorte Balkan i Sava. Izmerene su sledeće fizičke osobine: dimenzije, ekvivalentni prečnik, sferičnost, gustina zrna, nasipna masa, koeficijent trenja, dinamički ugao nasipanja, zapremina zrna i mehaničke osobine. Vlažnost semena soje bila je u rasponu od 8 do 20%. U ovom radu daju se preliminarni rezultati iz prve godine istraživanja. Uočeno je da većina fizičkih osobina semena zavisi od vlažnosti u izmerenom dijapazonu. Kao što je iz literature poznato deformisanjem semena (zrna) soje mogu nastupiti dva slučaja. Kod suvog semena krajnji ishod je drobljenje zrna, a kod vlažnijeg dolazi do gnječenja. Daju se preliminarne vrednosti sila loma kod slučaja drobljenja zrna i analizira se promena modula elstičnosti.

Ključne reči: *fizičke osobine zrna, mehaničke osobine zrna, vlažnost zrna, modul elastičnosti.*

INTRODUCTION

Engineering approach to solving problem of design and operation of agricultural technique, requires knowledge of agricultural material properties. From the aspect of technique it is very important to know the basic physical and mechanical properties of grain in order to construct a quality unit and the equipment used for planting, harvesting, transport, storage, processing or treatment in order to avoid its damage.

The purpose of these studies is to define physical and mechanical properties of soybeans. Mechanical hardness test implies defining of modulus of elasticity and breaking force, in order to determine the differences between the two most widespread varieties in Serbia. Among the various mechanical tests that are available, the most common and easiest is pressure test (*Mohsenin, 1980*).

Mechanical properties of agricultural materials are studied similar to the technical material, loading the tensile, compression, shear, bending and twisting. Considering the fact that using the standard "tube" in this case is not possible, these materials must be taken in its original form and size. This approach requires the specification of all relevant factors, and the results will be valid only for such conditions. Because of the statistical scatter of measurement results, it has to be taken enough samples for determining properties, in order to reduce measurement errors. (*Babic, M, 1994*).

Seed material is suitable for precise packing and for precise and reliable sowing only if is extremely unified by physical mechanical characteristics (shape, size and weight of each seed). (*Đukanovic Lana et al. 2008*).

Nomenclature

d_e (mm)	- equivalent diameter
E	- modulus of elasticity
F (N)	- force - sila
F_{max} (N)	- rupture force
P (%)	- porosity
R^2	- determination coefficient
V_z (cm^3)	- volume
w (%)	- moisture content on wet basis
x,y	- function
Δl (mm)	- deformation
Δl_{max} (mm)	- rupture deformation
α_{nd} (°)	- dynamic angle of repose
α_{ns} (°)	- static angle of repose
ε	- relative deformation
μ_s	- static friction coefficient
ρ (kg/m^3)- density	
ρ_n (kg/m^3)	- bulk density
σ_s (%)	- sphericity
σ_{ns} (N/mm^2)	- normal stress

MATERIAL AND METHODS

Samples were harvested at the experimental fields and taken in the processing center of the Institute of Field and Vegetable Crops. Tests of physical properties were carried out in laboratories biosystematics Engineering at the Department of Agricultural Engineering, Agricultural Faculty in Novi Sad and the National laboratory for seed testing Novi Sad.

The two soybean varieties widespread in Serbia, Balkan and Sava were taken as seed samples for testing. The soybean seed for sampling was collected in one harvest passage of the specific combine, Finnish company "Sampo rosenlew ", type: 2035 hydro turbo, working width 3.5 m. This was done in three replications with sample preparation of 3 kg mass for each variety (Balkan and Sava) and different seed moisture. The Sava and the Balkan varieties were collected at the planned levels of moisture**:** 8 to 9, 9 to 11, 12 and 13, 13 and 15 and 18 to 22%. Each sample was divided into two parts one of which is used to define the physical and mechanical seed properties (size, equivalent diameter, sphericity, grain density, bulk density, friction coefficient, dynamic angle of repose, grain volume and mechanical properties), and the other used as a control sample. The samples were tested in three replicates. All these values were tested by the usual methods (*Babic M. and Babic, Ljiljana, 2007*)

Mechanical properties were determined by measuring of seed hardness on pressure (*Mohsenin, 1980*), by the special device TMS - PRO "Food Technology Corporation" company. The device is connected to the PC, in which are measured values stored. During the test occur the compressive force (F) and deformation (Δl) are measured. The maximum force (Fmax), which occurs during the test is especially is registered.

