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MINERALS AND CHOSEN HEAVY METALS RETENTION IN IMMATURE COMMON BEAN (*PHASEOLUS VULGARIS* L.) SEEDS DEPENDING ON THE METHOD OF PRESERVATION

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ABSTRACT

Background. Legumes are a good source of protein, and are also abundant in carbohydrates, B-group vitamins, dietary fibre and mineral compounds.
Material and methods. This work evaluates the retention of ash, eleven minerals and two heavy metals in products obtained from two common bean cultivars harvested before reaching full maturity, with a dry matter content of about 40%. Analyses were conducted on raw, blanched and cooked seeds and three products prepared for consumption after 12-month storage: two frozen and one canned (sterilized). The former comprised two types of frozen product: one traditionally produced (blanching-freezing-frozen storage-cooking), the other a convenience, "ready-to-eat" product obtained using a modified method (cooking-freezing-frozen storage-defrosting-heating to consumption temperature in a microwave oven).
Results. In cooked bean seeds of both cultivars, levels of potassium, calcium, magnesium and copper were significantly lower, the only exception being the content of ash and sodium (due to added salt), than in blanched seeds; the changes in the remaining components were not so clear-cut and depended on the cultivar. Seeds frozen using the modified technology generally showed higher levels of the elements investigated than frozen products produced traditionally, with the exception of chromium, nickel and lead. Sterilized seeds had lower levels of ash, phosphorus, calcium, magnesium, iron, zinc, manganese, copper and chromium compared with both types of frozen product; retention levels of individual components depended on the cultivar examined.
Conclusions. Compared with the traditionally produced frozen product, prepared for consumption, seeds after modified method of freezing (convenience food) contained significantly higher levels of ash and all macroelements, regardless of the cultivar. Seeds preserved by sterilization, compared with frozen seeds (either method of production) prepared for consumption, had lower content of most of the analyzed components.

Key words: immature bean seeds, minerals, heavy metals, blanching, cooking, freezing, canning

INTRODUCTION

Legumes are one of the most important food components in the human diet, especially recommended for vegetarians, because they are a good source of protein. They are also abundant in carbohydrates and B-group vitamins; however, other constituents, including fat, dietary fibre or mineral compounds, are also not insignificant [Champ 2002, Souci et al. 2000, Suliburska et al. 2009]. Levels of mineral compounds depend on several factors, including species, cultivar, and localization of legume cultivation [Martínez et al. 1998,

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Srogi 2005]; in the case of heavy metals, an additional factor is their level in soil [Dąbkowska-Naskręt 2004]. Levels are also affected by processing methods and preparation of vegetables for consumption [Filipiak-Florkiewicz et al. 2012, Trinidad et al. 2010].

Legume seeds are consumed either at "physiological" maturity or before reaching this stage [Korus 2002], common bean also falling into the latter category. Immature seeds, a perishable raw material, can be canned or frozen. Canned products, as opposed to frozen, do not require culinary treatment and therefore meet the requirements of convenience food. However, freezing is superior for preserving nutritive food components such as mineral compounds, even though such products require additional preparation for consumption [Korus et al. 2003, Lisiewska et al. 2002]. The findings of Lisiewska et al. [2008 a] and Słupski [2010] revealed that frozen products obtained from pea and flageolet-type bean also meet the requirements of convenience food. According to Słupski and Lisiewska [2013], seeds of common bean can also be used to obtain convenience, "ready-to-eat" products when cooked rather than blanched prior to freezing.

The aim of this work was to evaluate ash retention, as well as the levels of 11 minerals and 2 heavy metals in products obtained from the seeds of two common bean cultivars intended for dry-seed production harvested at the wax stage of maturity, with a dry matter content of about 400 $g \cdot kg^{-1}$. Retention levels of the constituents examined were evaluated in the finished products after 12-month storage and preparation for consumption. The experimental material comprised frozen products and canned products preserved by sterilisation. The frozen products were produced traditionally (blanching prior to freezing) and by means of a modified method (cooking prior to freezing), the latter resulting in a convenience, "ready-to-eat" product which merely requires defrosting and heating in a microwave oven.

