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Availability of essential and trace elements in frozen leguminous vegetables prepared for consumption according to the method of pre-freezing processing

Zofia Lisiewska *, Jacek Słupski, Waldemar Kmiecik, Piotr Gębczyński

Department of Raw Materials and Processing of Fruit and Vegetables, University of Krakow, 122 Balicka Street, 30-149 Krakow, Poland

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Abstract

The content of ash and P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, Cr and Ni was determined in broad bean and pea seeds of milk-wax maturity and in French-bean pods. The investigation covered the raw material; blanched and cooked material and frozen products prepared from blanched or cooked vegetables after 12 months of storage at −30 °C. Frozen products were prepared for consumption either by cooking or by defrosting and heating in a microwave oven. The smallest general loss of constituents caused by blanching was found in broad bean seeds, while the greatest loss was in French-bean pods. Cooking the same batch of the raw material increased the loss by 0–14%, depending on the species and the analysed element. In 100 g of product, prepared for consumption using the modified method (cooking–freezing–defrosting and heating in a microwave oven), the content of ash was greater by 4–12%; of phosphorus by 2–11%; of potassium by 16–36%; of magnesium by 17–31%; of iron by 7–23%; of zinc by 4–12%; of manganese by 4–16% and of copper by 3–13% compared with products obtained using the traditional method (blanching–freezing–cooking). The recorded level of the remaining elements was not always higher: in the case of calcium the difference varied from −2% to +7%; of sodium from −11% to +24%; of chromium from −14% to +9%; and of nickel from −4% to +54%.

Keywords: Broad bean; Pea, French-bean; Freezing; Cooking; Minerals

1. Introduction

Leguminous vegetables are characterised by a high content of carbohydrate compounds, proteins and group B vitamins (Kunachowicz, Nadolna, Przygoda, & Iwanow, 2005; Souci, Fachmann, & Kraut, 2000). Hence the researchers paid special attention to the above-mentioned nutrients. Only a few previous works deal with the content of mineral compounds in these vegetables and the products obtained from them, despite the fact that they are a rich source of these compounds (Kunachowicz et al., 2005).

In the climatic conditions of central-eastern Europe, the leguminous vegetables most popularly grown and consumed are pea and broad bean, at the stage of milk-wax maturity and French-beans. Unfortunately, the consumption of these vegetables is still too low in comparison with dietary recommendations (WHO/FAO Expert Report, 2003). This may be due to incorrect dietary habits but also due to the insufficient supply of ready-to-eat products easily prepared by the consumer.

Only a small amount of the species mentioned above are consumed directly after harvest, since the period of their supply during the growing season is very short. Both broad bean and pea, as well as French-bean, are valuable raw materials for canning and freezing. In contrast to frozen products, canned food can be consumed without further culinary preparation. However, as Kmiecik, Lisiewska, and Jaworska (2000); Korus, Lisiewska, and Kmiecik (2003); Lisiewska, Kmiecik, and Gębczyński (1999) and

* Corresponding author. Tel./fax: +48 12 662 47 57.
E-mail address: rrlisiew@cyf-kr.edu.pl (Z. Lisiewska).

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Lisiewska, Korus, and Kmiecik (2002) report, frozen products retain greater amounts of almost all chemical constituents compared with canned food, even after preparation for consumption by cooking in water.

The aim of this work was to evaluate the retention of the level of ash and 11 mineral constituents in frozen leguminous vegetables, prepared for consumption after 12 months of refrigerated storage. The investigation included seeds of pea and broad bean at the stage of milk-wax maturity and pods of French-bean. The investigated products were obtained using the traditional and the modified freezing processes, the modification being cooking to consumption consistency instead of blanching before freezing.

2. Materials and methods

2.1. Material

The investigated material consisted of three species of leguminous vegetables, namely broad bean – *Vicia faba* var. major (Windsor Biały cv.), pea – *Pisum sativum* – (Konsul cv.) and French-bean – *Phaseolus vulgaris* – (Delfina cv.). The seeds of broad bean and pea were at the stage of milk-wax maturity. The content of ash, P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, Cr and Ni was determined in fresh vegetables (A), after blanching (B), after cooking in 2% brine to consumption consistency (C); and in frozen products from samples B and C, after 12 months of storage at −30 °C and then prepared for consumption. Frozen products from sample B were cooked in brine, this yielding sample D and frozen products from sample C were defrosted and heated in a microwave oven, yielding sample E.

The raw material was obtained from the experimental field of the department carrying out the technological and analytical investigations. During the cultivation, all agrotechnological recommendations regarding soil preparation, fertilisation, sprinkling and plant protection against diseases and pests were taken into consideration.

2.2. Preparation of frozen products

Two variants of the pre-freezing treatment of the raw material were used. In variant I, which followed the traditional technology, the raw material was blanched and frozen and after refrigerated storage the product was cooked to consumption consistency. In variant II the raw material was cooked to consumption consistency before freezing and the subsequently frozen product was defrosted and heated to consumption consistency, in a microwave oven.

