ACTA SCIENTIARUM POLONORUM Acta Sci. Pol., Technol. Aliment. 10(4) 2011, 475-486
ISSN 1644-0730 (print) ISSN 1889-9594 (online)

EVALUATION OF THE EFFECT OF PRETREATMENT AND PRESERVATION ON MACRO- AND MICROELEMENTS RETENTION IN FLAGEOLET (*PHASEOLUS VULGARIS* L.) BEAN SEEDS

Jacek Słupski
University of Agriculture in Krakow

Background. Legume seeds, including beans, are a good source of mineral constituents. The level of these compounds depends among other factors, on the species, cultivar and the methods of processing applied. However, there are no studies in the literature which deal with the content of mineral constituents in physiologically immature bean seeds.
Material and methods. The aim of this study was to evaluate the retention of ash and 13 mineral constituents in immature seeds of three bean cultivars. The investigation included raw, blanched and cooked seeds and three products prepared for consumption after 12-month storage: a frozen product obtained using the traditional method (blanching-freezing-frozen storage-cooking); a frozen product obtained using the modified method (cooking-freezing-frozen storage-defrosting and heating in a microwave oven); and a sterilized canned product.
Results. The application of technological processes; the storage of frozen and sterilized products; and the preparation of frozen products for consumption had an effect on minerals content in finished products. The frozen product obtained using the modified method retained greater amounts of the investigated elements (apart from calcium, lead and cadmium) than the traditional frozen product. Canned bean seeds retained less ash, phosphorus, potassium, calcium, magnesium, sodium and iron than the products of the two ways of freezing, while the retention of the remaining constituents depended on the cultivar.
Conclusions. Modified method of freezing of immature bean seeds resulted in greater retention of the investigated components in products prepared for consumption than the traditional method of freezing or canning.

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

Corresponding author – Adres do korespondencji: Dr inż. Jacek Słupski, Department of Raw Materials and Processing of Fruit and Vegetables of University of Agriculture in Krakow, Balicka 122, 30-149 Krakow, Poland, e-mail: rrslupsk@cyf-kr.edu.pl

INTRODUCTION

Seeds of leguminous plants are chiefly characterized by a high content of carbohydrates, proteins and B-group vitamins [Souci et al. 2000]. However, they also contain other important compounds, such as fats, dietary fiber, saponins, phytosteroles and mineral constituents [Champ 2002, Lisiewska et al. 2008, Sandberg 2002]. The level of mineral constituents depends, among other factors, on the species and cultivar [Martínez et al. 1998, Moraghan and Grafton 2001]. Heavy metal content is also connected with the site of plant growth [Srogi 2005] and the content of metals in the soil [Dąbkowska-Naskręt 2004].

Seeds of such species as pea, bean, grass pea, lentils or soy bean are most frequently consumed when physiologically mature. However, some seeds, including green pea, broad bean, grass pea, green bean, are also consumed when still immature, particularly in European countries [Korus 2002, Gębczyński 2008]. Flageolet beans are also consumed when not fully ripe. This vegetable is commonly grown in France, Belgium, the Netherlands and, more recently, Poland.

In view of their seasonal availability, leguminous vegetables are preserved using various methods, most frequently by canning in air tight containers and freezing. Unlike frozen products, canned vegetables are ready for consumption without any culinary preparation and may therefore be regarded as a convenience food. However, as shown by Kmiecik et al. [2000] and Lisiewska et al. [2002], even after preparation for consumption, frozen products preserve all chemical constituents, including mineral compounds, to a higher degree than canned food. Moreover, Gębczyński [2008] and Słupski [2010] demonstrated the possibility of producing frozen "do-it-for-me" products by cooking the raw material before freezing instead of blanching.

The aim of the work was to evaluate the retention of ash and 13 mineral constituents in three flageolet bean cultivars following blanching, cooking, canning, freezing and preparing products for consumption. Frozen products were obtained using two methods: the traditional method, in which the raw material is blanched before freezing; and the modified method, where the raw material was cooked before freezing, yielding a convenience food requiring only defrosting and heating in a microwave oven before consumption.

