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PHYSICOCHEMICAL PROPERTIES DETERMINING THE COOKING TIME OF PEA (*PISUM SATIVUM* L.) SEEDS

ABSTRACT

Undamaged pea seeds of Agra, Wenus, Kwestor, Bursztyn, Rola, Turkus, Set, Kujawski and Ramrod cultivars divided into 3 size fractions were evaluated for physicochemical properties, the rate of fresh weight increments, leachate electroconductivity as well as cooking time. In Kujawski, Turkus, Bursztyn and Ramrod cultivars or in the case of small seeds, the mean fresh weight increments during seed incubation in water were greater, while in Set and in the case of large seeds, the increments were smaller. Seed leachates in Bursztyn showed the highest, while in Set – the lowest electroconductivity; besides, electrolyte leaching from small seeds was only a little bit greater than from the large ones. The greatest convergence of the fresh weight increment rate and the results of the electroconductivity test and the cooking time was found after 2 and 24 hours of seed incubation in water. Bursztyn seeds cooking time was shortest, while that of Rola seeds, with one of the thickest seed coats, highest share of coat in the seed weight and the highest seed fiber content, was longest. Seeds of Set cultivar required a long cooking time due to a close proximity of seed coat to cotyledons. No significant correlations were found between the cooking time and the physicochemical properties, except for the share of seed coat and the fiber content in seeds; the greater the share and the content, the longer the cooking time.

Key words: cooking time, pea cultivars, physicochemical properties of seeds

INTRODUCTION

Over the last few years there has been observed a regular decrease in legume seed consumption in Poland (Prusiński and Kotecki 2006) and in the world (Champ 2001). However, it is well-known that legume seeds are an extremely precious diet component due to their high nutritive value and the content of anti-nutritional compounds, so far considered harmful for people but, in fact, having a great effect on limiting diseases of civilization (Soral – Śmietana and Krupa 2005).

The pea seed nutrients are dominated by starch, which accounts for more than a half of dry matter. The contents of protein and fiber are also high. The direct dry pea seeds consumption applicability is mostly determined by cooking time. Cultivars whose seeds imbibe fast and more in water are considered by

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the Centre for Cultivar Testing (COBORU) as also capable of cooking faster (Dolata and Wiatr 2004, Wiatr 2002). The literature offers reports on pea seed cooking time in automated Mattson cooker apparatus, which records the time needed to prick a single cooked seed (Wang and Daun, 2005). The results of the test well coincide with the organoleptic evaluation of seeds. Also this method shows that pea (Savage *et al.* 2001, Wang *et al.* 2003) and bean (Boros 2003) seed cooking time decreases with an increase in the imbibition rate.

The properties conditioning legume seed cooking time, reported in literature, include seed coat color and the proximity of seed coat to cotyledons (Powell 1989), seed coat permeability (Black *et al.* 1998), thickness (Wang *et al.* 2003) and fiber content (Panobianco *et al.* 1999) as well as seed damage and initial water content (Prusiński 1997). The imbibition process is accompanied by organic substance leaching, dependent on seed maturity and deterioration and also the degree of mechanical and imbibition damage (Prusiński 1997, Prusiński and Borowska 1996).

The research hypothesis assumes that pea cultivars differ in their cooking quality, especially in cooking time. The aim of the present study was to determine the seed-fractionated cooking time of 9 pea cultivars which can result from seed size as well as physicochemical properties of seeds and seed coats.

MATERIAL AND METHODS

The experiment involved mechanically undamaged pea seeds of 9 cultivars: Agra, Wenus, Kwestor, Bursztyn, Rola, Turkus, Set, Kujawski and Ramrod, harvested in 2003. The two-factor lab experiment was carried out with 2 kg seed samples of each cultivar. All the seeds whose seed coat wrinkled over 15-20 minutes of soaking in water were regarded as damaged and eliminated from further study. The seed samples were fractionated with the automatic sorter, depending on the seed thickness, into 3 fractions: small seeds < 6.0 mm thick, medium 6.0 – 6.4 mm thick and large > 6.5 mm thick.

The following parameters were determined for each fraction:

1. physical properties, i.e.

— 1000 seed weight – 500 seeds were counted and weighted and the result was multiplied by 2,

— seed coat thickness in four 50-seed samples – the seed coat was removed from slightly imbibed seeds with the scalpel and the thickness was measured, each time in the centre of the coat, with the micrometer; the results are given in mm,

— seed coat share in seed weight;

2. chemical composition, i.e.