MATERIAL AND METHODS

Materials. The investigated material consisted of fresh, immature seeds of two common bean cultivars used as the raw material; seeds after blanching or cooking, regarded as half-finished products; seeds processed using sterilisation in air-tight cans; and seeds processed by freezing using two different methods. Final products were evaluated after 12-months' storage, frozen products being evaluated when prepared for consumption.

The investigated material consisted of the cultivars Igołomska ("Polan" KHiNO), and the cultivar Laponia (PlantiCo HiNO Zielonki). The cultivars were harvested and processed at 40% dry matter.

The beans were grown in the experimental field of the Department which carried out the technological and analytical investigations, situated in the western outskirts of Krakow in southern Poland. The beans were harvested when seeds reached the pre-determined dry matter content, which was after approximately 90 days' growth. Immediately after harvest, seeds were shelled, sorted and the content of mineral constituents in the raw material was evaluated.

The preparation of semi-prepared products. The processing of seeds into canned products was preceded by blanching the raw material; the freezing process was preceded by blanching (treatment I) or cooking (treatment II), depending on the method applied. Blanching of bean seeds was carried out using tap water in a stainless steel vessel; the proportion of the raw material to water was 1:5. The blanching temperature was 96-98°C and all cultivars were blanched for the experimentally determined time of 3 minutes. These conditions permitted a decrease in the activity of catalase and peroxidase to the levels below 5% of the initial values. After blanching the material was immediately cooled in cold water and placed on sieves to drip.

Cooking of beans was carried out in a stainless steel vessel in a 1:1 proportion of the raw material to brine at a concentration of 1.6% NaCl. Bean seeds were placed in boiling water; the cooking time required to obtain consumption consistency of seeds was 37 minutes for the cultivar Igołomska and 29 minutes for Laponia, including the time for the water to return to the boil. After cooking, the material was placed on sieves and cooled in a stream of cold air.

Processing of beans by freezing and sterilisation. For freezing, blanched (treatment I) and cooked (treatment II) samples were placed on trays in a layer of 30 mm and frozen at –40°C in a Feutron blast freezer 3625-51 (Greiz, Germany). The time required to attain a temperature of –20°C was 105 min. The resulting frozen product was packed in portions of 500 g in polyethylene bags suitable for storing frozen food and left in a storage chamber at –20°C until evaluation in 12 months' time.

Sterilization (treatment III) was carried out in cans 510 cm^3 in volume using brine at a concentration of 2.4% NaCl. Each can contained 360 g seeds and 180 g brine. The sterilisation conditions were determined by technological tests, attention being paid to the shelf--life of canned products and obtaining the right consistency of seeds. It was found that the appropriate quality of canned products was obtained using a sterilisation temperature of 120 ±2°C for 14 minutes for the cultivar Igołomska and 13 minutes for Laponia; the time for the temperature to reach sterilisation level and the cooling time was 15 minutes in each case. After complete cooling and drying, the cans were placed in an air-conditioned store at a temperature of 8 ±2°C and stored in these conditions for 12 months until evaluated.

Preparation of frozen and sterilized products for evaluation. Frozen products pre-treated by blanching (treatment I) were cooked in water with 1.6% added salt, the proportion of vegetable to water being 1:1. As in the case of cooking the raw material, frozen bean was put in boiling water. The cooking time for the seeds to reach the right consistency, including the time for the water to return to the boil, was 33 minutes for the cultivar Igołomska and 31 minutes for Laponia. After cooking, the water was drained and product was cooled in a stream of cold air to a temperature of 20°C and its chemical composition was evaluated.

The frozen product cooked before freezing (treatment II) was defrosted and heated in a Panasonic NN--F-621 (Matsushita Electric UK) microwave oven. A 500 g sample was put in a heat-resistant covered vessel. The time of defrosting and heating the product to a temperature of 75°C accordingly with Codex Alimentarius [1993] was 11 minutes. After cooling in a stream of cold air to 20°C, the material was evaluated.