On the basis of the pairs of values, diagrams of tensile – deforming force, are obtained. Secant modulus of elasticity are also calculated (*Mohsenin, 1980*), for all samples.

RESULTS AND DISCUSSION

Soybean grain is in most commercial varieties of elliptical shape and can have all the transitions between spherical and elongated to almost flat grain. 1000 grain weight ranged from 20 g of wild soybean, to over 500 g in some varieties of soybean culture. Commercial varieties usually have a medium large grain, 1000 grain mass from 150 to 190 g (*Hrustić, Milica and Miladinović, J, 1998*).

The average values of equivalent diameter and sphericity is given in the table below (table 1). It is noticeable that decreased grain moisture content for both varieties, causes decreasing of equivalent diameter values of and increasing sphericity.

Grain density (table 1), for the Balkan variety decreases from 1200.28 to 1184.33 kg/m^3 with an increase of grain moisture of 8.6 to 18.5%. For the Sava variety grain density decreases from 1211.98 to 1187.74 kg/m^3 with an increase of grain moisture of 9.5 to 20.7%.

Table 1. Physical properties of soybean seed

Varieties	Moisture content on wet basis (%)	Equi - valent diameter d_e(mm)	Sphericity $\sigma = de/a$	Density ρ (kg/m3)	Bulk density ρ_n (kg/m3)	Static friction coefficient $\mu = \text{tg}\ \alpha$	Dynamic angle of repose α_{nd} (^{o})	Volume V_z(cm^3)
Balkan	8.6	6.45	0.90	1200.28	739.82	0.26	30.43	0.13
	12.6	6.84	0.89	1184.54	715.38	0.28	32.24	0.17
	18.5	7.07	0.88	1184.33	692.58	0.31	32.83	0.20
Sava	9.5	6.34	0.91	1211.98	743.35	0.21	24.93	0.131
	11.1	6.44	0.91	1205.82	739.80	0.21	28.39	0.151
	12.5	6.60	0.90	1199.02	724.04	0.22	31.10	0.157
	15.7	6.74	0.90	1196.35	718.30	0.25	31.12	0.162
	20.7	6.79	0.88	1187.74	692.37	0.40	33.52	0.169

Analysis of variance for the given values confirms that the factor of humidity has an impact on the grain density of (Fig. 1). For the Sava variety that dependence can be expressed by the equation (1) with the coefficient of determination R^2 = 0.517.

$$\rho = 1279.6w^{-0.0247}\ (\text{kg/m}^3) \quad (1)$$

While for the Balkan variety this dependence is expressed by the equation (2) with a low coefficient of determination: R^2 = 0, 2619.

$$\rho = 1244.3w^{-0,0174} \quad (2)$$

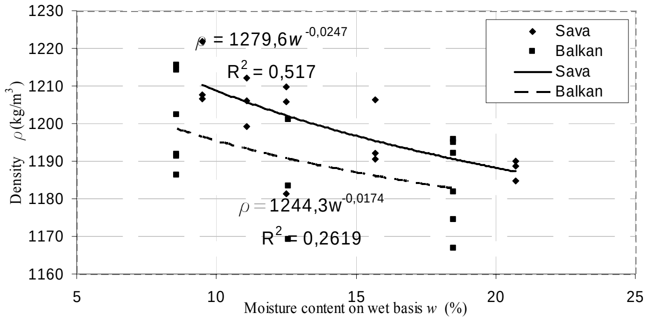

Fig. 1. Variation in soybeans density depending on grain moisture

With increasing grain moisture content for both varieties (table 1) bulk density shows decreasing values. For the Balkan variety bulk density ranged from 739.82 to 692.58 kg/m^3, while for the Sava variety ranged from 743.35 to 692.37 kg/m^3. It was found that bulk density depends on the moisture content of grain (Fig. 2) and this dependence can be defined by using the equation (3) Variety Sava, the coefficient of determination R^2 = 0.9118.