MATERIAL AND METHODS

Material. The investigated material consisted of fresh, immature seeds of three Flageolet bean cultivars used as the raw material; seeds after blanching or cooking, regarded as half-finished products; seeds processed using sterilization 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 Alamo and Flaforte, produced by the Dutch firm Pop Vriends Seeds BV, and the cultivar Mona, produced by the Polish firm "Polan" KHiNO. The cultivars were harvested and processed at 40% dry matter. At this stage of maturity the average weight for 1000 seeds and yield per hectare were:

Alamo, 450 g and 4.9 t·ha^{-1}; Flaforte, 370 g and 5.7 t·ha^{-1}; and Mona, 570 g and 6.7 t·ha^{-1} (unpublished data).

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 predetermined 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 sterilized 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 (Fig. 1). 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.

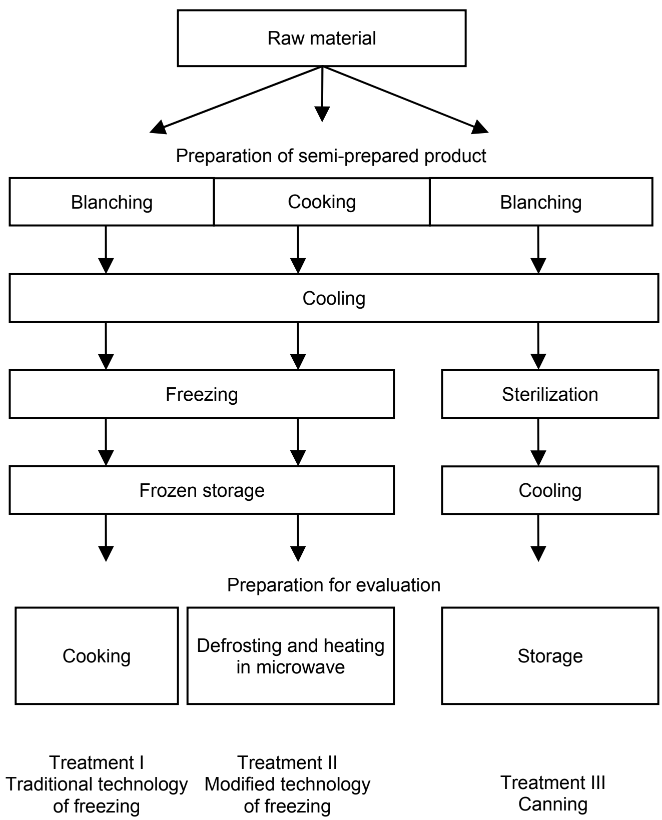

Fig. 1. Diagram of the processing

The 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 cultivars Alamo and Flaforte and 32 minutes for the cultivar Mona, 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 sterilization. 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 in 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 sterilization 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 sterilization temperature of 120 ±2°C for 16 minutes for the cultivars Alamo and Flaforte, and 14 minutes for the cultivar Mona; the time for the temperature to reach sterilization 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 38 minutes for the cultivars Alamo and Flaforte and 35 minutes for the cultivar Mona. After cooking, the water was drained and the 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 level of dry matter was determined using the method 32.064 given in AOAC [1984]. 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 individual mineral 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 mineral constituents in the raw material, semi-prepared products and final products prepared for consumption was expressed in terms of kg fresh matter. Presenting the results in this way made it possible to ascertain which of the different methods of freezing and preparation for consumption resulted in better retention of mineral constituents in the product as eaten. However, in order to allow for the possibility of expressing the results as dry substance, the dry matter content was quoted at each stage of the evaluation.

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 6.1 (StatSoft Inc., Tulsa, OK, USA) software.

RESULTS AND DISCUSSION

The content of ash in fresh bean seeds with a dry matter content of 40% was in the range of 16.5-17.5 g in 100 g fresh matter. The dominating constituent of ash was potassium (Table 1). The highest amount of potassium, constituting 30% of the total content of ash, was found in the seeds of the cultivar Mona. In the remaining two cultivars the potassium content was significantly lower, not exceeding 23%. Of the cultivars investigated, Alamo contained the highest amounts of calcium, zinc, manganese, copper, nickel and lead; Flaforte the highest amounts of sodium, chromium and cadmium; and Mona the highest amounts of ash, phosphorus, magnesium and iron; however, the differences were not always statistically significant (Tables 1, 2). The reported contents of mineral constituents in fresh bean seeds approximated to the ranges given by Korus [2002] and Lisiewska et al. [2006] for grass pea harvested at a similar stage of seed maturity and exceeded the quantities found for broad bean seeds at the stage of milk-wax maturity [Lisiewska et al. 2008, 1999].

