POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2003, Vol. 12/53, No 2, pp. 9–13

PHYSICAL PROPERTIES OF SELECTED LEGUME SEEDS AS INDICATORS OF TECHNOLOGICAL SUITABILITY OF SMALL-SEED BROAD BEAN

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Key words: broad bean seeds, hardness, water-holding capacity, technological value

Selected physical properties of small-seed broad bean varieties, determining their technological value, were studied. Seeds of small-seed broad bean varieties Gobik and Goral were used as the experimental material. Large-seed varieties Batom and Windsor Biały and seeds of three edible pea varieties: Albatros, Karat, Miko, were used for comparison. The studies included the determination of: 1000 seeds mass, percentage of seed coats, seed hardness before and after soaking, and water-holding capacity. Due to their physical properties, small-seed varieties of broad bean resemble pea more than its large-seed varieties. Small-seed varieties, compared with large-seed ones, show smaller differences in mechanical resistance and better water-holding capacity, which makes them more suitable for technological processing.

INTRODUCTION

Among leguminous plants, pea is commonly used for consumption purposes, whereas the use of broad bean is limited. This is caused by low mechanization of technological processes, especially as regards harvest and production line processing. New opportunities were provided by small-seed varieties of broad bean. The studies conducted so far concerned raw material at the stage of milk ripenes. There is scant information on the possibilities of using it at the stage of full physiological maturity. New varieties can be accepted as fully valuable raw material for the production of foodstuffs on the basis of a complex evaluation of their physical, chemical and nutritive properties.

Among physical properties of leguminous plant seeds, important quality parameters are: 1000 seed mass, size, colour, and shape. They allow to distinguish between particular species, as well as between varieties within a species. Mechanical resistance of seeds is a physical property which may – to a certain extent – determine the parameters of the technological process and affect the reological properties of the final product.

Soaking of leguminous plant seeds is the initial stage of most technological processes in this group of raw materials. Proper selection of soaking conditions is important, as it affects the “behaviour” of seeds during further processing, as well as the nutritive and sensory quality of the final product. The amount of water absorbed by seeds during soaking decides about protein denaturation and the degree of starch granule gelatinization during heat treatment. That is why it is one of the most important factors determining good seed texture [El-Tabey-Shehata, 1992; Reyes-Moreno & Paredes, 1993; Sadowska *et al.*, 1996; Youssef *et al.*, 1982]. Water absorption kinetics during seed soaking determines the optimum time of this process.

The paper presents selected physical properties of small-seed varieties of broad bean in terms of their technological value.

MATERIAL AND METHODS

Seeds of Polish small-seed broad bean varieties Gobik and Goral were used as the experimental material. Large--seed varieties Bartom and Windsor Biały and seeds of three edible pea varieties: Albatros, Karat and Miko, were used for comparison. In the case of pea varieties, the criterion of choice were differences between them concerning their cookability [Borowska *et al.*, 1998]. The raw material were seeds at the stage of full physiological maturity.

The studies included determination of: 1000 seed mass, mass fraction of seed coat and cotyledon, seed hardness before and after soaking, and water-holding capacity.

Determination of the percentage of seed coat-mass fraction of seed coat and cotyledon. The percentage by mass of particular morphological seed parts was determined on the basis of the mass of: seeds before hulling, cotyledons and seed coats.

Determination of seed hardness. Hardness of dry seeds and seeds subjected to soaking was determined as maximal force-displacement required to crush seeds by a penetration test, applying a machine for resistance testing INSTRON 4301.

The specifications of test and universal testing machine Instron 4301 were as follows: load cell capacity – 1 kN; crosshead speed – 3 mm/min; displacement – 4 mm; conical indenter, with face angle of 53°10’.

The determinations were made in 20 replications at ambient temperature of 22–23°C and relative humidity of 50%.

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The results obtained were analyzed by means of software INSTRON SERIES IX AUTOMATED MATERIALS TESTING SYSTEM VER. 8.04.

Soaking of seeds. Two methods of soaking were applied for both broad bean and pea seeds: traditional cold soaking (in water at room temperature) and hot soaking.

a) Traditional cold seed soaking

Seeds were covered with water, at water to raw material ratio of 3:1 (v:w). Broad bean seeds were left at room temperature for 9, 12 and 18 h. Pea seeds, following the results of previous investigations [Borowska *et al.*, 1998], were soaked for 9 h. After that time, the seeds were separated from the remaining (non-absorbed) water on a sieve, dried on absorbent paper and weighed to determine their water-holding capacity.

b) Hot seed soaking

Seeds were covered with boiling water, at water to raw material ratio of 3:1 (v:w), and left at room temperature for 2 h. The procedure of determining their water-holding capacity was the same as described above.