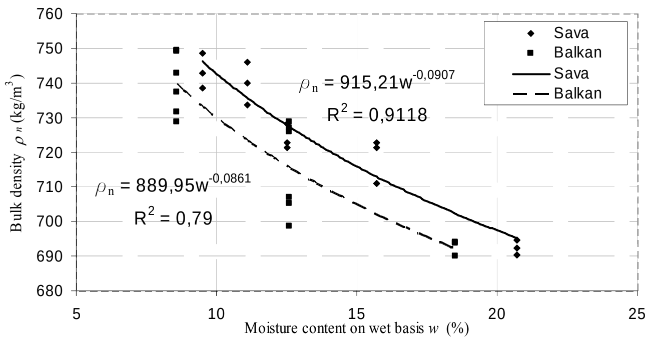

Fig. 2. Variation in bulk density depending on the grain moisture

$$\rho_n = 915.21w^{-0.0907} \quad (3)$$

For the Balkan variety this dependence is expressed by the equation (4) with the coefficient of determination R^2 = 0.79.

$$\rho_n = 889.95w^{-0.0861} \quad (4)$$

The static friction coefficient for both soybean varietes, shows an increasing trend due to the grain moisture content increase. (Table 1). The reason is an increased adhesion between the seed and material surface at higher humidity. It implies that in the tested range, seed moisture content has an impact on the measured data (Fig. 3) and that dependence, for the Sava variety, can be defined by the equation (5) with the coefficient of determination $R^2 = 0.8111$.

$$\mu = 0.029 w^{0.8281} \quad (5)$$

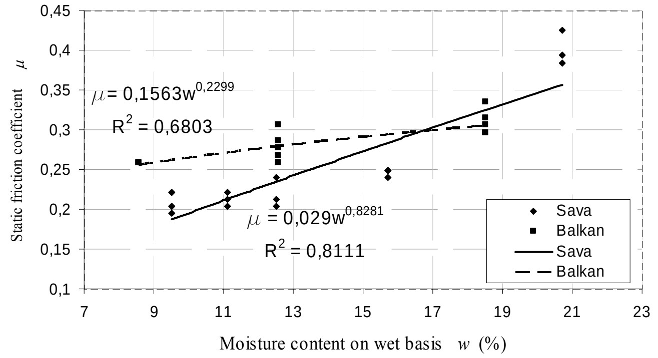

Fig. 3. Variation of coefficient of friction depending on the grain moisture

For the Balkan variety, this dependence is expressed by the equation (6) with the coefficient of determination $R^2 = 0.6803$.

$$\mu = 0.1563 w^{0.2299} \quad (6)$$

The moisture content of seeds shows the influence of the dynamic angle of repose (table 1). In the Sava variety values increase from 24.93° to 32.52° on about, while in the Balkan variety, values rise from about 30.43° to 32.83°.

The effect of moisture on the dynamic angle of repose (Fig. 4) can be expressed in the Sava variety by the line equation (7) with the coefficient of determination $R^2= 0.5268$, while in the Balkan variety this dependence is defined by equation (8) with the coefficient of determination $R^2 = 0.497$.

$$\alpha_{nd} = 12.149 w^{0.0343} \quad (7)$$

$$\alpha_{nd} = 25.315 w^{0.0909} \quad (8)$$

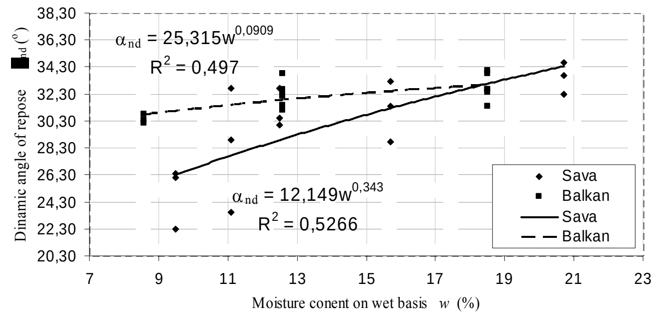

Fig. 4. Variation of the dynamic angle of repose depending on the grain moisture content

The values of grain volume (table 1) for both varieties, show a growing trend, depending on the grain moisture content and for the Sava variety ranging from 0.131 to 0.169 cm^3, whereas for the Balkan variety ranging from 0.13 to 0.20 cm^3.

Analysis of variance for the given values confirms that the factor of humidity has an impact on the volume of grain (Fig. 5).