Canned products (treatment III) from the cool chamber were warmed to room temperature. The cans were then opened and their contents placed on sieves. The material was analysed after the fluid fraction had dripped off.

Analytical procedures. The content of ash was determined by incineration in a Nabertherm model L 9/S 27 furnace oven (Nabertherm, Germany) at 460°C according to the method 32.027 given in AOAC [1984]. In order to determine the level of the individual elements, the material was mineralized in a 3:1 mixture of nitric and perchloric acids. A 50 g portion of the material and 30 cm^3 of the acid mixture were placed into 250 cm^3 test tubes of the Tecator Kjeltec Auto Plus II mineralization set. The mineralized samples were diluted with ultra-pure water to a volume of 100 cm^3. The content of the individual elements in the solution was determined using an inductively coupled argon plasma emission spectrophotometer JY 238 Ultrace-Jobin Yvon (France). The most sensitive wavelengths for the determination of analyses were as follows: for K – 766.490 nm, Ca – 422.673 nm, Mg – 279.533 nm, Na – 589.592, Fe – 234.349 nm, Zn – 213.856 nm, Mn – 257.610 nm, Cu – 224.700 nm, Cr – 205.552 nm, Ni – 232.003 nm, Cd – 228.802 nm, Pb – 220.353 nm. The level of P was determined by method 3.098 given in AOAC [1984].

Expression of results. The content of elements in the raw material, semi-prepared products and final products prepared for consumption was expressed in terms of kg fresh matter (Table 1 and 2) and in terms of kg dry matter (Table 3 and 4).

Statistical analysis. Statistical calculations allowing a comparison of the content of minerals in the fresh and processed seeds after preparation for consumption were performed using single-factor analysis of variance (ANOVA) and Duncan's test, with probability level $p < 0.05$ with the use of Statistica 9.1 (StatSoft Inc., Tulsa, OK, USA) software.

RESULTS AND DISCUSSION

Fresh been seeds of Igołomska and Laponia contained 19.3 and 21.7 g ash per kg of edible portion respectively (Table 1). The dominant component in ash was potassium, comprising over one third of its total content. Seeds of the two cultivars analysed had similar levels of most elements examined; Igołomska had higher amounts of phosphorus, calcium and lead, while Laponia was more abundant in iron and chromium (Tables 1 and 2). Levels of the mineral compounds found in fresh been seeds were similar to grass pea,

Table 1. Content of ash and macroelements in raw, blanched, cooked and frozen then prepared for consumption and canned bean seeds, in fresh matter (means ±SD)*

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 months storage		
					frozen seeds		
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	canned seeds (treatment III)
Ash, g·kg^{-1}	Igołomska	21.7ab ±0.04**	18.3cd ±0.09	22.3a ±0.06	18.9cd ±0.05	22.6a ±0.06	16.8e ±0.07
	Laponia	19.3c ±0.07	15.1f ±0.09	19.2c ±0.09	17.7de ±0.09	20.5b ±0.08	14.5f ±0.06
P, mg·kg^{-1}	Igołomska	2 892a ±126	2 645bcd ±88	2 509de ±59	2 190f ±47	2 773ab ±54	1 578h ±59
	Laponia	2 683bc ±69	2 511de ±80	2 385e ±76	2 012g ±121	2 619cd ±78	1 373i ±66
K, mg·kg^{-1}	Igołomska	7 266a ±250	6 555b ±170	4 647d ±252	3 404e ±136	5 211c ±239	2 880f ±290
	Laponia	7 086a ±230	6 588b ±319	4 699d ±220	3 246e ±229	4 554d ±168	3 305ef ±116
Ca, mg·kg^{-1}	Igołomska	856bc ±87	1 106a ±66	940b ±49	934b ±66	1 100a ±46	780cd ±36
	Laponia	667e ±52	880bc ±93	721de ±56	692de ±49	777cd ±31	511f ±32
Mg, mg·kg^{-1}	Igołomska	786bc ±69	819ab ±44	659de ±42	585e ±56	695cd ±30	443ef ±31
	Laponia	863ab ±97	954a ±107	708cd ±89	576e ±35	698cd ±37	386f ±27
Na, mg·kg^{-1}	Igołomska	176d ±30	216d ±48	3397b ±241	3 164b ±227	4 016a ±276	2 631c ±129
	Laponia	226d ±52	257d ±38	2871c ±178	2 657c ±110	3 186b ±137	2 842c ±202

