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Strength Properties of Horse Bean Seeds (*Vicia faba L var. minor*)

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Summary. The research results of the seed strength properties concerning three horse bean varieties are presented here. The investigation was carried out under quasistatic conditions by means of the apparatus Instron 4302. Individual horse bean seeds were placed with their cotyledons parallel to the apparatus base and loaded with plate, slat or penetrator. The maximum force values and corresponding to them deformation values capable of transporting a seed to the destruction moment have been read off from the obtained force-deformation characteristics. In the course of investigations, it was found out that the hardness features depended to a great extent on a given variety. It has been stated additionally that the increase of seeds moisture content causes a considerable decrease of their hardness.
Key words: horse bean, variety, strength properties.

INTRODUCTION

In Poland, where animal feeding is In 80% based on imported soya grits, the crucial problem is finding the alternating source of protein in animal feeding [10]. Oil industry products (rapeseed oil cake and press cake) as well as seeds of leguminous plants (e.g. lupine, horse bean and pea) are the domestic products which can replace soya bean having comparable protein content [9]. Horse bean seeds containing from 26% to 32% of the protein constitute a good component for the production of the feed mixture [11]. The protein from horse bean seeds is characterized by the high biological value and the wide usefulness for feeding. The interest in horse bean (*Vicia faba SPP. minor*) cultivation as a valuable feeding has developed in Poland and other countries with similar climate conditions [17].

The physical properties of seeds are to be known for design and improve of relevant machines and facilities for harvesting, storing, handling and processing [2, 5, 12, 13, 16]. A wide survey of literature shows small number of publications in the research work concerning horse bean seeds (*Vicia faba L. var. minor*) hardness. The investigations on this subject have been carried out only by few researches [4, 6, 7, 14, 18]. Only few papers deal with investigations of mechanical properties of (*Vicia faba L. var. major*) [1, 8]. Taking into consideration the fact that the knowledge of horse bean seeds hardness is indispensable in working out technological processes and preservation of machines necessary in their processing and allows to characterize the quality of material, and therefore it is well motivated to carry out the research work whose results aim at establishing the characteristics of horse bean seeds (*Vicia faba L. var. minor*). In measuring seed resistance loading by means of penetrators with different endings /in the shape of cylinder, cone, or semicircle/ has been used. Taking into account fact that in processing seed material into feed there is a wide use of a beater in which a working element differs in its shape from loading elements used in resistance measurements, it has been decided to carry out such investigations using a loading slat with blunt edge – an element similar in its shape to beater. The seed of loading plays an important role in all investigations concerning seed resistance that aim at reflecting the conditions approximating these in real life, while to carry out any investigations under such conditions is very difficult therefore measurements presented here have been carried out under quasistatic loading conditions.

The goal of this research work has been to determine hardness features of horse bean seeds having different moisture content under quasistatic loading of seeds with plate, slat and penetrator. Additionally, the results obtained enabled to comparison of the values of seed resistance measured by three different methods.

MATERIAL AND METHODS

The research work has been carried out on horse bean seeds of Dębek, Nadwiślański and Jasny varieties. In order to establish the influence of seeds moisture content and size on the investigated hardness features, the input material was humidified into eight moisture content levels in the range from 10 % to 24 % every ca 2 %, and then it was divided according to thickness. The seeds moisture contents were determined using the oven-drying method. Selected fraction of seeds with thickness from 7.0 to 8.0 mm was used for the compression experiments. For each moisture, 30 repetitions were done. The measurements of hardness features have been carried out by means of Instron 4302 apparatus equipped with head with a loading range 0-1.0 kN. Individual seeds have been placed with their cotyledons parallel to the lower stationary plate, and then, they were loaded by means of a disc, cutting slat 1 mm thick or a penetrator with a cylinder end with diameter 1,0 mm thick. Loading elements have been moving in all cases with a constant speed v = 10 mm·min^{-1} according to the standard proposition presented by Frączek et al [3]. The loading force operated along the seed thickness. The measurements have been carried out to the seed destruction moment i. e. splitting, cutting, or puncturing of seed coat. After that, they ended. The force curve as deformation functions were recorded. Then, the values of deformation forces for the seeds loaded with plate F_n, slat F_c or penetrator F_p were read from the obtained graphs together with the relative deformation values (e_n, e_c, e_p) corresponding to these forces. The deformation work for seeds loaded with plate (W_n), slat (W_c) and penetrator (W_p)was determined as the area below the curve in the force – deformation relation [15].

