Mechanical and Physical Properties of Soybean (*Glycine hispida*) Seed

M. Babić[1], Ljiljana Babić[1], V. Lonačević[2], I. Pavkov[1], M. Radojcin[1], Svetlana Balešević[2]

[1]University of Novi Sad, Faculty of Agriculture, Trg Dositeja Obradovica 8, Novi Sad, 21000, Serbia
[2]Institute of Field and Vegetable Crops, Maksima Gorkog 30, Novi Sad, 21000, Serbia

e-mail of corresponding authors: mbab@polj.uns.ac.rs

Abstract

Soybean is one of the most important agricultural crops in the world. The basic physical and mechanical properties were studied at different moisture content of soybean seeds. The studies were carried out for two soybean varieties that are grown in Serbia. The range of moisture content of the harvested soybean was from 8.6 to 21.74% wb. The volume of seed is higher if moisture content of seed is higher. The rupture force and secant modulus of elasticity decrease with higher moisture content of the seed. Germination energy, as an indicator of seed viability, is higher if the seed has greater rupture force. Statistical methods were used for studying correlations between these traits of soybean seeds.

***Key words:** soybean, moisture content, rupture force, secant modulus of elasticity, energy germination*

Introduction

Soybean (Glycine hispida) is an important field crop in Serbia. Production of soybean in the world has reached the pinnacle in terms of economic importance. Consequently, the production and maintenance of the quality of soybean seeds is of utmost importance. Soybean is very sensitive to mechanical effects due to its specific morphological characteristics. Seed cover is very thin, it can break easily and it makes poor protection for seeds. From the moment of harvest until sowing the seeds were exposed to various adverse mechanical effects leading to reduced seed viability (Babic, Ljiljana and Babić M, 2000). Seed resistance to mechanical stress can be very important for seed quality. It is, therefore, important to study the mechanical properties of seeds. Since the soybean is harvested at different moisture contents, it is necessary to investigate how seed moisture at the harvest time affects the mechanical strength. Different soybean varieties have different mechanical resistance. The influence of moisture content on the physical and mechanical properties for different granular agricultural materials has been researched by different authors (Tavakoli et al., 2009, Coskun et al., 2005, Amin et al., 2004; and Igbeka Olajide, 2003; Razavi and Milani, 2006; Kiani Deh Kiani et al., 2008). All the authors have concluded that the moisture content is an important factor of the basic physical and mechanical properties of grain.

Material and methods

For the study of physical and mechanical properties of soybean seed samples, two varieties were chosen, the *sava* and the *balkan*, which differ greatly in their varietal characteristics. The *Balkan* variety has a longer period of vegetation and a slightly larger grain.

The samples were taken at different harvest seed moisture content ω, from $8.6\%_{wb}$ to $21.74\%_{wb}$ (wet basis), with planned five level values. A certain amount of samples was taken during two years of production: 2009 and 2010. The moisture content was determined by gravimetric method according to ISTA (International Seed Testing Association) rules (Rules, ISTA, 2003), for each sample, with three repetitions. From each sample 20 grains were taken, and dimension, volume and mechanical properties were measured for each grain. One of the geometric characteristics was the volume of the seeds measured using equipment Kern PLJ 360 - 3M, Switzerland.

Although during testing other basic physical properties were also measured, a representative of the geometric properties in the paper is the dependence of the seed volume on the moisture content. The dimensions of the seeds were determined using the sliding gauge.