— starch content in seeds with polarimetric method, according to the Official Methods of Seed Analysis, 12th ed., Washington, USA (AOAC 1975), modified in order to separate monosaccharides earlier and hot hydrolysis; the

starch content was determined in 3 reps, with 4.95 multiplier and expressed in% of dry matter,
— content of N with the Kjeldahl method,
— fiber content in seeds and seed coat with Hanneberg and Stohmann method;
3. seed coat permeability and embryo condition, i.e.
— imbibition rate in distilled water at 20°C – four 50-seed samples were weighted after 15, 30, 60 minutes and after 2, 4, 8 and 24 hours of imbibition; the results are given as the percentage of fresh weight increments,
— electroconductivity of seed exudates – four 50-seed samples were incubated in 250 ml of distilled water at 20°C; electroconductivity was measured with Radelkis OK 104 conductometer after 15, 30, 60 minutes and after 2, 4, 8 and 24 hours and expressed as $\mu S \times cm^{-1} \times g^{-1}$ of fresh seeds.
4. seed cooking time
— 14 g of seeds of each cultivar and each fraction were cooked in 140 ml of distilled water in the cylinder, weighted down with 140 g weight, in BZ-3 viscometer (Madajewski *et al.* 1983); the operation of the viscometer involves an increase in temperature by 1.5°C per minute from 20 to 95°C and a constant recording of the weight indications on the record tape. The seeds were considered to be cooked when the weight demonstrated the same level on the record tape as the one at the test start; the results are given in minutes needed for seed cooking.

Results of all the tests were statistically verified with variance analysis for completely randomized blocks with the Tukey test at $\alpha = 0.05$.

RESULTS

As a result of fractionating of four-500 g seed samples of nine cultivars, three seed fractions were obtained. The small seeds < 6.00 mm thick accounted for 30.2% of the sample, the share of medium seeds (6.0 - 6.4 mm thick) was 41.2%, while the share of large seeds (> 6.5 mm) – 28.6%.

Mean 1000 pea seed weight amounted to 270 g; in Ramrod the 1000 seed weight was significantly highest, while in Wenus, Agra and Bursztyn – lowest (Table 1). Each time the sieve mesh size was increased, the 1000 seed weight increased significantly for all the cultivars studied. Mean seed coat thickness was 0.18 mm. The significantly thinnest seed coat was found in Agra seeds (Turkus, Set and Ramrod, with slightly but non-significantly thicker coats, constituted a homogenous group); the thickest coats, 29% thicker than in Agra, were found in Wenus and Rola. In large seeds, the thickness of seed coat was significantly higher than in medium and small ones. Mean share of seed coat in seed weight accounted for 8.43% and was highest both in Set and Kujawski cultivars, while in Kwestor and Agra – lowest. The greater the seed thickness, the lower the share of the seed coat.

As given in Table 2, the lowest starch content was found in Rola seeds, while the highest – in Ramrod seeds. Less than 60% of starch was also recorded in

Table 1

Physical properties of pea seeds

Cultivars	1000 seed weight [g]	Seed coat thickness [mm]	Share of seed coat [%]
Agra	240 de	0.15 e	7.90 de
Wenus	235 e	0.21 ab	8.17 cd
Kwestor	254 d	0.18 cd	7.75 e
Bursztyn	246 de	0.19 bc	7.91 cde
Rola	277 c	0.21 ab	8.83 b
Turkus	253 d	0.17 cde	8.31 c
Set	298 b	0.16 de	9.40 a
Kujawski	295 b	0.18 cd	9.53 a
Ramrod	328 a	0.17 cde	8.05 cde
Seed fractions			
Small	229 C	0.18 B	8.79 A
Medium	271 B	0.18 B	8.37 B
Large	308 A	0.19 A	8.14 C

Means followed by the same lower-case letters for cultivars and the capital ones for seed fractions did not differ significantly at $\alpha = 0.05$

