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MECHANICAL PROPERTIES OF DIFFERENT SOYBEAN SEED GRADES

MEHANIČKE OSOBINE SEMENA SOJE RAZLIČITIH FRAKCIJA

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ABSTRACT

Knowledge of mechanical properties of agricultural materials is important for designing and exploitation of agricultural machines and equipment, as well as for successful preservation of biological values of seed during drying, processing and storage. As the shape of soybean seeds is generally round, they can be graded by a simple procedure, using different sieve settings. In this study we assessed the impact of seed grade on the mechanical properties of seed of the soybean varieties which differed in seed size. The initial tangent modulus of elasticity and maximum rupture force were used as indices of mechanical properties of seed, and they were discussed in detail in the paper. The values of the initial tangent modulus of elasticity went down as seed size increased. The lowest value, 9.26 N/mm^2, was recorded for grade 6.0 to 6.5 mm in the variety Balkan. The highest value, 18.84 N/mm^2, was recorded for grade 4.0 to 4.5 mm in the variety Victoria. Unlike the values of the initial tangent modulus of elasticity, the values of maximum rupture force increased in proportion with increase in seed size. The highest value, 176.18 N, was recorded for grade 5.5 to 6.0 mm in the variety Victoria, and the lowest value, 92.15 N, was recorded for grade 4.0 to 4.5 mm in the variety Balkan.

Key words: *soybean seed, mechanical properties, grades.*

REZIME

Poznavanje mehaničkih osobina poljoprivrednih materijala je veoma važno prilikom konstruisanja i eksploatacije poljoprivrednih mašina i opreme ali je neophodno i za očuvanje bioloških vrednosti semena prilikom sušenja, skladištenja i procesa dorade. Seme soje na osnovu fizičkih osobina ima okruglast oblik pa je moguće kalibraciju uraditi jednostavnim postupkom pomoću sita raznih dimenzija i otvora. U radu je ispitan uticaj frakcija na mehaničke osobine semena soje za sorte koje se karakterišu različitom krupnoćom zrna. Kao pokazatelji mehaničkih osobina semena korišćeni su početni tangentni modul elastičnosti i maksimalna sila razaranja koji su detaljno prikazani u radu. Vrednosti početnog tangentnog modula elastičnosti su sa povećanjem dimenzije zrna imale manje vrednosti. Tako je najmanja vrednost zabeležena kod sorte Balkan za frakciju 6,0-6,5 mm od 9,26 N/mm^2, dok je najveća vrednost zabeležena kod sorte Victoria za frakciju 4,0-4,5 mm od 18,84 N/mm^2.Za razliku od početnog tangentnog modula elastičnosti, vrednosti maksimalne sile razaranja su se povećavale sa povećanjem dimenzija semena, tako da je najveća vrednost zabeležena kod sorte Victoria za frakciju 5,5-6,0 mm od 176,18 N dok je najmanja vrednost zabeležena kod sorte Balkan za frakciju 4,0-4,5mm od 92,15 N.

Ključne reči: *seme soje, mehaničke osobine, frakcije.*

INTRODUCTION

Knowledge of mechanical properties of agricultural materials is important for designing and exploitation of agricultural machines and equipment. Mechanical properties of agricultural materials include the resistance to torsion, compression, shearing, bending and twisting. In all cases of destruction of material (mowing, cutting, grinding, tearing, shaking, husking, peeling, fluid materials transport, briquetting, pelleting, pressing, extrusion, etc.), it is necessary to reliably know what outside influences (force, pressure, speed, etc.) are needed to complete a certain mechanical operation *(Babić and Babić, 2007)*. Knowledge of mechanical properties of seeds is necessary to preserve their biological values during their drying and storage, and beside that knowledge of the physical properties of the seed is very important for the design of equipment for cleaning, drying and storage *(Kheiralipour et al., 2008)*. It is also important to know which mechanical properties play a role in seed processing. On this basis it is possible to design and adjust the agricultural and processing machines so that their working bodies do not damage seeds when coming in contact with them. To achieve that, all relevant factors, such as moisture content, variety, seed dimensions, agrotechnical and climatic conditions of production, etc. should be specified, and the values of these factors are valid only for the given conditions. *Đukić et al.* (*2011*), pointed out that the amount and distribution of rainfall, temperature conditions during the growing season, and the time of occurrence, duration and intensity of droughts significantly affect soybean seed yield, 1000-seed weight and germination. To reduce measurement errors which occur due to the statistical scatter of the obtained results, it is necessary to analyze a sufficiently large number of samples *(Babić, 1994)*. *Tavakoli et al.* (*2009*) described a detailed procedure for evaluating the impact of soybean seed moisture content on some physical properties, and change of mechanical seed damage during loading force compression. They used four humidity levels ranging from 6.92% to 21.19%. The deformation work (destruction energy) increased with the increased seed moisture content, while the maximum force destruction decreased. Differences in mechanical properties of soybean seed result from the impact of various factors including the technology of drying and storage conditions *(Babić and Babić, 2000)*. *Kaifas* (1984) stated that the nonhomogeneous structure and irregular geometrical shape make the testing of mechanical properties of agricultural materials difficult. Among the various mechanical tests that are available, the most common and simplest is the loading strength test. The sample is submitted to a controlled loading from one direction and uncontrolled loading from the other two dimensions, which causes a change in shape. The plate that exerts the load on the sample has to be larger in diameter than the sample in order to simulate realistic compression conditions. When testing the indirect pressure on seeds, transmitters of force act on the projecting surfaces, which results in a complex load distribution *(Mohsenin, 1980)*. As a consequence to this phenomenon, there occur problems in the interpretation of the obtained results. Various sensors are used to measure changes in the loading force and the resulting deformations and these results are used to explain certain regularities. The goal of such studies is to define the mechanical properties of soybean seed. *Babić and Babić* (2007) claimed that the theoretical approach to the resistance of material is valid for agricultural materials too. Unlike the conventional engineering materials which need to be tested for the relation compression - deformation, agricultural materials often require to be tested for the relationship deformation - force. It can be seen that agricultural materials, when subjected to small loads, behave similarly to technical materials.