The mechanical properties were measured by the texture device TMS - PRO by "Food Technology Coorporation" (USA). This device was used for determining the dependence between force and deformation. Soybean seeds were pressured in the direction of seed thickness measurement. Due to the specific occurrence of elastic and plastic deformation of the plant materials, the property characteristics force - deformation almost always have a nonlinear character (Babic et al., 2000). In these cases the modulus of elasticity is defined in various ways. In this research the secant modulus of elasticity was selected as the best representative of this size in a wider range of force, or stress (Mohsenin, 1980). Soybean seed is very close to the shape of an ellipsoid. The shape of the grain is approximated to an ellipsoid in this research. The complex stress state in the body of variable cross-section is simplified by calculating the mean cross-sectional area in the direction of action force (Figure 1). The change of the cross-sectional area is of the value A_{min} = 0 to the maximum value A_{max} in the middle of a grain. Taking into account the elliptical change of this value a mathematical expression for the mean cross-sectional area A_s is derived (Pivnički, 2001):

$$A_s = \frac{a\,b\,p^3}{64}$$

where a and b are axis of the ellipse in the middle of a seed, *i.e.* its length and width.

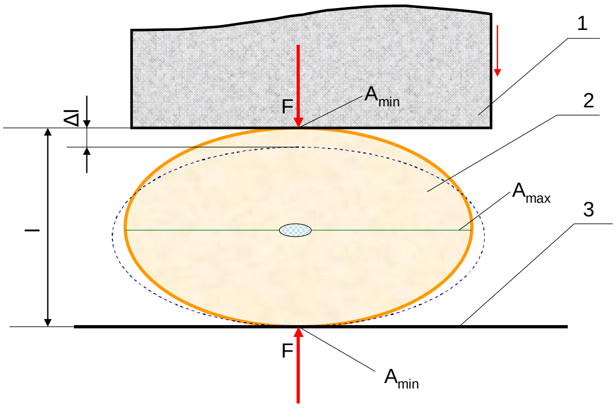

Figure 1 Sheme of force action on seed (1 – hold-down, 2 – seed, 3 - base)

During the loading of the sample, the force and the medium stress increase to the critical value (point K in Fig. 2), when the destruction (rupture) occurs. It then reaches the maximum force F_{max}. The average value of the normal stress at the critical value of force is:

$$s_k = \frac{F_{\max}}{A_s}$$

During the execution of the experiments two characteristic cases were observed. In the first case the sample was crushed (ruptured) at the end of the test (Figure 2, left). In the case of a wetter seed, at the end of the test the seed was kneaded (Figure 2, right). In the latter case, the rupture force (critical force) F_{max} could not be observed. The secant modulus of elasticity Es was determined only in the case of grain crushing (rupture) as:

$$E_s = \frac{s_k}{\Delta l_k / l}$$

where: Δl_k - deformation at the maximum force Fmax, l - thickness of the seed before deformation and $\Delta l_k / l$ - strain.

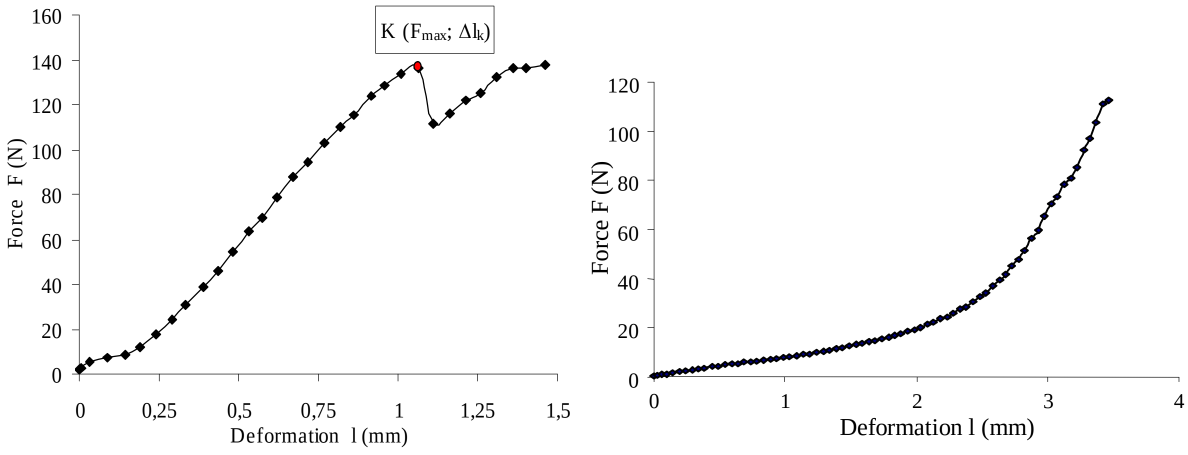

Figure 2 Two case of seeds destruction (left – seed rupture, right – kneading to seed)

Seed viability is represented by the germination energy value. Germination energy, as a cold test, is determined by the standardized test (Rules, ISTA, 2003).
Statistical analyses were performed using Microsoft Office Excel 2007.