Prefreezing processing contributed to changes in the content of different constituents. In all the cultivars, blanching brought about significant decreases in the content of ash (15% on average); phosphorus (8%); potassium (20%); magnesium (8%) and zinc (22%). A 14% increase was found in the content of calcium, while the level of sodium and manganese did not change. Moreover, in Alamo the content of iron, copper, nickel and lead was lower compared with the raw material; in Flaforte decreases were found in the content of chromium and cadmium; and in Mona the iron content was reduced.

Irrespective of the cultivar, the cooking of bean seeds to consumption consistency brought about a significant increase in the content of ash and sodium owing to the addition of table salt, and a decrease in the content of phosphorus, potassium, magnesium, iron, zinc, copper, lead and cadmium. Cooked Alamo seeds also contained less nickel compared with fresh seeds; Flaforte seeds contained less manganese, chromium and nickel but more calcium; and Mona seeds less manganese.

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

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 month storage		
					frozen seeds		
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	canned seeds (treatment III)
Dry matter $g \cdot kg^{-1}$	Alamo	398.7	371.5	358.6	347.8	393.3	293.2
	Flaforte	396.1	372.7	364.6	369.3	404.0	294.7
	Mona	400.0	373.7	354.9	353.4	389.3	293.6
Ash $g \cdot kg^{-1}$	Alamo	17.3^{e} ±0.6**	14.7^{b} ±0.4	18.5^{gh} ±0.3	18.7^{h} ±0.2	21.6^{j} ±0.2	14.5^{b} ±0.3
	Flaforte	16.5^{d} ±0.5	13.9^{a} ±0.4	18.0^{fg} ±0.4	18.8^{h} ±0.1	20.1^{i} ±0.2	14.7^{b} ±0.1
	Mona	17.5^{ef} ±0.8	14.8^{b} ±0.4	18.4^{gh} ±0.3	18.7^{h} ±0.2	19.9^{i} ±0.4	15.7^{c} ±0.2
P $mg \cdot kg^{-1}$	Alamo	2 120^{fg} ±66	1 978^{cde} ±44	1 833^{b} ±132	1 828^{b} ±56	1 963^{cde} ±130	1 298^{a} ±57
	Flaforte	2 000^{def} ±5.5	1 785^{b} ±71	1 865^{bc} ±68	1 795^{b} ±97	198^{cde} ±132	1 270^{a} ±88
	Mona	2 148^{g} ±62	2 008^{ef} ±51	1 873^{bcd} ±59	1 813^{b} ±53	203^{efg} ±130	1 333^{a} ±40
K $mg \cdot kg^{-1}$	Alamo	4 000^{hi} ±222	3 270^{g} ±220	2 310^{d} ±124	2 020^{c} ±104	2 500de ±92	1 490^{a} ±69
	Flaforte	3 820^{h} ±193	2 950^{f} ±131	2 530de ±69	1 840^{bc} ±78	2 610^{e} ±124	1 690^{ab} ±64
	Mona	5 182^{j} ±223	4 160^{i} ±264	3 060^{fg} ±74	2 400de ±83	2 900^{f} ±181	1 950^{c} ±64
Ca $mg \cdot kg^{-1}$	Alamo	745^{h} ±27	833^{j} ±31	779^{hi} ±28	843^{j} ±27	799^{ij} ±25	683^{fg} ±44
	Flaforte	573^{bc} ±47	650^{ef} ±18	653^{ef} ±27	748^{hi} ±41	728^{gh} ±27	593^{cd} ±23
	Mona	540^{b} ±27	628de ±40	583^{bcd} ±39	623^{cde} ±27	593^{cd} ±51	473^{a} ±47
Mg $mg \cdot kg^{-1}$	Alamo	538^{ij} ±28	495^{gh} ±16	406^{c} ±34	411^{cd} ±18	453^{ef} ±27	308^{a} ±25
	Flaforte	553^{j} ±23	506^{ghi} ±38	469^{fg} ±17	427^{cde} ±15	496^{gh} ±20	353^{b} ±13
	Mona	553j ±27	513^{hi} ±29	447^{def} ±19	415^{cd} ±20	475^{fg} ±30	328^{ab} ±22
Na $mg \cdot kg^{-1}$	Alamo	14.4^{a} ±0.8	20.8^{a} ±1.8	2 273de ±162	2 398^{fg} ±65	2 423^{fg} ±60	1 558^{b} ±137
	Flaforte	20.1^{a} ±0.11	26.1^{a} ±1.3	2 465^{fg} ±54	2 515^{g} ±114	2 635^{h} ±30	2 068^{c} ±55
	Mona	8.8^{a} ±0.9	20.3^{a} ±1.4	2 259de ±118	2 370^{ef} ±131	2 899^{i} ±87	2 155^{cd} ±80