Statistical analysis of the data was performed with Statistica software (Statistica 6.1, StatSoft Inc., Tulsa, OK, USA) using analysis of variance for factorial designs. The significance of differences between mean values was determined using Fisher's exact test at a level of $p < 0.05$. The investigation parameters have been made to depend on moisture content and the obtained relations have been described by means of regression equation.

RESULT AND DISCUSSION

In Table 1 the minimal and maximum force values obtained by means of different methods of horse bean seed loading has been presented. The highest hardness value of seeds loaded by plate, slat and penetrator is characteristic of dry horse bean seed of Jasny variety. The lowest hardness value of seeds loaded by plate, slat and penetrator is characteristic of dry horse bean seed of Dąbek variety.

Table 1. Deformation force *F* values for horse bean seeds loaded by plate, slat and penetrator

Variety	Moisture content, %	Extreme value of forces F, N		
		plate loading	slat loading	penetrator loading
Dębek	10.1-23.9	156.1-445.2	48.2-199,1	20.4-212.2
Nadwiślański	10.4-23.8	148.2-554.3	53.4-279.9	26.2-342.4
Jasny	10.2-23.9	188.2-665.4	94.2-295.3	31.1-408.9

The greatest difference of force values occur in the case of horse bean seeds of Nadwiślański i Jasny variety loaded by penetrator. In this case maximum forces are nearly 13 times higher than the minimum ones. Much smaller differences between the maximum and minimum forces were observed in case of seeds loaded with a plate.

The changes of the values of deformation forces depending on seed moisture content were shown in Fig. 1, 2 and 3. The increase of seed moisture content causes a considerable decrease of their hardness.

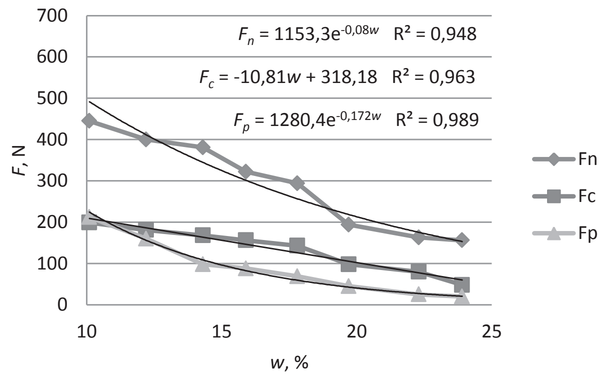

Fig. 1. The influence of moisture content (%) on deformation force for horse bean seed variety Dębek loaded by plate (F_n), penetrator (F_p) and slat (F_c)

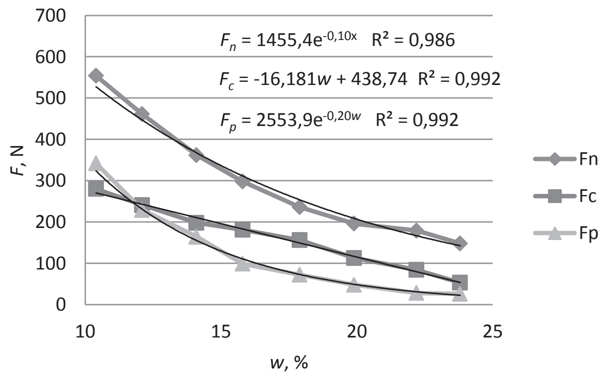

Fig. 2. The influence of moisture content (%) on deformation force for horse bean seed variety Nadwiślański loaded by plate (F_n), penetrator (F_p) and slat (F_c)