Determination of the water-holding capacity of seeds [Hincks & Stanley, 1986]. The degree of water absorption by seeds was determined for all of the soaking variants applied.

The results were analysed statistically employing a one-factor analysis of variance. The significance of differences was estimated by the Duncan's test. The Pearson's coefficient of correlation was determined for selected properties. Statistical analysis was made at the significance level of p = 0.05.

RESULTS AND DISCUSSION

Morphological characteristics, 1000 seed mass

The local small-seed broad bean varieties analyzed in the paper, *i.e.* Gobik and Goral, differed considerably in size and shape, compared with large-seed varieties – Bartom and Windsor Biały. The 1000 seed mass was similar for Gobik and Goral (706 g and 678 g, respectively) (Table 1), placing them between large-seed broad bean varieties and pea varieties.

It should be emphasized that small-seed broad bean varieties were characterized by similar shapes, resembling the shape of pea seeds. This is a very desirable trait, making mechanization of seed processing much easier.

Coat colour is another important feature affecting the sensory quality of broad bean products, especially if seeds are not hulled in the technological process. Seed coats of Gobik and Goral varieties were gray-beige, similar to the colour of pea seeds. Seed coats of large-seed varieties were much darker – dark brown or brown. Therefore, this trait can have a significant effect on consumer's acceptance of the product. It follows that in the case of Bartom and Windsor Biały varieties, seed hulling could affect positively their colour, but with 14% share of coats (Table 1) the hulling process might decrease the productivity of raw material to a much higher degree that in the case of small-seed broad bean varieties or pea.

TABLE 1. Mass of 1000 seeds and mass fraction of seed coat and cotyledon and share of shell in the studied varieties of bean and peas.

Variety	1000 seeds mass [g]	Percentage of	
		Coat	Cotyledon
Gobik	706	11.47	88.53
Goral	678	12.68	87.30
Bartom	1392	13.78	86.22
Windsor Biały	1920	14.09	85.91
Albatros	268	10.51	89.49
Karat	255	10.23	89.77
Miko	210	10.64	89.36

Water-holding capacity of seeds

In each of the four variants of soaking, broad bean and pea seeds differed significantly in the amount of water absorbed (Table 2). The 9-h soaking recommended for pea suggests high water-holding capacity of this species (74.79–86.76%). It was much lower in the case of small-seed varieties of broad bean (37.29% and 49.01%), and the lowest (5.95% and 9.32 %) in that of its large-seed varieties. Better water-holding capacity of pea seeds, compared with broad bean seeds, was also reported by other authors [El-Moniem *et al.*, 2000]. This indicates the need to extend the time of broad bean soaking according to the traditional method. Broad bean seeds are characterized by thicker coats, which – following other authors [Sefa-Dedeh & Stanley, 1979] – decides about the amount of water absorbed in the first hours of soaking. It should be noted that seeds of the pea varieties examined in the present

TABLE 2. Water holding capacity [%].

Variety	Traditional cold soaking						Hot soaking	
	9 h		12 h		18 h		2 h	
	x	$\hat{S}$	x	$\hat{S}$	x	$\hat{S}$	x	$\hat{S}$
Gobik	49.01^{aA}	0.190	67.44^{aB}	0.140	80.42^{aC}	0.060	54.58^{aD}	0.290
Goral	37.29^{bA}	0.060	56.02^{bB}	0.130	79.62^{bC}	0.453	47.17^{bD}	0.030
Bartom	9.32^{cA}	0.080	10.68^{cB}	0.130	29.99^{cC}	0.160	35.56^{cD}	0.160
Windsor Biały	5.95^{dA}	0.150	9.31^{dB}	0.090	14.32^{dC}	0.230	35.91^{dD}	0.180
Albatros	74.79^{eA}	0.170					68.08^{eB}	0.170
Karat	78.35^{fA}	0.100					72.07^{fB}	0.135
Miko	86.76^{gA}	0.070					79.51^{gB}	0.150

x – mean value; $\hat{S}$ – standard deviation. The values whith the same small letter in a column or the same capital letter in a line do not indicate statistically significant differences at p=0.5.

studies show a medium level of water absorption, compared with its other varieties [Borowska *et al.*, 1998].