*The 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 $p < 0.05$.

Table 2. Content of selected microelements in raw, blanched, cooked and frozen prepared for consumption and canned flageolet bean, in fresh matter*

Component	Cultivar	Raw seeds	Seeds before freezing		Product prepared for consumption after 12 month storage		
					frozen seeds		
			blanched	cooked	blanched before freezing (treatment I)	cooked before freezing (treatment II)	canned seeds (treatment III)
1	2	3	4	5	6	7	8
Fe mg·kg^{-1}	Alamo	16.6^{i} ±0.7**	15.5^{h} ±0.4	13.2^{def} ±0.7	12.6^{cd} ±0.3	14.8^{gh} ±0.4	11.2^{ab} ±0.7
	Flaforte	15.3^{gh} ±0.9	15.0^{gh} ±0.7	12.7^{cde} ±0.5	13.7^{ef} ±0.5	14.2^{fg} ±0.7	12.1^{bc} ±0.7
	Mona	16.9^{i} ±0.5	15.0^{gh} ±0.9	13.7^{ef} ±0.6	12.5^{cd} ±1.1	14.9^{gh} ±0.8	11.0^{a} ±0.8
Zn mg·kg^{-1}	Alamo	15.7^{j} ±0.7	11.8^{def} ±1.1	11.3^{de} ±0.7	10.1^{bc} ±0.6	13.0^{ghi} ±0.4	9.2^{ab} ±1.1
	Flaforte	13.7^{hi} ±0.5	10.7^{cd} ±0.5	10.7^{cd} ±0.5	10.6^{cd} ±0.5	11.7^{def} ±0.5	8.9^{a} ±0.5
	Mona	15.6^{i} ±0.7	12.6^{fgh} ±0.4	12.2^{efg} ±0.5	12.3^{efg} ±0.7	13.9^{i} ±0.5	12.6^{fgh} ±1.6
Mn mg·kg^{-1}	Alamo	5.50^{ij} ±0.42	5.35^{hij} ±0.49	5.00^{fghi} ±0.42	4.67^{defg} ±0.37	5.68^{j} ±0.45	4.28^{bcde} ±0.31
	Flaforte	5.35^{hij} ±0.34	5.18^{ghij} ±0.33	4.68^{defg} ±0.47	4.78^{efgh} ±0.39	5.10^{ghij} ±0.33	3.89^{ab} ±0.47
	Mona	4.25^{bcde} ±0.31	3.90^{abc} ±0.16	3.56^{a} ±0.39	3.67^{ab} ±0.34	4.10^{abcd} ±0.37	4.48^{cdef} ±0.67
Cu mg·kg^{-1}	Alamo	3.15^{i} ±0.29	2.65^{gh} ±0.24	1.89^{bc} ±0.21	2.00^{bcd} ±0.12	2.15^{cde} ±0.24	1.10^{a} ±0.18
	Flaforte	2.58^{fgh} ±0.31	2.30^{def} ±0.18	1.80^{b} ±0.24	1.18^{a} ±0.06	1.78^{b} ±0.17	2.00^{bcd} ±0.08
	Mona	2.80^{h} ±0.42	2.53^{fgh} ±0.21	1.68^{b} ±0.05	1.98^{bcd} ±0.10	2.38^{efg} ±0.22	2.80^{h} ±0.29
Cr mg·kg^{-1}	Alamo	0.06^{abc} ±0.01	0.07^{abcd} ±0.01	0.07^{abcd} ±0.01	0.06^{ab} ±0.01	0.07^{abcd} ±0.01	0.11^{ef} ±0.02
	Flaforte	0.11^{f} ±0.02	0.06^{ab} ±0.01	0.04^{a} ±0.01	0.08^{bcd} ±0.01	0.10^{def} ±0.01	0.10^{cdef} ±0.01
	Mona	0.09^{bcdef} ±0.01	0.08^{bcde} ±0.01	0.08^{bcd} ±0.02	0.12^{f} ±0.001	0.08^{bcd} ±0.01	0.09^{bcdef} ±0.01
Ni mg·kg^{-1}	Alamo	0.82^{k} ±0.03	0.71^{j} ±0.07	0.52^{gh} ±0.02	0.35^{c} ±0.02	0.51^{gh} ±0.03	0.37^{cd} ±0.02
	Flaforte	0.60^{i} ±0.02	0.56^{hi} ±0.04	0.38^{cd} ±0.02	0.29^{b} ±0.03	0.47^{fg} ±0.06	0.30^{b} ±0.02
	Mona	0.41^{de} ±0.02	0.44^{ef} ±0.04	0.42^{de} ±0.03	0.25^{ab} ±0.03	0.22^{a} ±0.02	0.29^{b} ±0.03
Pb µg·kg^{-1}	Alamo	0.42^{g} ±0.04	0.35^{def} ±0.01	0.29^{a} ±0.002	0.33^{bcdef} ±0.02	0.29^{a} ±0.02	0.29^{a} ±0.02
	Flaforte	0.35^{def} ±0.03	0.42^{g} ±0.02	0.30^{ab} ±0.002	0.31^{abcd} ±0.02	0.32^{abcde} ±0.04	0.34^{bcdef} ±0.02
	Mona	0.41^{g} ±0.03	034^{cdef} ±003	0.35^{ef} ±0.002	0.37^{f} ±0.01	0.37^{f} ±0.01	0.31^{abc} ±0.03