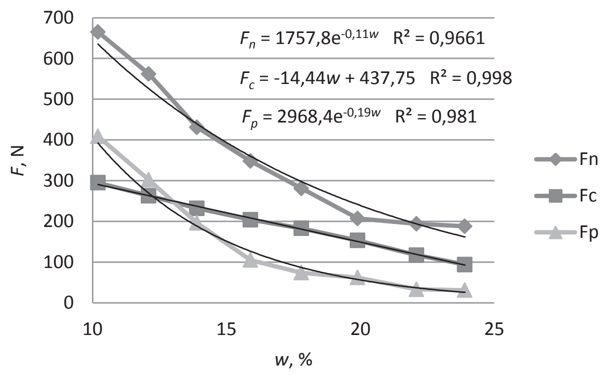

Fig. 3. The influence of moisture content (%) on deformation force for horse bean seed variety Jasny loaded by plate (F_n), penetrator (F_p) and slat (F_c)

In Table 2 the relative deformation values corresponding to the deformation force values obtained by seed loaded with plate, slat and penetrator have been presented. It has been stated that deformation values depend moisture content and horse bean variety. The highest deformation values in all loading cases have been obtained for horse bean seeds with about 24 % moisture content of Jasny variety.

Table 2. Relative deformation *e* values for horse bean seeds loaded by plate, slat and penetrator

Variety	Moisture content, %	Min-max value of relative deformation *e*, %		
		plate loading	slat loading	penetrator loading
Dębek	10.1-23.9	4.9-26.4	5.1-22.9	4.8-14.2
Nadwiślański	10.4-23.8	5.6-25.6	6.8-24.1	5.2-14.4
Jasny	10.2-23.9	5.2-25.6	6.9-26.9	6.8-17.2

For all the varieties, the increase of seed moisture content causes the increase of deformation values and the maximal values are 3-5 times higher than minimal. The lowest values of the relative deformation were obtained for seeds loaded with the penetrator. The changes of the values of relative deformation depending on seed moisture content were shown in Fig. 4, 5 and 6. In each case the increase in moisture content of seeds causes the increase in the relative deformation values.

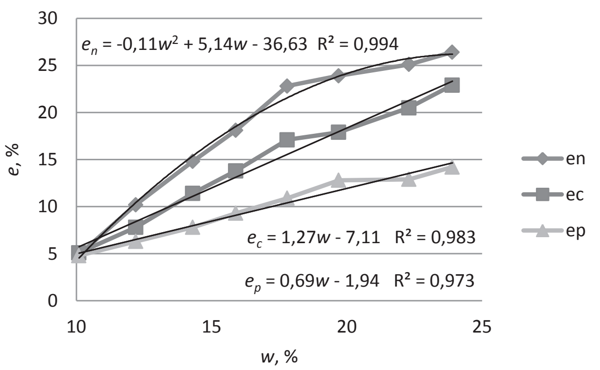

Fig. 4. The influence of moisture content (%) on relative deformation *e* for horse bean seed variety Dębek loaded by plate (e_n), slat (e_c) and penetrator (e_p)

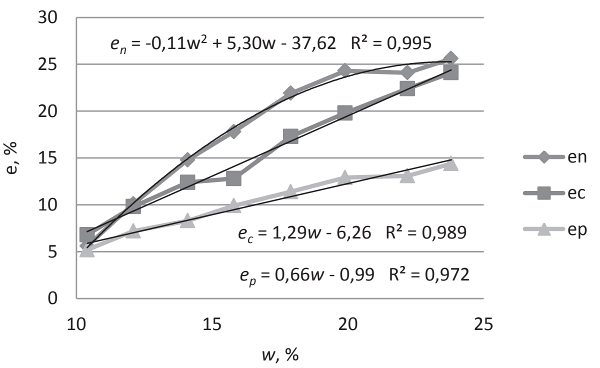

Fig. 5. The influence of moisture content (%) on relative deformation *e* for horse bean seed variety Nadwiślański loaded by plate (e_n), slat (e_c) and penetrator (e_p)