*Data reported are means of two independent experimental replications; all chemical analyses were carried out in two parallel samples.
**Means on the same element with different letters are significally different at $p < 0.05$.

broad bean and flageolet-type bean harvested at similar maturity, or slightly higher [Korus 2002, Lisiewska et al. 2006, 2008 b, Słupski 2011]. Since there is no data in the literature on ash constituents in the seeds of common bean harvested at wax maturity, the results have also been expressed in dry matter. Data in Tables 3 and 4 shows that levels of the constituents examined did not differ considerably from those reported by Filipiak-Florkiewicz et al. [2011] and Souci et al. [2000] in dry matter of bean seeds.

Compared with the raw material, blanching resulted in reduced levels of ash (16 and 22%), phosphorus (9 and 6%) and potassium (10 and 7%), and significant increases in calcium (29 and 32%); only the levels of magnesium, sodium, iron, zinc and nickel remained unchanged. In addition, Igołomska showed significantly lower levels of manganese, copper and lead, whereas Laponia was found to have lower chromium but higher cadmium content.

A comparison between levels of the elements investigated in blanched and cooked samples prior to freezing shows that cooked seeds, regardless of the cultivar, contained higher amounts of ash and sodium (due to the salt added in cooking) but lower levels of potassium, calcium, magnesium and copper. Furthermore, cooked seeds of the cultivar Laponia were less abundant in iron, zinc, manganese, and chromium. Although in this experiment cooked seeds were a semi-product, they can also be assessed as a finished product prepared for consumption.

The changes observed varied according to cultivar and type of preliminary processing, but, as is stated in the literature, can also depend on the proportion of medium to the material investigated, pH, time of

Table 2. Content of selected microelements and heavy metals in raw, blanched, cooked and frozen then prepared for consumption and canned bean seeds, in fresh matter (means ±SD)*