Table 2 – cont.

1	2	3	4	5	6	7	8
Cd $\mu g \cdot kg^{-1}$	Alamo	nd***	nd	nd	nd	nd	nd
	Flaforte	0.10[a] ±0.02	0.08[a] ±0.03	nd	nd	nd	nd
	Mona	nd	nd	nd	nd	nd	nd

*/**The explanations are as in Table 1.
***nd – not detected.

A comparison between blanched and cooked seeds prior to freezing showed that, irrespective of the cultivar, cooked seeds contained more ash and sodium (owing to the addition of table salt to water) but less iron, copper and lead. Moreover, cooked seeds of the cultivar Alamo contained less phosphorus, calcium, magnesium and nickel; seeds of the cultivar Flaforte contained less chromium; and in Mona, as was the case with Alamo, there was less phosphorus and magnesium.

It is known that extended thermal processing in water, in other words cooking, can lead to greater leaching of soluble constituents into water [Lisiewska et al. 2008, Bressani et al. 2004, Habiba 2002]. The mechanisms by which the level of soluble constituents decreases, or in some cases increases, are varied and the changes can be real or apparent. During hydrothermal processing the swelling of starch and the absorption of water by vegetable tissue bring about the "thinning" of constituents [Lisiewska et al. 2008, Habiba 2002, Lyimo et al. 1992]. In other cases, the shrinking of vegetable tissues and release of water can occur, resulting not in the "thinning" but in the "concentration" of constituents. The contact surface area between the raw material and the medium is also important in determining the extent to which constituents migrate [Lisiewska et al. 2008]. The cultivars investigated varied in weight per 1000 seeds by over 50%, hence the surface area open to the leaching of soluble compounds was also different. The seed coat also manifested different tendencies to crack during thermal processing, possibly leading to varied migration of mineral constituents. As stated by Lyimo et al. [1992] and Lestienne et al. [2005] different elements are distributed in different parts of seeds, hence they are more or less liable to leaching; the compounds in which they occur are characterized by different solubility in water, hence they are more or less resistant to leaching. Another factor affecting the leaching of mineral constituents can be the reduction of phytic acid and polyphenols, leading to the release of mineral constituents bound in the form of insoluble complexes [Duhan et al. 1999, Kheterpaul and Chauhan 1991]. On the other hand, the addition of salt during cooking and the use of tap water, which contains soluble substances, plays a protective role in limiting the losses [Kimura and Itokawa 1990]. This is particularly so if, as was the case in the present study, hard water is used.