Table 2

Chemical composition of pea seeds, % of dm

Cultivars	Starch content	N content	Fiber content in seeds	Fiber content in coats
Agra	57.7 d	3.50 c	4.38 c	51.4 cd
Wenus	62.0 b	3.18 f	4.69 b	55.7 b
Kwestor	58.5 cd	3.29 e	5.07 a	54.0 b
Bursztyn	59.5 c	3.70 a	4.80 ab	54.7 b
Rola	56.1 e	3.57 b	5.17 a	57.7 a
Turkus	59.2 c	3.59 b	4.73 b	52.5 c
Set	59.3 c	3.41 d	4.61 b	51.8 cd
Kujawski	59.1 c	3.56 b	4.35 c	48.3 d
Ramrod	63.4 a	3.41 d	4.02 d	48.8 d
Seed fractions				
Small	59.2 A	3.43 B	4.87 A	52.8 A
Medium	59.5 A	3.44 B	4.52 B	52.9 A
Large	59.5 A	3.52 A	4.55 B	52.7 A

Means followed by the same lower-case letters for cultivars and the capital ones for seed fractions did not differ significantly at $\alpha = 0.05$

Agra, Kujawski, Turkus, Set, Kwestor, Bursztyn and above 60% - in Wenus. There was indicated no significant effect of seed fractionating on the content of starch in seeds. Mean content of nitrogen in seeds was 3.47%. The seeds of large fraction and the seeds of Bursztyn showed significantly the highest, while the seeds of Kwestor and Wenus – the lowest N content. Of all the pea cultivars, the highest content of fiber was noted in Kwestor and Rola seeds and in seed coat – in Rola seeds. There was no significant effect of seed fractionating on the content of fiber in seed coats, while in medium and large seed fraction its accumulation was significantly lower than in the small ones.

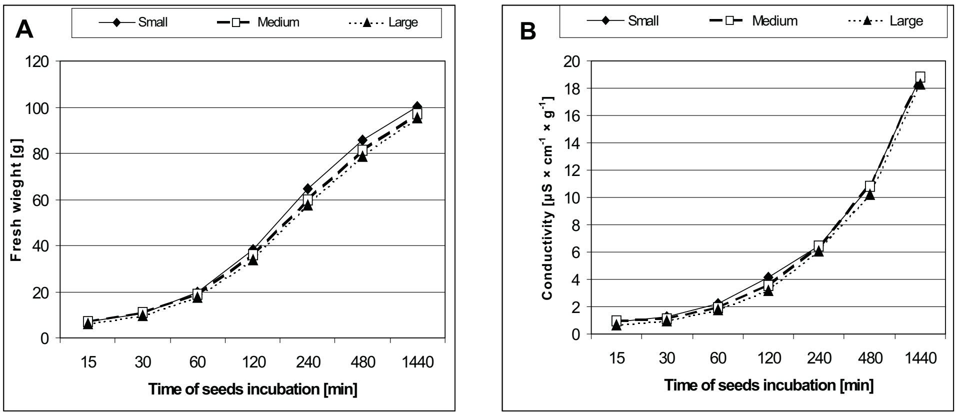

Fig. 1. Fresh weight increments (A) of fractionated pea seeds and leachate electroconductivity (B) over 24 hours of imbibition

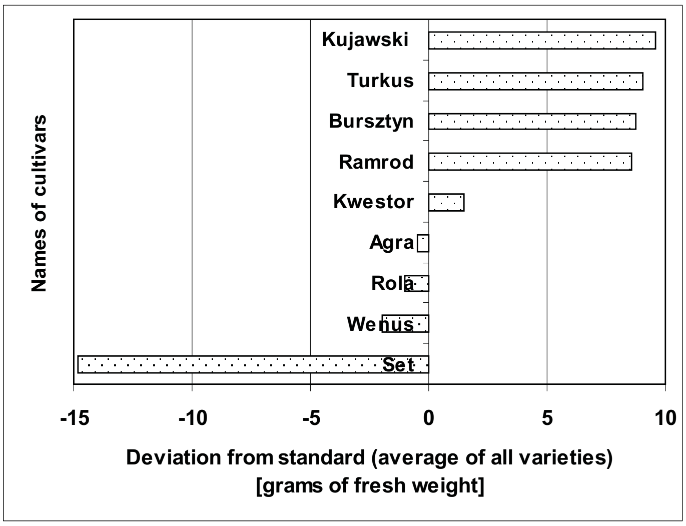

Fig. 2. Fresh weight increments deviations from the check (cultivar mean) for the pea cultivars studied after 2 hours of seed imbibition

The fresh weight increments and exudates leaching in pea were greatest in the first four hours of incubation (Fig. 1). Small seeds imbibed slightly faster than the large ones, especially starting from the second hour of imbibition. However, after 24 hours of imbibition, there were no significant differences in fresh weight increments and the exudates electroconductivity of fractionated seeds.