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 months storage		
					frozen seeds		canned seeds (treatment III)
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	
Fe, mg·kg^{-1}	Igołomska	50.1b** ±7.8	36.8bd ±3.7	40.8cd ±4.3	35.3d ±3.3	55.2ab ±5.6	32.0de ±3.3
	Laponia	61.2a ±5.2	61.8a ±8.7	48.1bc ±5.6	25.7ef ±2.9	39.9cd ±3.0	28.1f ±2.4
Zn, mg·kg^{-1}	Igołomska	20.7bc ±3.0	19.2cd ±0.8	17.8cde ±1.1	15.6efg ±0.8	20.5bc ±0.8	14.4fg ±0.5
	Laponia	22.8ab ±2.7	23.9a ±3.2	18.7cde ±1.6	16.6def ±0.6	19.3cd ±0.7	12.9g ±1.0
Mn, mg·kg^{-1}	Igołomska	10.59a ±0.92	9.36bcd ±0.48	8.43de ±0.61	7.79e ±0.47	10.10ab ±0.60	6.39f ±0.35
	Laponia	9.77abc ±0.51	10.31ab ±0.83	9.02cd ±0.34	7.71e ±0.29	9.41bcd ±0.22	6.30f ±0.55
Cu, mg·kg^{-1}	Igołomska	4.23a ±0.44	3.81b ±0.34	3.18c ±0.16	2.67d ±0.28	3.62bc ±0.08	2.44d ±0.28
	Laponia	4.02ab ±0.35	3.69b ±0.30	3.20c ±0.11	2.49d ±0.15	3.17c ±0.26	1.84e ±0.13
Cr, mg·kg^{-1}	Igołomska	0.25c ±0.05	0.20cd ±0.02	0.19cd ±0.04	0.16de ±0.04	0.19d ±0.03	0.13f ±0.02
	Laponia	0.37a ±0.04	0.31b ±0.04	0.19cd ±0.02	0.15de ±0.02	0.16de ±0.01	0.12f ±0.02
Ni, mg·kg^{-1}	Igołomska	8.16abc ±0.45	7.33abc ±0.65	6.80abc ±0.57	6.20c ±0.46	8.34abc ±0.73	6.73bc ±0.71
	Laponia	9.14abc ±0.65	7.45abc ±0.64	9.88a ±0.66	9.30abc ±0.35	9.53ab ±0.45	9.37ab ±0.72
Pb, mg·kg^{-1}	Igołomska	0.08a ±0.01	0.06bcd ±0.02	0.06bcd ±0.01	0.07abc ±0.02	0.06bcd ±0.02	0.06bcd ±0.02
	Laponia	0.04d ±0.01	0.04d ±0.02	0.05cd ±0.02	0.05cd ±0.01	0.07abc ±0.01	0.08ab ±0.02
Cd, mg·kg^{-1}	Igołomska	0.03b ±0.01	0.04b ±0.01	0.03b ±0.01	0.02c ±0.00	0.03b ±0.01	0.03b ±0.01
	Laponia	0.03b ±0.00	0.05a ±0.01	0.05a ±0.01	0.04a ±0.01	0.05a ±0.01	0.05a ±0.01

*Data reported are means of two independent experimental replications; all chemical analyses were carried out in two parallel samples.
**Means on the same element with different letters are significantly different at $p < 0.05$.

technological treatment and the raw material [Oboh et al. 2000]. Despite noting some decreases in amounts of the elements analysed, Koplik et al. [2004 b] found no significant differences in levels of phosphorus, manganese, iron, nickel and copper between fresh, blanched, and cooked pea seeds. This was confirmed by Puupponen-Pimiä et al. [2003], according to whom the losses in mineral compounds in pea due to blanching were statistically insignificant. However, the losses in ash, potassium and phosphorus, as well as the increase in calcium content reported by Korus [2002] in blanched seeds of grass pea, were similar to the results obtained for beans in the present study. Lisiewska et al. [2008 b], on the other hand, found that levels of zinc, manganese and nickel were lower in both blanched and cooked broad bean, while in green pea, only levels of potassium and nickel were lower; no changes were noted in the levels of the remaining elements.

There are various mechanisms whereby a fall or even a rise in the level of soluble constituents may occur; such changes may be real or apparent. During thermal processing in water, starch and proteins

Table 3. Content of ash and macroelements in raw, blanched, cooked and frozen then prepared for consumption and canned bean seeds, in dry matter* (means ±SD)**