Extending the time of seed soaking to three and nine hours caused a significant increase in the water-holding capacity of the broad bean varieties analyzed (Figure 1, Table 2). Water absorption intensity between the 9th and 12th hour of seed soaking was similar in Gobik and Goral varieties, and highly differentiated in large-seed varieties. When the time of seed soaking was again extended by six hours (to 18 h), the water-holding capacity increased by 19% in Gobik and 180% in Bartom variety. The water-holding capacity of large-seed broad bean varieties increased considerably between the 9th and 18th hour of soaking, but it was still lower than the water-holding capacity of small-seed varieties, which was comparable with the values noted for pea seeds after nine hours of soaking.

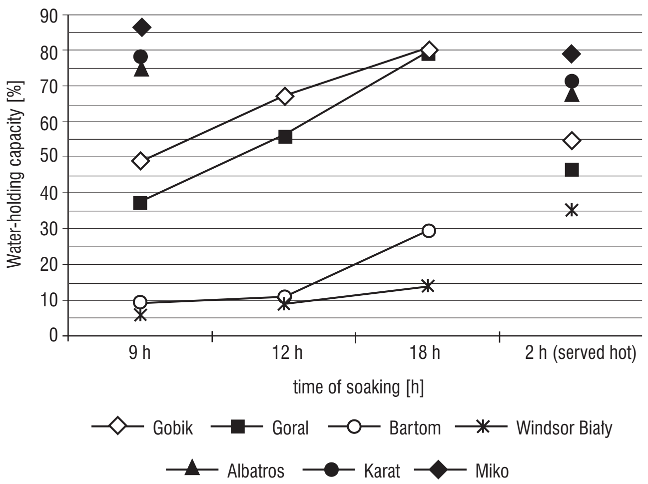

FIGURE 1. Water-holding capacity.

Apart from traditional cold soaking, also the method of hot soaking was applied in the studies. In this case the water-holding capacity of broad bean seeds varied from 35.56% to 54.58% after two hours (Table 2). For small-seed varieties, these values corresponded to the water-holding capacity observed between the 9th and 12th hour of traditional soaking, and were higher than those obtained for Bartom and Windsor Biały varieties. As to pea, its water-holding capacity was lower in the case of this method than in that of traditional soaking. However, the results of other studies show that this method allows shortening the time of seed soaking in leguminous plants, assuring equally high water absorption as in the case of traditional soaking [Waszkiewicz-Robak & Świderski, 1991].

In all soaking variants small-seed varieties Gobik and Goral were characterized by better water-holding capacity than large-seed varieties Bartom and Windsor Biały. A faster rate of water absorption by small-seed broad bean allows shortening the time of its soaking. The method of hot soaking may be recommended rather for small-seed broad bean varieties than for the other varieties examined in the experiment.

Mechanical resistance of dry seeds and changes in seed hardness during soaking

Mechanical resistance tests of broad bean and pea seeds, made by means of INSTRON, show that their resistance is species-dependent. Resistance expressed by force causing destruction was much higher for both small-seed and large-seed varieties of broad bean than for pea. As concerns broad bean, the Gobik variety was characterized by the lowest resistance, and the Windsor Biały variety – by the highest one. The average values of force causing seed structure destruction were: 0.258 and 0.442 kN, respectively. There were statistically significant differences between broad bean varieties, except for Gobik and Bartom (Table 3). It should be stressed that the mechanical resistance of small-seed varieties Gobik and Goral was at a similar level, which may facilitate parameter selection in the technological process and allow to obtain products with the same quality standards. Large-seed varieties were characterized by considerable differences (especially Windsor Biały). The mechanical resistance of pea varieties – Albatros, Karat and Miko varied from 0.110 to 0.122 kN (Table 3).

The differences in mechanical resistance noted between the species and varieties examined in the present studies are consistent with the results of previous investigations concerning seeds of leguminous plants [Borowska *et al.*, 1996 b; Sadowska *et al.*, 1994].

The humidity of raw material was at a similar level, *i.e.* Gobik – 11.31%, Goral – 10.55%, Bartom – 12.53%, Windsor Biały – 10.92%, Albatros – 12.16%; Karat – 11.31%, Miko – 12.27%, but seeds were characterized by different hardness, which is undoubtedly a variety-dependent trait, affecting water absorption at next stages of processing. In the case of traditional soaking, the highest changes in seed hardness were observed for most broad

TABLE 3. Maximal force-displacement required to crush seeds by penetration test.