Table 3

Matrix of correlation coefficients between physicochemical properties of pea seeds and fresh weight increments during incubation in water

Independent variables	Fresh weight increments during incubation after time [min]						
	15	30	60	120	240	480	1440
1000 seed weight	0.18	0.04	-0.17	-0.52*	-0.59*	0.34	0.04
Seed coat thickness	-0.15	-0.07	0.01	0.06	0.06	0.01	-0.44
Seed coat share	-0.02	0.01	-0.08	-0.17	-0.25	-0.17	0.10
Fiber content in seeds	-0.38	-0.30	-0.19	-0.09	-0.30	0.45	-0.47
Fiber content in seed coat	-0.44	-0.37	-0.25	-0.15	0.16	0.32	0.27
Starch content in seeds	0.23	0.13	0.14	0.10	-0.14	-0.32	0.38
N content in seeds	0.31	0.42	0.40	0.32	0.31	0.44	-0.01

r significant at $\alpha = 0.05$

The physical seed properties studied, except the 1000 seed weight, were not significantly correlated with the fresh weight increments during imbibition (Table 3). The lower the 1000 seed weight, the higher the increments after 2 and 4 hours of imbibition. Similarly, the 1000 seed weight was negatively correlated with leachate electroconductivity after 2 hours of imbibition, while the content of N – positively correlated after 30 minutes (Table 4). Besides, a greater share of seed coat was accompanied by a lower leakage of electrolytes, especially after 8 and 24 hours.

Table 4

Matrix of correlation coefficients between physicochemical properties of pea seed and the electroconductivity of seed exudates

Independent variables	Electroconductivity of seed exudates after time [min]						
	15	30	60	120	240	480	1440
1000 seed weight	-0.11	-0.34	-0.39	-0.51*	-0.43	-0.41	-0.27
Seed coat thickness	-0.16	0.16	0.21	0.19	0.12	0.11	0.14
Seed coat share	0.20	-0.19	-0.31	-0.26	-0.47	-0.50*	-0.54*
Fiber content in seeds	0.17	0.27	0.36	0.37	0.12	0.09	0.07
Fiber content in seed coat	0.15	0.27	0.31	0.28	0.10	0.08	0.02
Starch content in seeds	-0.05	-0.18	-0.23	-0.17	0.09	0.17	0.19
N content in seeds	0.22	0.54*	0.44	0.28	0.11	-0.08	0.05

r significant at $\alpha = 0.05$

The results of the fresh weight increment test after 2 hours of imbibition and of the electroconductivity test after 24 hours were most correlated with the pea seed cooking time (Table 5), which facilitated cultivar ordering as deviations from the check (mean for all the cultivars tested). The fresh weight increments were greater than the check in Kujawski, Turkus, Bursztyn, Ramrod and Kwestor, whereas seeds of Set imbibed slowest (Fig. 2). After 24 hours of soaking electroconductivity test of Bursztyn as well as Ramrod, Kwestor, Wenus and Kujawski seeds showed the highest leakage of electrolytes, and of Set, again – lowest (Fig. 3).

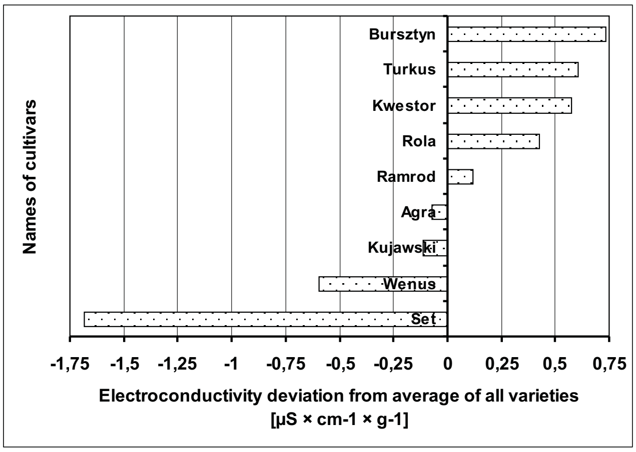

Fig. 3. Seed leachate electroconductivity deviations from the check (cultivar mean) for the pea cultivars studied after 24 hours of imbibition