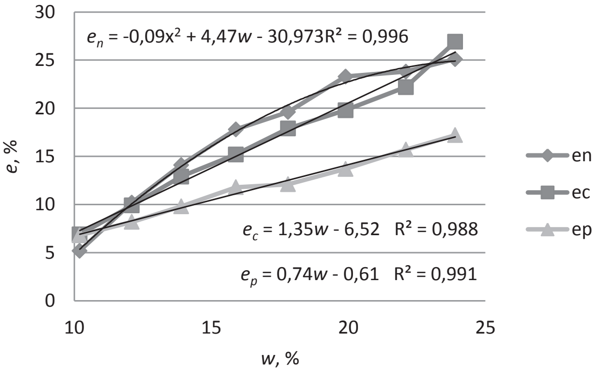

Fig. 6. The influence of moisture content (%) on relative deformation *e* for horse bean seed variety Jasny loaded by plate (e_n), slat (e_c) and penetrator (e_p)

In Table 3 the work of deformation values obtained by seed loaded with plate, slat and penetrator have been presented. It has been stated that the work of deformation values depend on moisture content of seeds and horse bean variety. The biggest differences between the minimum and maximum values of the deformation work were observed in case of the penetrometric test.

Table 3. Work of deformation *W* values for horse bean seeds loaded by plate, slat and penetrator

Variety	Moisture content, %	Min-max value of work of deformation *W*, J		
		plate loading	slat loading	penetrator loading
Dębek	10.1-23.9	0.053-0.221	0.211-0.681	0.007-0.051
Nadwiślański	10.4-23.8	0.112-0.292	0.212-0.821	0.024-0.084
Jasny	10.2-23.9	0.093-0.231	0.223-0.912	0.022-0.141

The changes of the values of relative deformation depending on the seed moisture content were shown in Fig. 7, 8 and 9. In case of seeds loaded with plate and slat the value of deformation work gradually increases with the increase in moisture content of seeds and after reaching the maximum it slightly decreases. In case of the penetrometric test the increase in seed moisture causes the constant gradual decrease in work deformation value.

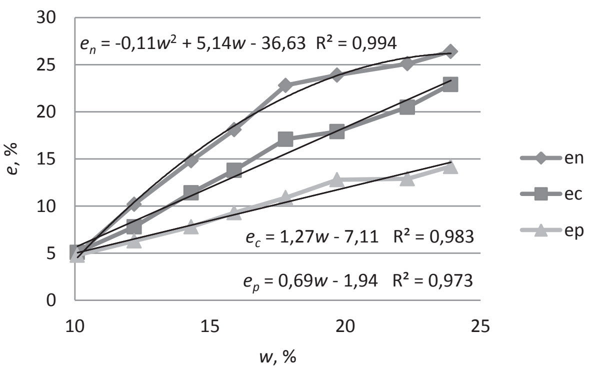

Fig. 7. The influence of moisture content (%) on the work of deformation for horse bean seed variety Dębek loaded by plate (W_n), penetrator (W_p) and slat (W_c)

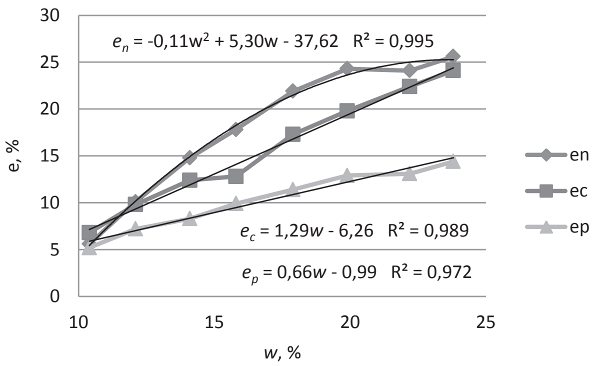

Fig. 8. The influence of moisture content (%) on the work of deformation for horse bean seed variety Nadwiślański loaded by plate (W_n), penetrator (W_p) and slat (W_c)