The grain volume dependence of grain moisture, for the Sava variety, can be expressed by the equation (9) with the coefficient of determination $R^2 = 0.5731$, while for the Balkan variety this dependence is expressed by the equation (10) with the coefficient of determination $R^2= 0.8194$.

$$V_z = 0.0728 w^{0.2869} \quad (9)$$

$$V_z = 0.0367 w^{0.5843} \quad (10)$$

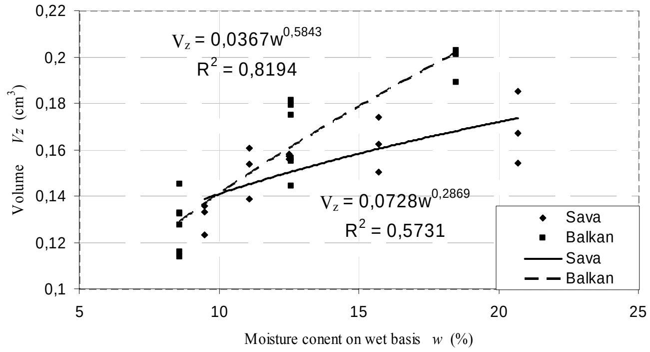

Fig.7. Change in volume of grain, depending on the moisture content of grain

Literature sources indicate that other authors have reached similar results. Kibar and Ozturk (2008) have determined physical and mechanical soy properties in the range of the grain moisture content from 8 to 16%. In this range of grain moisture it was the increasing of the grain length from 7.24 to 8.19 mm, width from 6.79 to 7.12 mm, thickness from 5.78 to 6.23 mm, the arithmetic average equivalent diameter of 6.60 to 7.18 mm and a geometric average diameter of 6.57 to 7.14 mm. Volume and surface area of grain were increased linearly from 130.97 to 160.32 cm3 and from 125.46 to 144.39 mm^2.

Sphericity, the total density and true density decreased linearly from 0.91 to 0.87, 766.12 to 719.00 kg/m^3 and 983.33 to 905.67 kg / m^3 respectively.

The angle of internal friction increased linearly from 27.37 to 31.81 with increasing moisture content.

The coefficient of friction increased from 0.385 to 0.571 for a concrete foundation, 0.304 to 0.441 for a wooden base and 0.164 to 0.286 for galvanized metal surface.

However, the results of measurements in these cases, are only valid for the given conditions.In examining the **mechanical properties** of agricultural materials, the dependence of tensile-deforming force is usually required, whose analysis reveals that at low tensile forces, occur similar phenomena as in the technical material. This means that there is an area of elasticity when the material is deformed elastically. By further activity of the tensile force, the material behaves elastically and plasticly. Loaded material acts as a solid body. After a certain point the material begins to „flow", and the material properties in this area responds Non Newtonian fluids properties (Non Newtonian fluids) (Babic, 1994). Destructive and deforming force were determined by acting on the y-axis, i.e. in the direction of thickness measurement of grain.

By collecting the measured values for rupture force (Fmax), the deformation on the destruction (Δlmax) and grain dimension, as values of secant modulus of elasticity (E) and relative deformation (ε) were calculated for all samples, and their average values are given in the teble (table 2). According to (Ebubekir, 2008), the highest breaking force, deformation and stress at all levels of grain moisture were obtained by pressing the grain along the y-axis.

The average values of secant modulus, (Table 2) indicate that sample number (B10) in the Balkan variety, and sample number (S8) in the Sava variety, have the highest average value of modulus of elasticity, from the zero load to the limit.

The largest measured values of destruction force are of the sample (S10), the Sava variety and (B8), the America variety, (Table 2). The value of destructive forces in the Balkan variety, decreases with increasing moisture content, so the sample number (B16) is not possible to determine the fracture line, but there was crushing grain.

Table 2. The average values of the parameters of the mechanical properties

Sorta	Broj uzorka	Vlažnost (%)	F_{max} (N)	σ_{max} (N / mm^2)	Δl_{max} (mm)	ϵ	E
Balkan	B8	8.5	145.27	6.585	1.24	0.221	29.765
	B10	8.6	139.09	5.879	0.98	0.170	34.620
	B12	12.4	116.57	4.536	2.22	0.375	12.082
	B14	12.8	86.52	3.276	2.80	0.467	7.012
Sava	S8	9.5	138.40	6.120	1.37	0.241	25.436
	S10	11.1	152.60	6.933	2.14	0.381	18.183
	S12	12.5	116.90	4.869	2.80	0.483	10.072
	S14	15.7	75.75	3.070	2.69	0.448	6.850
	S16	20.7	69.58	2.669	2.91	0.502	5.318

Based on measured data diagrams of the force (F) - deformation (Δl) for each sample individually are made. An example diagram is shown in the (Fig. 6).