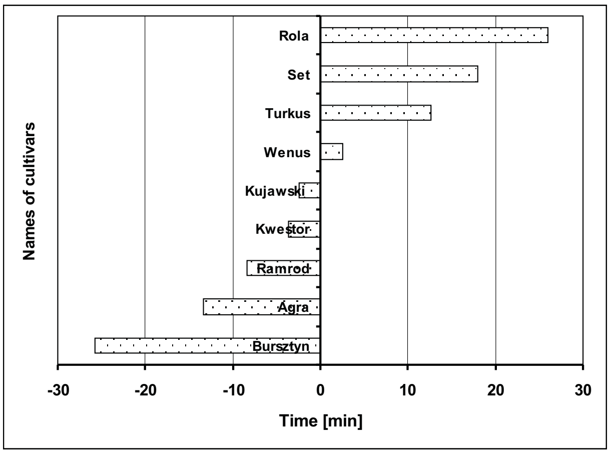

Fig. 4. Cooking time of pea seeds with seed coat for the cultivars studied

The mean cooking time of intact pea seeds was 122 minutes, while of pea seeds without coat – 58 minutes. The fractionating of seeds did not affect cooking time significantly (Table 6). Seeds of Rola and Set needed the longest cooking time and the seeds of Bursztyn and Agra – the shortest time (Fig. 4). However, having removed seed coats, it appeared that Turkus and Rola seed cooking time was significantly longest, whereas Wenus and Kwestor seed cooking time – shortest (Fig. 5).

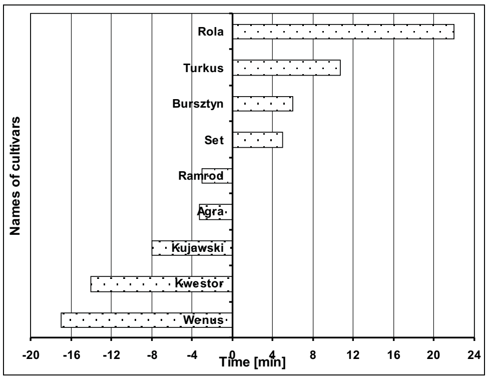

Fig. 5. Cooking time of pea seed without seed coat for the cultivars studied

Table 5

Correlation coefficients matrix between the fresh weight increment rate over pea seed imbibition and the results of electroconductivity test and seed cooking time

Variables	Measurement time						
	15	30	60	120	240	480	1440
Fresh weight increments	-0.30	-0.33	-0.36	-0.41*	-0.29	-0.21	-0.10
Electroconductivity of seed exudates	0.12	-0.25	-0.23	-0.22	-0.49*	-0.56*	-0.67*

r significant at $\alpha = 0.05$

Table 6

Pea seed cooking time determined with the BZ-3 viscometer

Specification	Cooking time of seeds	
	With seed coat	Without seed coat
Cultivars		
Agra	108 de	45 de
Wenus	124 cd	42 e
Kwestor	118 d	51 de
Bursztyn	96 e	56 c
Rola	148 a	55 cd
Turkus	131 bc	69 b
Set	138 ab	64 bc
Kujawski	120 d	65 bc
Ramrod	117 d	81 a
Seed fractions		
Small	126 A	56 A
Medium	119 A	58 A
Large	120 A	60 A

Means followed by the same lower-case letters for cultivars and the capital ones for seed fractions did not differ significantly at $\alpha = 0.05$

The share of seed coat (r = 0.57) and the content of seed fiber (r = 0.42) were significantly, positively correlated with the cooking time (Table 7). No significant correlation between other physicochemical properties of pea seeds and their cooking quality was found.

Table 7

Matrix of correlation coefficients between physicochemical properties of pea seeds and seed cooking time

Independent variables	Cooking time
1000 seed weight	0.04
Seed coat thickness	0.11
Seed coat share	0.57*
Fiber content in seeds	0.30
Fiber content in seed coat	0.42*
Starch content in seeds	-0.24
N content in seeds	- 0.20

* r significant at $\alpha = 0.05$

DISCUSSION

Over 2000 – 2004 the edible pea plantation area in Poland was 38 thousand ha (Prusiński and Kotecki 2006). On wheat complex soils white-flowering pea cultivars are grown for dry seeds used as components of high-protein feed, and some, of top quality (large, yellow and smooth fast cooking seeds) are used for cooking purposes. The present research involved undamaged seeds of nine white-flowering pea cultivars, whose initial water content was 13.5%.