Unlike mechanical materials, agricultural materials do not show linear behavior at the beginning of deformation. Therefore, the initial tangent modulus of elasticity, secant modulus of elasticity and tangent modulus of elasticity have to be defined in relation to elastic deformation of agricultural materials *(Mohsenin, 1980)*. The initial tangent modulus of elasticity is applicable to very small loads of material and it should be accounted for an immediate vicinity of the point for which it is determined. When test results show no clear delineation between elastic and plastic deformations, it is advisable to define the range in which the relationship compression - deformation is definitely known to be linear. Based on studies conducted at the Laboratory for Biosystems Engineering of Faculty of Agriculture in Novi Sad, it was concluded that a range of up to 2% of relative deformation can be safely considered as the range in which only elastic deformations occur.

MATERIAL AND METHOD

Soybean varieties developed at Institute of Field and Vegetable Crops in Novi Sad were used in this study. These varieties differed in seed size: Balkan had large seed (1000-seed weight above 190 g), Victoria had medium large seed (1000-seed weight 170-190 g), while Trijumf represented soybean varieties with small seed (1000-seed weight under 170 g). The seed used was harvested in 2011, which was unfavorable for soybean seed production. The moisture content in seed was quite low, ranging from 7.0% to 7.4%. The seed were graded with a Kamas Westrup UB-600 type grader. The sieves had rectangular holes which had the following dimensions: 4.0, 4.5, 5.0, 5.5, 6.0 and 6.5 mm. Seed lots were separated into six grades (4.0 to 4.5 mm, 4.5 to 5.0 mm, 5.0 to 5.5 mm, 5.5 to 6.0 mm, 6.0 to 6.5 mm and larger than 6.5 mm) After grading, average samples were made by cultivar and by grade, which were subsequently used for determination of the basic mechanical characteristic of seed. After preparation, samples were submitted to mechanical tests. Ten randomly selected seeds from each sample were measured for the three axial dimensions, height, width and thickness. Loading resistance of seed *(Mohsenin, 1980)* was tested with a TMS-Pro texture analyzer manufactured by Food Technology Corporation. According to the Hooke law, the elasticity modulus is defined as the ratio of normal stress and relative deformation, where normal stress is the ratio between force and the surface on which this force acts. However, defining the cross-section surface is a problem, because soybean seed do not have equal cross sections at all points along the axis upon which the force acts. Therefore, a mean value of all cross-section surfaces was determined by the integral calculus *(Pivnički, 2001)*. For the purposes of this calculation, the soybean seed was approximated to be an ellipsoid. The mean cross-section surface (As) was calculated separately for each seed, by the following formula:

$$A_s = \frac{ab\pi^3}{64} \quad (1)$$

where: A_s- mean values of seed cross-section (mm^2), seed length (mm), seed width (mm)

Mean values of seed cross-section were determined in ten replications for each sample. Maximum rupture force was determined in three replications, with ten seeds per sample. The values of initial tangent modulus of elasticity were determined by loading/compressing the samples within the range of relative deformation from 0 to 2%. This range was selected because, according to previous experiences gained at the Laboratory for Biosystems Engineering, it maintained a linear relationship between compression load and relative deformation. The number of measurements within the range was sufficient for a reliable statistical determination of the elasticity modulus. Deformation (l) is the value registered by the measuring device which represents the elastic deformation of seed prior to the rupture point. This is the distance that the transmitter of force travels from the moment it touches seed surface to the point where seed is ruptured.