Because the factors affecting changes occurring in the mineral constituents of plant material are many and varied, there can be no clear-cut explanation for the changes in the investigated material; moreover, the results quoted in the literature differ markedly. However, in a study on blanched immature grass pea seeds, Korus [2002] recorded losses similar to those found in the investigated bean with respect to ash, potassium and phosphorus, and a slightly higher increase in calcium content. Lisiewska et al. [2008] found decreases in the level of zinc, manganese and nickel after both blanching and cooking immature broad bean seeds, but in green pea decreases were found only in potassium and nickel, no differences being noted in the remaining elements. In the investigation of pea Koplik et al. [2004] observed a decrease in the level of investigated elements; however, no significant differences were found in the content of phosphorus, manganese, iron, nickel and copper between fresh, blanched and cooked seeds.

In all the bean cultivars, the cooking of frozen products obtained using treatment I (blanching-freezing-frozen storage-cooking) brought about a statistically significant increase in the content of ash and sodium and, as was the case in cooking fresh vegetables, a decrease in the level of potassium, magnesium, iron, copper and nickel, compared with blanched seeds prepared for freezing. Alamo seeds contained less phosphorus, zinc and manganese; Flaforte seeds more calcium and chromium but less cadmium; and Mona seeds less phosphorus and lead. As in the bean seeds investigated here, Kmiecik et al. [2000] found more ash, sodium and calcium but less potassium and zinc in cooked broad beans frozen using the traditional method compared with the raw material; no changes were found in the level of phosphorus, iron, sodium or manganese. Preparing seeds obtained using treatment II (cooking-freezing-frozen storage-defrosting and heating in a microwave oven) for consumption brought about an increase in the content of most constituents analysed; however, in all cultivars the increases were significant only in ash, sodium and iron content. Changes in the level of the remaining constituents varied in the different bean cultivars and were not always statistically significant. An increase in the content of ash constituents in the fresh matter of seeds obtained using treatment II can be explained by the evaporation of water during microwave heating, this being corroborated by an increase of about 10% in dry matter content in these products, that is, a "thickening" of constituents in the fresh matter of seeds.

Canned seeds (treatment III) contained significantly less ash (15% on average) than raw seeds, this being similar to the content in blanched seeds; however, the content of most elements analysed was significantly lower than in blanched seeds. These changes were largely due to the reduced content of dry matter (on average 26% less than in the raw material) and to the partial replacement of minerals by table salt in the brine.

Seeds obtained using treatment II contained significantly more ash, phosphorus, potassium and magnesium than those obtained using treatment I, irrespective of the cultivar. Moreover, Alamo also contained more iron, zinc, manganese and nickel and less lead; Flaforte more sodium, copper and nickel; and Mona more sodium, copper, iron and zinc, but less chromium.

Compared with frozen products prepared for consumption, canned bean seeds retained less ash (13-30%); phosphorus (27-36%); potassium (8-40%); calcium (15-24%); magnesium (17-32%); sodium (9-36%); and iron (11-26%). Changes in the content of the remaining constituents varied in the investigated cultivars. The above losses were largely only apparent and resulted from the considerable absorption of water by seeds; the dry matter content in these seeds was 16-27% lower than that found in frozen products prepared for consumption. According to Korus [2002], canned grass pea seeds, as in the bean seeds investigated here, contained less ash, phosphorus, potassium, magnesium and iron compared with seeds frozen using the traditional method and prepared for consumption. According to Habiba [2002], the autoclaving of vegetable pea brought about higher losses of ash and phosphorus than did cooking in water or heating in a microwave; prolonging the processing time increased these losses.