Results and Discussion

The variance analysis was completed after data ordering. It proved that the factor of moisture content influences the seed volume. The correlation was tested by regression analysis. A mathematical model of power function, applied also by other authors, was selected. Good agreement between the model and the data was obtained (Fig. 3):

$V_z = 0.0399\ w^{0.559}$ (variety *balkan*) and

$V_z = 0.0784\ w^{0.273}$ (variety *sava*)

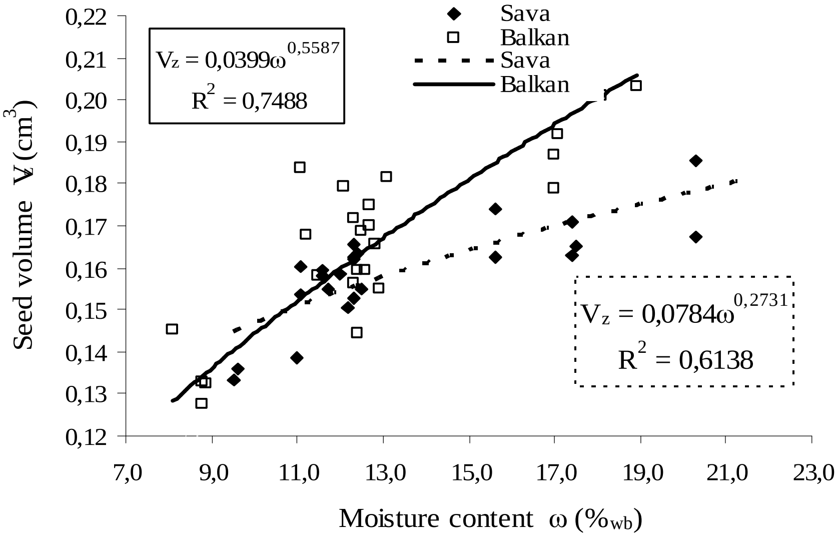

Figure 3 Influence of seed moisture content on the seed volume

The influence of seed moisture on the rupture forse (maximum force) is also significant. This is confirmed by varinace analysis. The correlation was tested by regression analysis, as well. The power function as a mathematical model has good value of coefficient of determination (Fig. 4):