Variety	Dry seeds		Traditional cold soaking						Hot soaking	
			9 h		12 h		18 h		2 h	
	x	Ŝ	x	Ŝ	x	Ŝ	x	Ŝ	x	Ŝ
Gobik	0.258^{aA}	0.0525	0.022^{aB}	0.0103	0.015^{aB}	0.0031	0.021^{aB}	0.0492	0.018^{aB}	0.0085
Goral	0.38^{2bA}	0.0571	0.044^{aB}	0.0268	0.015^{aC}	0.0045	0.020^{aBC}	0.0044	0.023^{aBC}	0.0120
Bartom	0.374^{bA}	0.0585	0.234^{bC}	0.1579	0.354^{bA}	0.1104	0.018^{aB}	0.0054	0.090^{bB}	0.0834
Windsor Biały	0.442^{cA}	0.1001	0.336^{cC}	0.0899	0.392^{bAC}	0.1142	0.377^{bAC}	0.1305	0.171^{cB}	0.1123
Albatros	0.122^{dA}	0.0309	0.016^{aC}	0.0301					0.006^{aB}	0.0015
Karat	0.114^{dA}	0.0343	0.017^{aC}	0.0020					0.006^{aB}	0.0016
Miko	0.119^{dA}	0.0290	0.015^{aC}	0.0026					0.005^{aB}	0.008

x – mean value; Ŝ – standard deviation; The values whith the same small letter in column or the same capital letter in line do not indicate statistically significant differences at p=0.5.

bean varieties during the first nine hours (Table 3). Despite considerable differences in seed hardness, the mechanical resistance of varieties Gobik and Goral, and pea, did not differ much after this period of time. Soaked seeds of small--seed broad bean varieties were characterized by Figures 2, 3, 4. In the case of these varieties, extended time of seed soaking had an inconsiderable effect on changes in hardness, expressed by penetration force. There were no statistically significant differences in the mechanical resistance of seeds of these varieties after 9-h and longer soaking (Table 3).

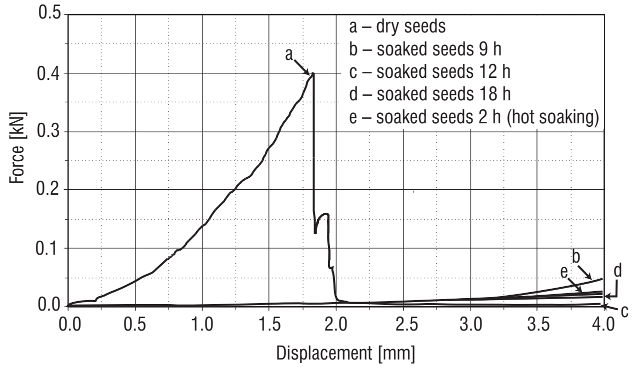

FIGURE 2. Typical force-displacement curves for broad bean of Goral variety.

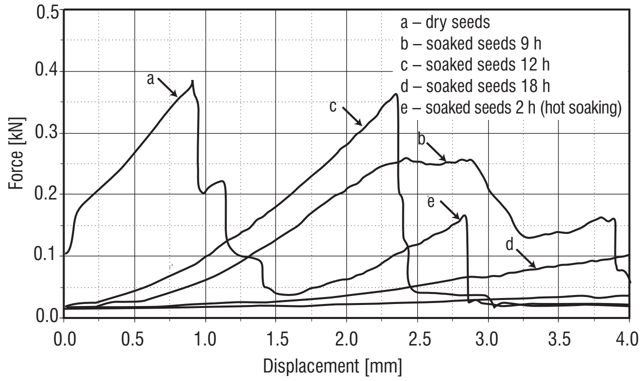

FIGURE 3. Typical force-displacement curves for broad bean of Bartom variety.

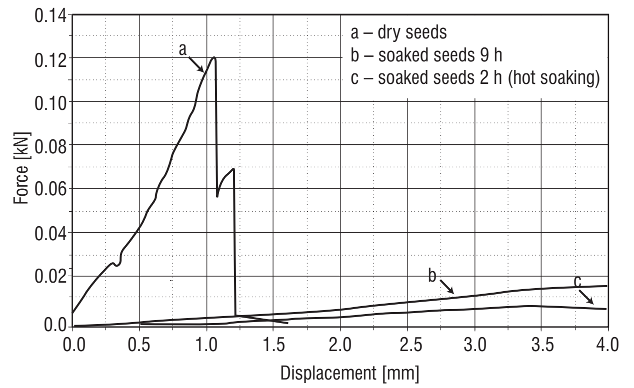

FIGURE 4. Typical force-displacement curves for pea of Albatros variety.