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 months storage		
					frozen seeds		
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	canned seeds (treatment III)
Ash, $g \cdot kg^{-1}$	Igołomska	5.48b ±0.09***	4.81c ±0.24	6.82a ±0.18	5.40b ±0.13	5.46b ±0.14	4.66c ±0.18
	Laponia	4.84c ±0.17	4.03d ±0.23	5.58b ±0.27	4.72c ±0.23	4.74c ±0.19	4.71c ±0.21
P, $mg \cdot kg^{-1}$	Igołomska	7 303b ±319	6 961bc ±231	7 673a ±180	6 257d ±136	6 714c ±131	4 347f ±162
	Laponia	6 741c ±173	6 696c ±213	6 933c ±220	5 365e ±321	6 048d ±180	4 458f ±213
K, $mg \cdot kg^{-1}$	Igołomska	18 348a ±630	17 250a ±447	14 211b ±772	9 726d ±389	12 617c ±579	7 934e ±799
	Laponia	17 804a ±577	17 568a ±850	13 660b ±638	8 656e ±610	10 517d ±388	10 731d ±376
Ca, $mg \cdot kg^{-1}$	Igołomska	2 162b ±219	2 911a ±175	2 875a ±150	2 669a ±189	2 663a ±112	2 149b ±100
	Laponia	1 676d ±131	2 347b ±247	2 096bc ±162	1 845cd ±130	1 794d ±71	1 659d ±102
Mg, $mg \cdot kg^{-1}$	Igołomska	1 985b ±175	2 155b ±116	2 015b ±129	1 671c ±159	1 683c ±73	1 220d ±86
	Laponia	2 168b ±244	2 544a ±285	2 058b ±259	1 536c ±93	1 612c ±86	1 253d ±88
Na, $mg \cdot kg^{-1}$	Igołomska	444e ±77	568e ±125	10 388a ±737	9 040bc ±790	9 724ab ±667	7 248d ±357
	Laponia	568e ±131	685e ±102	8 346c ±517	7 085d ±294	7 358d ±317	9 227b ±654

*Content of dry matter is given in Słupski and Lisiewska [2013].
**Data reported are means of two independent experimental replications; all chemical analyses were carried out in two parallel samples.
***Means on the same element with different letters are significally different at $p < 0.05$.

swell and the tissue of vegetables absorbs water. These transformations cause an increase in the product mass, resulting in simultaneous "dilution" of components [Lisiewska et al. 2008 b, Habiba 2002]. However, in other cases the vegetable tissue may shrink with the release of water, causing compounds to be more concentrated rather than diluted. The extent of such changes may also depend on the size of the raw material-medium contact area, which determines the extent of migration of soluble components [Lisiewska et al. 2008 b]. Ribeiro et al. [2012] and Lestienne et al. [2005] proved that particular elements are located in various parts of plants, which affects their exposure to leaching. In addition, the compounds in which mineral components occur in seeds are of varying solubility, which may explain how susceptible or resistant they are to leaching [Koplik et al. 2004 a]. They can also be reduced through the release of mineral compounds bound in the form of insoluble complexes, as in the case of phytates and polyphenols [Duhan et al. 1999, Koplik et al. 2004 a, Suliburska et al. 2009]. It should be noted, however, that in this work bean seeds were cooked in hard tap water (unpublished data) with sodium chloride added, which reduces such losses [Kimura and Itokawa 1990].

Compared with blanched seeds, edible portion of cooked frozen seeds obtained from treatment I (blanching-freezing-12-month storage-cooking) showed an increase in ash (only in Laponia) and sodium content (due to the salt added in cooking), a decrease in calcium, zinc, manganese and, as was the case when cooking fresh seeds, a reduction in levels of the phosphorus,

Table 4. Content of selected microelements and heavy metals in raw, blanched, cooked and frozen then prepared for consumption and canned bean seeds, in dry matter* (means ±SD)**