So far, the measure of seed weight increments during soaking is the method applied by COBORU to compare the cooking time of registered pea cultivars. Turkus seeds imbibition was fastest, while Rola and Set seeds – slowest over 2000 – 2002 (Wiatr 2002) and Wenus and Set seeds over 2002 – 2004 (Dolata and Wiatr 2004). In the present research the highest value of the correlation coefficient between the fresh weight increment rate and the cooking time was noted after 2 hours of imbibition; Kujawski, Turkus, Bursztyn and Ramrod seed water uptake was fastest, while Set seed water uptake – slowest. The results of the electroconductivity test show the highest and fastest electrolyte leakage from Bursztyn and Ramrod seeds, and the lowest – from Set seeds.

In the present study the cooking test in BZ-3 viscometer confirmed the shortest cooking time in Bursztyn, and the longest – in Rola and Set. The positive correlation between the water uptake time and the cooking time in automated Mattson cooker apparatus was also found in bean (Boros 2003) and in pea (Wang and Daun 2005, Wang *et al.* 2003, Savage *et al.* 2001).

The mean cooking time of seeds without coat was two-fold shorter than that of seeds with intact coats. The importance of seed coat in seed life, seed deterioration, water uptake time and vigor are well-known. One of the seed coat functions is to slow down the imbibition rate which can depend on the seed coat color, proximity to cotyledons (Powell 1989) and its mechanical damage (Prusiński and Borowska 1996, Prusiński 1997). Therefore one of the basic conditions of seed cooking-test credibility is intact seed coat. The white seed coat is slightly adjacent to cotyledons, which facilitates a fast water movement into seeds, while a closely adjacent seed coat in color seeds limits such movement, even if the coat is damaged (Powell 1989). In the present research closely adjacent seed coat in Set was most probably responsible for a long cooking time, since once the seed coats were removed, the cooking time was much shorter. Rola was found to be the only cultivar which seed cooking time was longest, with or without the seed coat. The contents of fiber in seeds and in seed coats in Rola were amongst the highest, and thus the electrolyte leaching must have been the lowest. Similarly, as reported by Panobianco *et al.* (1999), the greater the content of lignin in soybean seeds, the lower the electroconductivity of seed exudates. Of all the cultivars tested, the highest electroconductivity of seed exudates was found in Bursztyn seeds and the lowest – in Set and Rola seeds, which confirms a high negative value of the coefficient of the correlation between the test results and the seed cooking time.

Although the 1000 seed weight, thickness and share of seed coat as well as the contents of starch and total N differed across cultivars, it was not possible to provide a final definition of the relationship between physicochemical properties and cooking time of seeds. The present study does not consider habitat conditions of pea plant growth and ripening. Neither does it include agronomic practices which can also, to some extent, affect the nutritive and anti-nutritive value of pea seeds and their cooking applicability. Some authors found no significant relationship between physicochemical properties of pea seeds and their cooking applicability (Black *et al.* 1998). Differences in the seed cooking time for various pea cultivars can be a result of changes in the starch grain diameter, structure and imbibition potential (Hoover and Vasanthan 1994) or due to changes in the share of dietary fiber and resistant starch fractions (Soral – Śmietana and Krupa, 2005) during cooking. Weather conditions over parental plants growth and development can also, despite genetic conditions, affect physicochemical properties of seeds (Boros and Wawer 2004).

CONCLUSIONS

The fresh weight increments during imbibition depended on both genetic properties of the cultivars studied and the seed size; in Kujawski, Turkus, Bursztyn, Ramrod cultivars or in the case of small seeds, the increments were greater, while in Set and in the case of large seeds, the increments were smaller.

Seed leachates in Bursztyn showed the highest, while in Set – the lowest electroconductivity; besides, electrolyte leaching from small seeds was only a bit greater than from the large ones.

The greatest convergence of the fresh weight increment rate and the results of the electroconductivity test and the cooking time was found after 2 and 24 hours of seed incubation in water.

Bursztyn seeds cooking time was shortest, while that of Rola seeds, with one of the thickest seed coats, highest share of coat in the seed weight and the highest seed fiber content, was longest. Seeds of Set cultivar required a long cooking time due to a close proximity of seed coat to cotyledons.

No significant correlations were found between the cooking time and the physicochemical properties, except for the share of seed coat and the fiber content in seeds; the greater the share and the content, the longer the cooking time.

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