Multi-directional changes were noted in the hardness of seeds of large-seed broad bean varieties as the time of soaking was extended. In contrast to small-seed varieties and pea, the diagrams illustrating the hardness of soaked seeds of large-seed varieties indicate their rather tender structure, similar to that of dry seeds (*e.g.* Figures 2, 3, 4). After 18-h seed soaking the hardness of seeds of small-seed broad bean varieties and the Bartom variety did not differ significantly. The extension of soaking time did not affect considerably the hardness of seeds of the Windsor Biały variety.

The 2-h hot seed soaking of seeds resulted in distinct changes in the mechanical resistance of all varieties of both species (Table 3). In this soaking method, changes in the hardness of seeds of small-seed broad bean were comparable with those observed during 9-h and 12-h traditional cold soaking. The hardness of seeds of small-seed broad bean and pea, soaked under these conditions, did not differ much. The situation was different in large-seed varieties. The mechanical resistance of the Bartom variety did not differ significantly from its resistance determined after 18-h traditional soaking. In both variants the seed structure changed from tender to plastic. The hardness of seeds of the Windsor Biały variety was significantly lower than after traditional soaking, but these seeds were characterized by a high degree of tenderness. Hot soaking of pea seeds resulted in a considerable decrease in hardness, compared with traditional soaking, preserving species homogeneity (Table 3). In spite of certain dependence between the water-holding capacity and hardness of seeds, there was no statistically significant correlation between them (Table 4).

TABLE 4. Estimation of significant correlation between the water--holding capacity and hardness of seeds.

Variety	Correlation calculated	Critical correlation	Qualification correlation
Gobik	0.5441	0.8997	–
Goral	-0.6554	0.8997	–
Bartom	-0.8622	0.8997	–
Windsor Biały	-0.8937	0.8997	–
Pea	0.3200	0.7267	–

"–" not statistically significant correlation

Analysis of changes in the water-holding capacity and hardness of seeds shows that in the case of small-seed varieties Gobik and Goral the time of cold soaking should not exceed 12 hours. Seeds of the Bartom variety require 18 h of soaking, which is still too short for the Windsor Biały variety. This process may be shortened if the method of hot soaking is employed, especially in the case of small-seed varieties.

CONCLUSIONS

1. Small-seed broad bean varieties Gobik and Goral, compared with large-seed varieties, are characterized by better (in terms of technological processing) physical properties, such as: 1000 seeds mass, a more regular shape – similar to the shape of pea seeds, a light colour of seed coats, and a similar level of mechanical resistance.

2. Small-seed varieties show also better water-holding capacity, confirmed by changes in the mechanical resistance of seeds. These varieties require shorter soaking than large--seed ones, and hot soaking may be an alternative for them, as it allows reducing the time of this process to two hours.

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Received April 2002. Revision received October 2002 and accepted December 2002.

CECHY FIZYCZNE WYBRANYCH NASION STRĄCZKOWYCH JAKO WYRÓŻNIKI PRZYDATNOŚCI TECHNOLOGICZNEJ NASION BOBU ODMIAN DROBNONASIENNYCH

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W pracy badano nasiona drobnonasiennych odmian bobu pod względem wybranych właściwości fizycznych warunkujących ich przydatność technologiczną. Surowcem do badań były nasiona odmian drobnonasiennych Gobik i Goral a porównawczo nasiona odmian wielkonasiennych Bartom i Windsor Biały oraz nasiona trzech jadalnych odmian grochu: Albatros, Karat, Miko. Badania obejmowały określenie: masy 1000 nasion, udziału okrywy nasiennej, twardości nasion przed i po procesie moczenia oraz wodochłonności. Drobnonasienne odmiany bobu pod względem badanych cech fizycznych są bardziej porównywalne z grochem aniżeli z wielkonasiennymi odmianami bobu. Mniejsze zróżnicowanie wytrzymałości mechanicznej nasion tych odmian oraz lepsza wodochłonność w porównaniu z surowcem wielkonasiennym czyni je korzystniejszymi dla przetwórstwa.