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 months storage		
					frozen seeds		
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	canned seeds (treatment III)
Fe, mg·kg^{-1}	Igołomska	126.5c ±19.7***	96.8d ±9.8	124.8c ±13.3	100.9d ±9.5	133.7bc ±13.6	88.2de ±9.0
	Laponia	153.8ab ±13.1	164.8a ±23.3	139.8bc ±16.3	68.5ef ±7.6	92.1de ±7.0	58.8f ±7.7
Zn, mg·kg^{-1}	Igołomska	52.3bc ±7.5	50.5bc ±2.2	54.4b ±3.5	44.6cde ±2.4	49.6bcd ±2.0	39.7e ±1.3
	Laponia	57.3ab ±6.7	63.7a ±8.5	54.4b ±4.6	44.3cde ±1.6	44.6cde ±1.7	41.9de ±3.2
Mn, mg·kg^{-1}	Igołomska	26.7ab ±2.3	24.6bc ±1.3	25.8ab ±1.9	22.3cd ±1.3	24.5bc ±1.4	17.6e ±1.0
	Laponia	24.5bc ±1.3	27.5a ±2.2	26.2ab ±1.0	20.6d ±0.8	21.7d ±0.5	20.5d ±1.8
Cu, mg·kg^{-1}	Igołomska	10.7a ±1.1	10.0abc ±0.9	9.7abc ±0.5	7.6de ±0.8	8.8cd ±0.2	6.7ef ±0.8
	Laponia	10.1ab ±0.9	9.8abc ±0.8	9.3bc ±0.3	6.6ef ±0.4	7.3e ±0.6	6.0f ±0.4
Cr, mg·kg^{-1}	Igołomska	0.63b ±0.13	0.53bcde ±0.04	0.58bc ±0.13	0.46cdef ±0.10	0.46cdef ±0.07	0.36f ±0.06
	Laponia	0.93a ±0.10	0.83a ±0.09	0.55bcd ±0.04	0.40def ±0.04	0.37ef ±0.02	0.39ef ±0.07
Ni, mg·kg^{-1}	Igołomska	20.6cde ±1.14	19.3de ±1.71	20.8cde ±1.75	17.7e ±1.32	20.2cde ±1.77	18.5e ±1.97
	Laponia	23.0bc ±1.63	19.9cde ±1.71	28.7a ±1.91	24.8b ±0.92	22.0bcde ±1.03	30.4a ±2.35
Pb, mg·kg^{-1}	Igołomska	0.20ab ±0.01	0.16bcd ±0.04	0.18bcd ±0.03	0.20abc ±0.04	0.15cd ±0.04	0.17bcd ±0.04
	Laponia	0.10d ±0.01	0.11d ±0.06	0.15cd ±0.06	0.13cd ±0.03	0.16bcd ±0.01	0.26a ±0.06
Cd, mg·kg^{-1}	Igołomska	0.08e ±0.02	0.11de ±0.02	0.09cde ±0.2	0.06e ±0.01	0.07e ±0.01	0.08e ±0.02
	Laponia	0.08e ±0.00	0.13bc ±0.01	0.15ab ±0.2	0.11bcd ±0.02	0.12bc ±0.02	0.16a ±0.06

*Content of dry matter is given in Słupski [2013].
**Data reported are means of two independent experimental replications; all chemical analyses were carried out in two parallel samples.
***Means on the same element with different letters are significally different at $p < 0.05$.

potassium, magnesium and copper (Tables 1 and 2). In addition, there were decreases in the levels of cadmium and iron in Igołomska and Laponia respectively. Kmiecik et al. [2000] observed that broad bean cooked after traditional freezing contained lower amounts of potassium and zinc, whereas levels of phosphorus, iron, copper and manganese remained unchanged.

Seeds after treatment II (cooking-freezing-12-month frozen storage-defrosting and heating in a microwave oven) prepared for consumption showed a substantial increase in phosphorus and sodium in both cultivars compared with seeds cooked prior to freezing. Igołomska was also found to contain higher levels of potassium, calcium, iron and manganese (Table 1 and 2). An increase in the constituents of ash in the fresh matter of seeds from treatment II may be explained by water evaporation during microwave heating, which is confirmed by the increase in the dry matter of such products [Słupski 2011]. An increase in dry matter during microwaving has also been confirmed by other authors, even when covering the heating vessel with a lid [Lisiewska et al. 2008 b].

Sterilised seeds after treatment III contained less ash than blanched seeds (the differences being significant only for Igołomska) and considerably lower quantities of most of the elements analysed with the exception of nickel, lead and cadmium, and, in Laponia, iron. To a large extent, these changes could have been the result of mineral compounds being partly replaced by the table salt in the brine; absorption of water by the beans; and the leaching of soluble constituents, resulting in a decrease in dry matter [Słupski 2011].