CONCLUSIONS

Modified method of freezing of immature bean seeds resulted in greater retention of the investigated components in products prepared for consumption than the traditional method of freezing or canning.

REFERENCES

AOAC, 1984. Official Methods of Analysis. Arlington, VA. Association of Official Analytical Chemists.

Bressani R., Turcios J.C., de Ruiz A.S.C., de Palomo P.P., 2004. Effect of processing conditions on phytic acid, calcium, iron, and zinc contents of lime-cooked maize. J. Agric. Food Chem. 52, 1157-1162.

Champ M.M.J., 2002. Non-nutrient bioactive substances of pulses. Br. J. Nutr. 88 (Suppl. 3), S307-S319.

Codex Alimentarius, 1993. Code of hygienic practice for precooked and cooked foods in mass catering. CAC/RCP 39. [online], http://www.codexalimentarius.net/web/ standard_list.jsp.

Dąbkowska-Naskręt H., 2004. The mobility of heavy metals in urban soils used for food production in Poland. Land Contam. Reclam. 12, 205-212.

Duhan A., Kheterpaul N., Bishnoi S., 1999. HCl-extrability of phosphorus of sprouted pigeon pea cultivars. Intern. J. Trop. Agric. 16, 211-215.

Gębczyński P., 2008. Zmiany zawartości wybranych związków przeciwutleniających w mrożonych warzywach w zależności od obróbki wstępnej, warunków składowania i sposobu przygotowania do spożycia [Changes in the contents of selected antioxidant in frozen vegetables as dependent on preliminary processing, conditions of storage and method of preparing for consumption]. Zesz. Nauk. AR Krak. 445, Rozpr. 322 [in Polish].

Habiba R.A., 2002. Changes in anti-nutrients, protein solubility, digestibility, and HCl-extractability of ash and phosphorus in vegetable peas as affected by cooking methods. Food Chem. 77, 187-192.

Kheterpaul N., Chauhan B.M., 1991. Effect of natural fermentation of phytate and polyphenolic content and in-vitro digestibility of starch and protein of pearl Millet (*Pennisetum typhoideum*). J. Sci. Food Agric. 55, 189-195.

Kimura M., Itokawa Y., 1990. Cooking losses of minerals in foods and its nutritional significance. J. Nutr. Sci. Vitaminol. 36, S25-S33.

Kmiecik W., Lisiewska Z., Jaworska G., 2000. Content of ash components in the fresh and preserved broad bean (*Vicia faba v. major*). J. Food Comp. Anal. 13, 905-914.

Koplik R., Kominková J., Borková M., Mestek O., Kvasnicka F., Suchánek M., 2004. Effect of technological processing and maturity stage of seeds on the content and speciation of phosphorus and trace elements in peas. Food Chem. 87, 423-432.

Korus A., 2002. Zawartość składników mineralnych w świeżych i konserwowanych nasionach dwóch odmian lędźwianu siewnego (*Lathyrus sativus L.*) o niepełnej dojrzałości fizjologicznej [Content of minerals components in fresh and preserved seeds of two grass pea (*Lathyrus sativus* L.) cultivars at the not fully mature stage]. Acta Sci. Pol., Technol. Aliment. 1, 35-44 [in Polish].

Lestienne I., Icard-Vernière C., Mouquet C., Picq C., Trèche S., 2005. Effects of soaking whole cereal and legume seeds on iron, zinc and phytate contents. Food Chem. 89, 421-425.

Lisiewska Z., Kmiecik W., Gębczyński P., 1999. Effect of maturity stages on the content of ash components in raw, frozen and canned broad beans. Food Chem. 67, 155-162.