RESULTS AND DISCUSSION

Lowest values of maximum rupture force were recorded in the smallest seed grades (Figure 1). The highest value of maximum rupture force, 176.18 N, was observed in grade 5.5 to 6.0 mm of the variety Victoria, while the lowest value, 92.15 N, was recorded in grade 4.0 to 4.5 mm of the variety Balkan. It was also noted that the variety Balkan had lower values of maximum rupture force than the varieties Trijumf and Victoria. As the variety Balkan has the largest 1000-seed weight, this variety was expected to have highest values of this parameter. However, highest values were recorded in the variety Victoria, indicating that this variety is more resistant to mechanical damage of seed than the varieties Trijumf and Balkan. Therefore, it followed that the maximum rupture force depended not only on seed size but also on the variety in question.

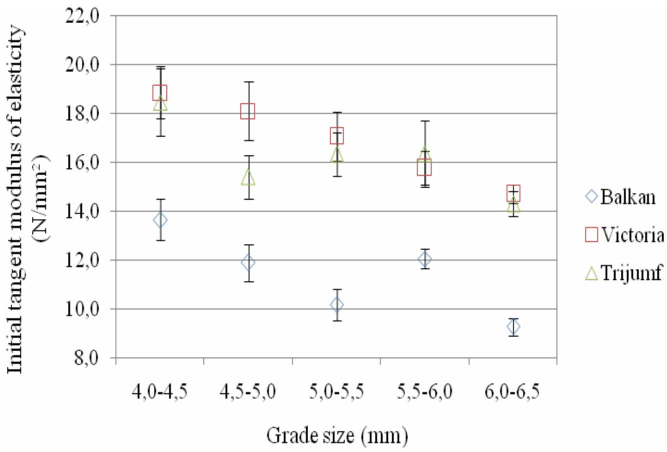

Fig. 1. Values of maximum rupture force (N)

This study confirmed the earlier observations from commercial production that the seed of the variety Balkan was sensitive to mechanical damage. Some authors *(Mehandžić-Stanišić et al., 2010)* found that the genotype influenced the maximum rupture force of seed in other crops too, while others attributed greater importance to seed moisture than to genotype *(Babić et al., 2011)*.

Lowest values of initial tangent modulus of elasticity were found in largest seed grades while highest values were observed in smallest grades (Figure 2). The lowest value of initial tangent modulus of elasticity, 9.26 N/mm^2, was observed in grade 6.0 to 6.5 mm of the variety Balkan, while the highest value, 18.84 N/mm^2, was recorded in grade 4.0 to 4.5 mm of the variety Victoria.

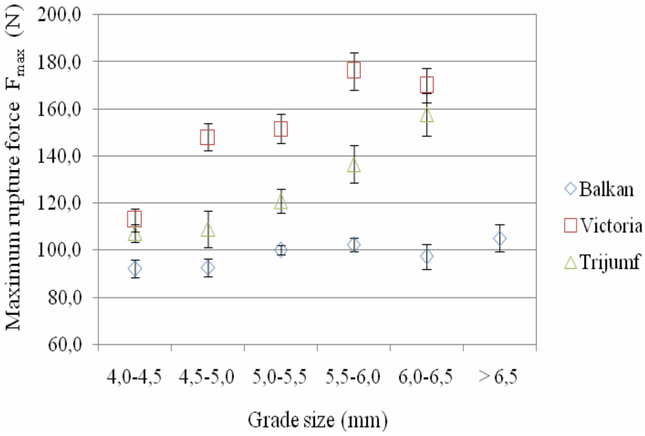

Fig. 2. Values of initial tangent modulus of elasticity (N/mm^2)

Opposite results were obtained by *Lončarević, (2012)*, that the value of the secant modulus of elasticity was higher in the variety Balkan than in the other tested varieties. As the smallest seed grades had highest values of initial tangent modulus of elasticity, the small-seeded variety Trijumf was expected to have most elastic seed. However, the obtained results showed that the variety Victoria had most elastic seed, suggesting that not only seed size but also the variety had a significant impact on the value of initial tangent modulus of elasticity.

CONCLUSION

Based on the results obtained in this study, it can be concluded that the grading of soybean seed can be done in quite a simple way. Soybean seed in this way is classified by physical characteristics. Lowest values of maximum rupture force were observed in smallest seed grades, highest values were observed in the largest grade. Specifically, the lowest values of maximum rupture force were recorded in the variety Balkan, the lowest were recorded in the variety Victoria. It can be stated that the variety Victoria is less sensitive to seed breakage than the varieties Balkan and Trijumf. The initial tangent modulus of elasticity had lowest values for the largest seed grade, while highest values were observed in the smallest grade. The highest value of initial tangent modulus of elasticity was recorded for the variety Victoria, the lowest for the variety Balkans. From the point of resistance to mechanical damage, the seed of the variety Victoria were more suitable for harvesting, storage and processing as compared with the seed of the varieties Trijumf and Balkan.

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