Compared with the traditionally produced frozen product (treatment I), seeds after treatment II prepared for consumption (convenience food) contained significantly higher levels of ash and all macroelements, regardless of the cultivar (Table 1). Among microelements, levels of iron, manganese and copper were higher in both cultivars, as well as zinc and cadmium in Igołomska (Table 2).

Compared with frozen seeds (either method of production) prepared for consumption, seeds preserved by sterilisation had a lower ash content (11-29%), as well as levels of phosphorus (28-48%), calcium (16-34%), magnesium (24-45%), iron (9-55%), zinc (8-33%), manganese (18-37%), copper (9-42%) and chromium (19-32%). Quantitative changes in the remaining elements depended on the cultivar. According to Korus [2002], sterilised seeds of immature grass pea were less abundant in ash, phosphorus, potassium, and iron than traditionally frozen seeds prepared for consumption.

Losses recorded at any given stage of the experiment were, to a large degree, apparent and caused by water being either absorbed or released by seeds; expressed in dry matter, differences in the levels of individual constituents in frozen and canned products were considerably smaller and, in many cases, insignificant (Tables 3 and 4).

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ZACHOWANIE SKŁADNIKÓW MINERALNYCH I WYBRANYCH METALI CIĘŻKICH W NIEDOJRZAŁYCH NASIONACH FASOLI ZWYCZAJNEJ (*PHASEOLUS VULGARIS* L.) W ZALEŻNOŚCI OD METODY UTRWALANIA

STRESZCZENIE

Wstęp. Rośliny strączkowe są dobrym źródłem białka, a także są bogate w węglowodany, witaminy z grupy B, błonnik pokarmowy i składniki mineralne.

Materiał i metody. W pracy oceniono zachowanie popiołu, 11 składników mineralnych i dwóch metali ciężkich w produktach z dwóch odmian fasoli zwyczajnej, zbieranych w stadium niepełnej dojrzałości o zawartości wody około 40%. W badaniach uwzględniono nasiona surowe, blanszowane i ugotowane oraz trzy produkty przygotowane do spożycia po 12 miesiącach przechowywania, w tym mrożonkę otrzymaną metodą tradycyjną (blanszowanie-mrożenie-zamrażalnicze składowanie-gotowanie), mrożonkę (traktowaną jako żywność wygodna) otrzymaną metodą zmodyfikowaną (gotowanie-mrożenie-zamrażalnicze składowanie-rozmrażanie i podgrzewanie do temperatury konsumpcyjnej w kuchni mikrofalowej) oraz konserwę sterylizowaną.

Wyniki. Gotowane nasiona fasoli w obu odmianach miały, z wyjątkiem popiołu i sodu (na skutek dodatku soli), istotnie mniej potasu, wapnia, magnezu i miedzi niż nasiona blanszowane, a zmiany pozostałych składników były niejednoznaczne i zależne od odmiany. W nasionach mrożonych według technologii zmodyfikowanej, w porównaniu z mrożonkami otrzymanymi metodą tradycyjną, na ogół było więcej badanych pierwiastków (z wyjątkiem chromu, niklu i ołowiu). Nasiona fasoli utrwalane na drodze sterylizacji zachowały, w porównaniu z produktami z obu sposobów mrożenia, mniej popiołu, fosforu, wapnia, magnezu, żelaza, cynku, manganu, miedzi i chromu, a zachowanie pozostałych składników zależało od badanej odmiany.
Wnioski. W porównaniu z produktem mrożonym tradycyjnie, przygotowane do spożycia nasiona mrożone metodą modyfikowaną (żywność wygodna) zawierały więcej popiołu i wszystkich makroelementów, niezależnie od odmiany. Nasiona utrwalone na drodze sterylizacji, w porównaniu z przygotowanymi do spożycia nasionami mrożonymi (z obu metod mrożenia), miały mniejszą zawartość większości analizowanych składników.

Słowa kluczowe: niedojrzałe nasiona fasoli, składniki mineralne, metale ciężkie, blanszowanie, gotowanie, sterylizacja, mrożenie

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