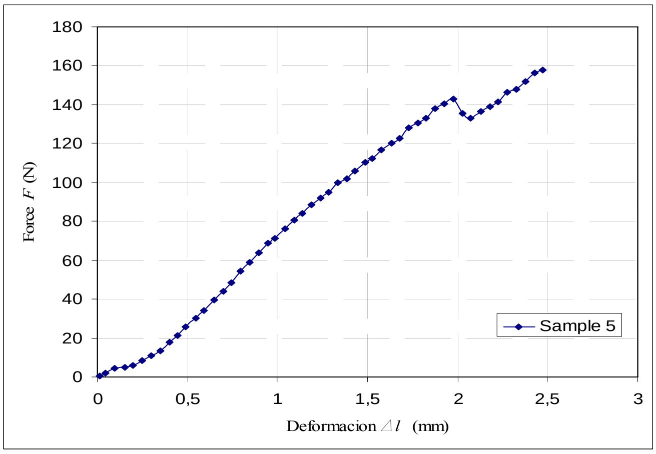

Fig. 6. Diagram of the force – deformation dependence (the effect of fracture)

For all values of grain moisture, the pressure force increases with increasing deformation up to a point where there is a sudden drop in force. This moment is recorded as the breaking point. With further increase of deformation, the force continues to grow, but the force-deformation curve has irregular features and is not considered important (*Gupta et al, 2000*) .

In practic, the forces acting on soybean is most likely to occur in two typical cases. The first is the case when there is a fracture (crushing) beads (Fig. 6) and the second when the effect of grain crushing occurs (eg, Fig. 7). In the latter case it is not possible to notice the boundary of the grain fracture. In any case, grain resistance to mechanical impact depends on the moisture content and physical properties of grains of the given variety.

Analyzing the given results, (*Babić, M., et al. 2000*) concluded that there is a very high dispersion of values of maximum destruction force , but with its slight decline with increasing humidity. Some varieties have a strong resistance to mechanical effects, while others do not.In the case of the higher moisture content, reduced breaking resistance, could be due to the fact that at higher moisture, seed becomes susceptible to cracking (*Yalcin et al. 2004*).

Testing the grain hardness by using load of pressure shows that moisture content has an impact both on the modulus of elasticity, and the destructive force of grain. According to (*Saiedirad et al,. 2008*) the great effect on the mentioned values (except for large grain moisture) have both position of grain and the grain size.

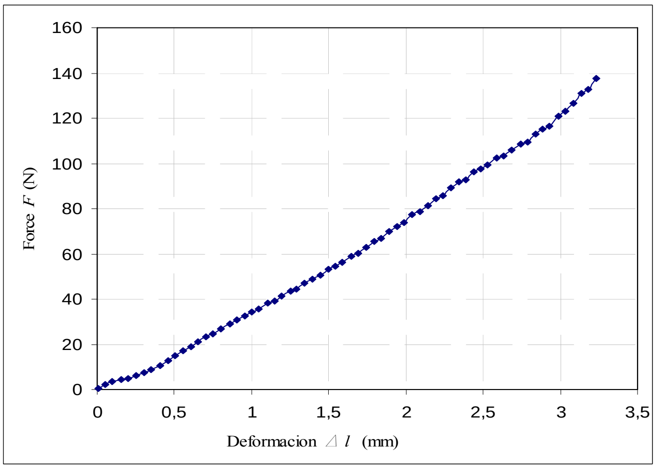

Fig. 7. Diagram of the force – deformation dependence (the crushing effect)

It is noticeable that the value of secant modulus of elasticity increases with decreasing moisture content of grain, and that the variety has an influence on the mechanical strength, but that the final moisture content is during the drying process, also of significant influence (*Babic, Ljiljana, 2001*).

CONCLUSION

Tested samples, of both soybean varieties, show differences in physical properties depending on the moisture content of seeds.

Analysis of variance show a significant effect of grain moisture on all the physical properties of grain. Both,mathematical dependences of the moisture effect on grain physical properties and diagrams for their graphical determination, are defined. Testing the grain hardness by using load of pressure, shows that moisture content has an impact both on the modulus of elasticity, and the rupture force of grain. The biggest breaking force, deformation and stress at all levels of grain moisture were obtained by pressing the bead along the y-axis. The measurement results are only valid for the given conditions. It is necessary to perform a certain number of tests repetitions for various moisture levels, in order to obtain reliable data with higher coefficients of determination.

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