$$F_{\max} = 567.8 \; w^{-0.608} \text{ (variety } \mathit{balkan}\text{) and}$$

$$F_{\max} = 1868 \; w^{-1.084} \text{ (variety } \mathit{sava}\text{)}$$

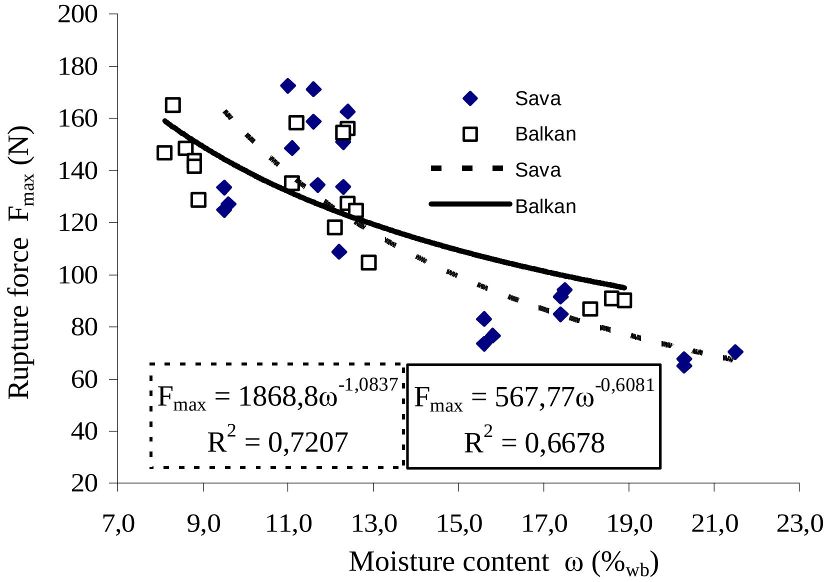

Figure 4 Influence of seed moisture content on the rupture force

The influence of seed moisture on the secant modulus of elasticity is significant, too, confirmed also by varinace analysis. The correlation was tested by regression analysis, as well. The power function as a mathematical model has very good value of coefficient of determination (Fig. 5):

$$E_s = 3074 \; w^{-2.15} \text{ (variety } \mathit{balkan}\text{) and}$$

$$E_s = 1628 \; w^{-1.91} \text{ (variety } \mathit{sava}\text{)}$$

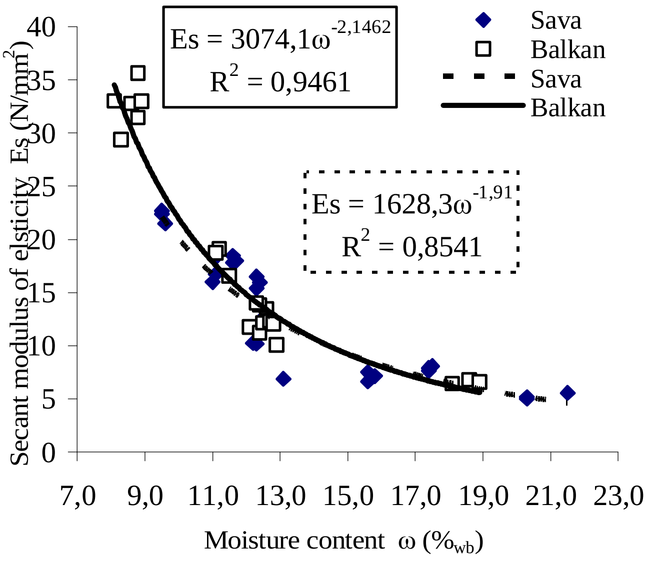

Figure 5 Influence of seed moisture content on the secant modulus of elasticity

The correlation between the physical and biological properties is particularly interesting. The correlation between the germination energy E_n, as a biological indicator of the seed quality, and the rupture force, as a mechanical property of the seeds was analyzed. Analysis of variance confirmed the interdependence in this case, as well. Regression analysis tested the power function as a mathematical model. Good correlations were obtained (Fig. 6). These are:

$E_n = 28.48\ F_{\max}{}^{0.235}$ (variety *balkan*) and

$E_n = 56.47\ F_{\max}{}^{0.0979}$ (variety *sava*)