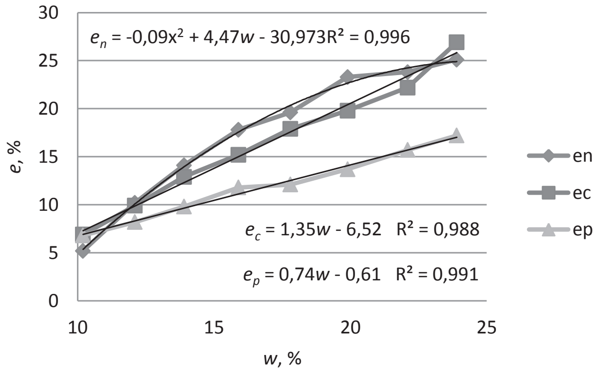

Fig. 9. The influence of moisture content (%) on the work of deformation for horse bean seed variety Jasny loaded by plate (W_n), penetrator (W_p) and slat (W_c)

The carried out analysis shows that using only one test in seed strength tests may not be enough. It is essential especially in case of the measurement of deformation work of loaded seeds. Different relationship between deformation work and seed moisture is observed depending on the test. In case of deformation strength and relative deformation, however, different scope and dynamics of the change with the increase in seed moisture depending on the used strength test was noticed.

CONCLUSIONS

The carried out investigations concerning hardness allow to formulate the following conclusions:

1. Deformation force, relative deformation and work of deformation depend on horse bean variety.
2. In the case of the all used tests the increase of seeds moisture content causes a considerable change of their strength properties.
3. The increase in seed moisture causes the significant decrease in the value of deformation strength. The dependence between the deformation strength and seed moisture was described by exponential equations in case of loading the seeds with the plate and penetrator and by linear equations in case of seeds loaded with the slat.
4. The increase in seed moisture causes the significant increase in relative deformation value. The dependence between the relative deformation and seed moisture was described with the linear equation in case of seeds loaded with the slat and penetrator and with quadratic equations in case of loading the seeds with the slat.
5. In case of seed loaded with the plate and slate the increase in seed moisture causes the gradual increase in deformation work and after reaching the maximum the decrease in its value. In case of the penetrometric test increase of seeds moisture content causes a considerable decrease of deformation force. The dependence between the deformation work and seed moisture was described by quadratic equations in case of seed loaded with the plate and slat and by exponential equations in case of penetrometric test.
6. The choice of strength test influences the scope and dynamics of changes of seed resistance for mechanical loading. Thus, to describe fully the changes of seed resistance for mechanical loading it is advisable to use the results obtained in different strength tests.

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WŁAŚCIWOŚCI WYTRZYMAŁOŚCIOWE NASION BOBIKU (*VICIA FABA L. VAR. MINOR*)

Streszczenie. W pracy przedstawiono wyniki dotyczące badań właściwości wytrzymałościowych nasion trzech odmian bobiku. Badania przeprowadzono w warunkach obciążeń quasistatycznych przy użyciu maszyny wytrzymałościowej Intron 43002. Nasiona umieszczano liścieniami równolegle do podstawy urządzenia a następnie obciążano przy pomocy płyty, noża i penetratora. Z wykresu siła-przemieszczenie wyznaczono maksymalną siłę prowadzącą do zniszczenia nasiona, odpowiadającą jej przemieszczenie i pracę deformacji. Wykazano, że wytrzymałość nasion istotnie zależy od odmiany. Stwierdzono, że wzrost wilgotności nasion powoduje wyraźny spadek ich wytrzymałości mechanicznej.

Słowa kluczowe: bobik, odmiana, właściwości wytrzymałościowe.