Lisiewska Z., Korus A., Kmiecik W., 2002. Changes in the level of vitamin C, beta-carotene, thiamine, and riboflavin during preservation of immature grass pea (*Lathyrus sativus* L.) seeds. Eur. Food Res. Technol. 215, 216-220.
Lisiewska Z., Korus A., Kmiecik W., Gębczyński P., 2006. Effect of maturity stage on the content of ash components in raw and preserved grass pea (*Lathyrus sativus* L.) seeds. Int. J. Food Sci. Nutr. 57, 39-45.
Lisiewska Z., Słupski J., Kmiecik W., Gębczyński P., 2008. Availability of essential and trace elements in frozen leguminous vegetables prepared for consumption according to the method of pre-freezing processing. Food Chem. 106, 576-582.
Lyimo M., Mugula J., Elias T., 1992. Nutritive composition of broth from selected bean varieties cooked for various periods. J. Sci. Food Agric. 58, 535-539.
Martínez C., Ros G., Periago M.J., Ortunõ J., López G., Ricón F., 1998. In vitro protein digestibility and mineral availability of green beans (*Phaseolus vulgaris* L.) as influenced by variety and pod size. J. Sci. Food Agric. 77, 414-420.
Moraghan J.T., Grafton K., 2001. Genetic diversity and mineral composition of common bean seed. J. Agric. Food Chem. 81, 404-408.
Sandberg A.S., 2002. Bioavailability of minerals in legumes. Br. J. Nutr. 88 (Suppl. 3), 281-285.
Słupski J., 2010. Evaluation of the amino acid content and sensory value of flageolet bean seeds (*Phaseolus vulgaris* L.) as affected by preprocessing methods before freezing. Int. J. Food Sci. Technol. 45, 1068-1075.
Souci S.W., Fachmann W., Kraut H., 2000. Food composition and nutrition tables. Medpharm Scientific Publ. Stuttgart.
Srogi K., 2005. Heavy metal content in soils and medicinal herbs. Bromat. Chem. Toksykol. 38, 183-194.

WPŁYW OBRÓBKI WSTĘPNEJ PRZED MROŻENIEM I SPOSOBU UTRWALANIA NA ZAWARTOŚĆ MAKRO- I MIKROELEMENTÓW W NASIONACH FASOLI TYPU FLAGEOLET (*PHASEOLUS VULGARIS* L.)

Wstęp. Nasiona roślin strączkowych, w tym fasoli, są dobrym źródłem składników mineralnych. Poziom tych związków zależy między innymi od gatunku, odmiany i metod przetwarzania. W literaturze nie ma informacji na temat zawartości składników mineralnych w nasionach fasoli o niepełnej dojrzałości.
Materiał i metody. W pracy oceniano retencję popiołu i 13 składników mineralnych w niedojrzałych nasionach fasoli trzech odmian. Badania obejmowały surowe, blanszowane, gotowane nasiona i trzy produkty przygotowane do spożycia po przechowywaniu przez 12 miesięcy: mrożone produkty otrzymane metodą tradycyjną (blanszowanie-mrożenie-zamrażalnicze przechowywanie-gotowanie), mrożone produkty uzyskane z użyciem metody zmodyfikowanej (gotowanie-mrożenie-zamrażalnicze przechowywanie-rozmrażanie i podgrzanie w kuchence mikrofalowej) oraz konserwy sterylizowane.
Wyniki. Zastosowane zabiegi technologiczne, przechowywanie produktów mrożonych i sterylizowanych oraz przygotowanie produktów mrożonych do spożycia miało wpływ na zawartość składników mineralnych w produktach gotowych. Mrożone produkty uzyskane metodą zmodyfikowaną miały większe ilości badanych składników (z wyjątkiem wapnia, ołowiu i kadmu) niż produkty mrożone tradycyjnie. Nasiona fasoli sterylizowane w puszkach miały mniej popiołu, fosforu, potasu, wapnia, magnezu, sodu i żelaza niż produkty z obu sposobów mrożenia, natomiast od odmiany zależała retencja pozostałych składników.

Wnioski. Mrożenie nasion fasoli o niepełnej dojrzałości metodą zmodyfikowaną wpłynęło na większą retencję badanych składników w produktach przygotowanych do spożycia niż mrożenie sposobem tradycyjnym lub utrwalanie na drodze sterylizacji.

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

Received – Przyjęto: 16.06.2011

Accepted for print – Zaakceptowano do druku: 21.08.2011

For citation – Do cytowania: Słupski J., 2011. Evaluation of the effect of pretreatment and preservation on macro- and microelements retention in flageolet (Phaseolus vulgaris L.) bean seeds. Acta Sci. Pol., Technol. Aliment. 10(4), 475-486.