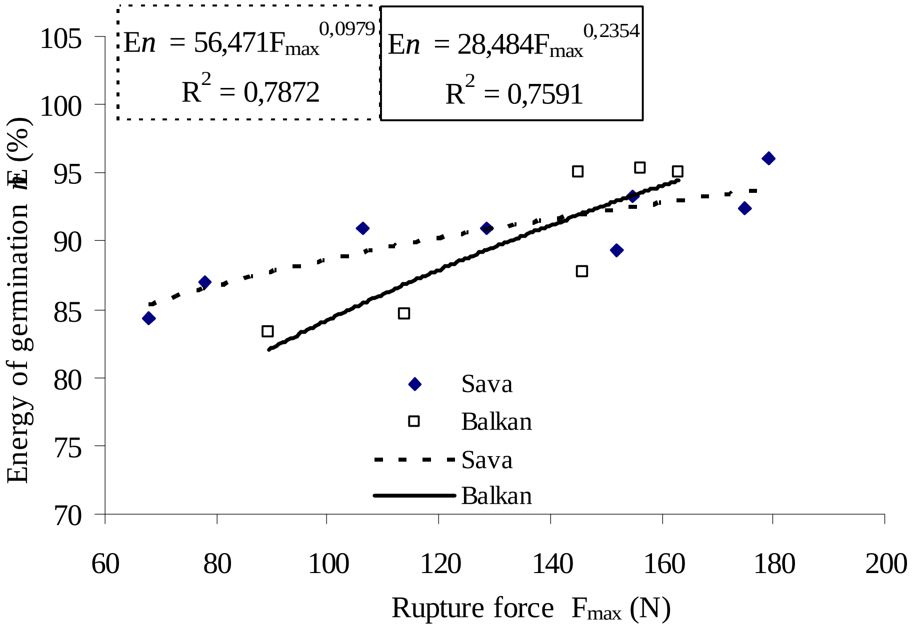

Figure 6 The interdependence between energy of germination and the rupture force

Conclusion

The studies have confirmed that the moisture content and the varieties influence the basic physical and mechanical properties of soybean seed. This fact must be taken into account when developing new soybean selections. The harvesting, transport, processing, storage and sowing can mechanically damage the seeds. It is, therefore, important to know the correlation between the seed moisture content and its physical properties.

It was found that greater firmness (rupture force) of the seed results in higher viability the seed.

Aknowledgement: *This research was supported by Serbian Ministry of Education and Science in the framework of the project TR. 31058*

References

Amin, M., N., Hossain, M., A., Roy, K., C., 2004. Effects of moisture content on some physical properties of lentil seeds. J. Food Eng. 65(1), p.83-87.

Babić Ljiljana, Babić M., 2000. Sušenje i skladištenje, Poljoprivredni fakultet Novi Sad. Serbia. 306 pp.

Babić Ljiljana, Babić M., Turan J., Lazić V., 2001. Uticaj sušenja na uslovni sekantni modul elastičnosti zrna soje, Časopis za procesnu tehniku i energetiku u poljoprivredi – PTEP, vol. 5, 1–2, 3–6.

Babić, M., Turan, J., Babić Ljiljana, Lazić, V., Molnar Vukica, Zarić, B., 2000. Uticaj tehnologije sušenja na mehaničke osobine soje, Časopis za procesnu tehniku i energetiku u poljoprivredi – PTEP, vol. 4, 3–4, 57–59.

Coskun, M.,B., Yalçin, I., Özarslan, C., 2005. Physical properties of sweet corn seed (Zea mays saccharata Cturt.). Journal of Food Engineering, 74 (4), p.523–528.

ISTA (2003). International Rules for Seed Testing, International Seed Testing Association, Switzeland.

Kiani Deh Kiani, M., Minaei, S., Maghsoudi, H., Ghasemi Varnamkhasti, M., 2008: Moisture dependent physical properties of red bean (Phaseolus vulgaris L.) grains, Int. Agrophysics, 22, p.231-237.

Mohsenin, N., N., 1986. Physical Properties of Plant and Animal Materials. Second edition. Gordon and Breach Science Publishers, New York. USA. 742 pp.

Olajide, J., Igbeka, J., C., 2003. Some physical properties of groundnut kernels. J. Food Eng., 58, p.201-4.

Pivnički, G., 2001. Uticaj sadržaja vlage i režima sušenja na mehaničke osobine zrna soje, Magistarska teza, Poljoprivredni fakultet, Novi Sad. 79 pp.

Razavi, C., Milani, E., 2006. Some physical properties of the watermelon seeds. Afr. J. Agric. Res., 13, p.65-69.

Tavakoli, H., Rajabipour, A., Mohtasebi, S., S., 2009. Moisture-Dependent Some Engineering Properties of Soybean Grains, Agricultural Engineering International: the CIGR Ejournal. Manuscript 1110. Vol. XI, Iran.