In variant I the raw material was blanched in water, in a stainless steel vessel at 95–98 °C, the proportion of the raw material to water being 1:5. The blanching time for the broad bean was 3 min 15 s, for French-bean −3 min and pea −2 min 30 s. The applied parameters of blanching brought about a decrease in the activity of catalase and peroxidase, to a level below 5% of the initial value. After blanching, the material was immediately cooled in cold water and left on sieves for 30 min to drain.

In variant II the vegetables were cooked in a stainless steel vessel in water, with 2% table salt, the proportion of the raw material to water being 1:1. The vegetables were put into boiling water. The time of cooking from the moment when the water came to the boil again was 12 min, 9 min and 8 min for broad bean, French-bean, and pea, respectively. After cooking to consumption consistency the material was placed on sieves and cooled in a stream of cold air.

The material from the blanched and cooked samples was placed on trays and frozen at −40 °C in a Feutron 3626-51 blast freezer. The time taken for the inside of the frozen products to reach the storage temperature of −30 °C was 120 min. The frozen products were packed in 500 g polyethylene bags and stored for 12 months.

2.3. Preparation of frozen products for evaluation

Samples blanched before freezing (B) were cooked in 2% brine, the proportion of brine to frozen product being 1:1. As in the case of cooking the raw material, frozen products were put into boiling water. The cooking time was measured from the moment the water came to the boil again. The cooking time was 8 min for broad beans and 6 min for French-beans and peas. After cooking, the water was immediately drained and the product was cooled to 20 °C (sample D being obtained) and analysed. Samples of the vegetables cooked before freezing were put into a covered heat-resistant vessel, defrosted and heated in a type NN-F 621 Panasonic microwave oven (sample E being obtained). The time taken to defrost and heat the product to 75 °C (Codex Alimentarius, 1993) was 8 min 15 s for all samples.

Whenever table salt was added, it was from the same batch.

2.4. Chemical analyses

The level of moisture was determined using the method given in AOAC (1984, 32.064). The content of ash was determined by incineration in a Nabertherm model L 9/S 27 furnace oven at 460 °C. In order to determine the level of individual mineral elements, the material was mineralised 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 mineralisation set. The treated samples were left until the next day, when complete mineralisation was carried out. The mineralised samples were diluted with ultra-pure water to a volume of 100 cm^3 and filtered into dry flasks. There was no residue left after filtration. 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. The accuracy of the vegetable analysis method was verified on the basis of certified reference material (GBW 08504 – State Metrology Bureau, Beijing, China) (cabbage), with concentration of K – 1.45 μg/g, Ca – 0.792 μg/g, Mg – 0.184 μg/g, Na – 0.757 μg/g, Fe – 52.0 μg/g, Zn – 26.7 μg/g, Mn – 22.0 μg/g, Cu – 3.00 μg/g and (IAEA/V-10 – International Atomic Energy Agency) (Hay) Cr – 6.5 μg/g, and Ni – 4.0 μg/g. All glassware and polyethylene flasks were soaked in 10% nitric acid for 24 h and then rinsed with ultra-pure water before use. The level of P was determined by the method given in AOAC (1984, 3.098). To an aliquot of the mineralised samples ammonium molybdate solution, hydroquinone solution and Na_2SO_3 solution were added. The solution was diluted and the absorbance, at 650 nm after 30 min incubation, was measured.

2.5. Statistical analysis

Analyses of the content of each component were carried out in three experimental replications, each in two parallel samples. The differences in the content of ash and analysed elements, between the compared samples from the investigated vegetable species, were established using single-factor analysis of variance (ANOVA) on the basis of the Snedecor F and Student's t tests and the least significant difference (LSD) was calculated at the probability levels of $p = 0.05$ and $p = 0.01$. The Statistica 6.1 program was applied.

3. Results and discussion

The content of mineral constituents in the raw material closely corresponds to ranges reported by Lisiewska et al. (1999) for broad bean, by Martínez et al. (1998) for French-bean and by Varo, Lähelmä, Nuurtamo, Saari, and Koivistoinen (1980) for pea. However, according to Singh and Garg (2006) the content of phosphorus, potassium, calcium, sodium, iron and manganese in pea seeds, was lower and the content of zinc was higher (Tables 2–4). Of the investigated species, broad bean seeds had the greatest content of ash, zinc and copper in 100 g fresh matter; pods of French-bean the greatest amounts of potassium, calcium and chromium and pea seeds of the remaining constituents in Tables 2–4. Owing to great differences in the level of moisture between the seeds of broad bean and pea and the pods of French-beans (Table 1), the calculation for the content of constituents to 100 g dry matter, showed that the French-bean contained the greatest amount of the analysed constituents with the exception of zinc and nickel, whose greatest content was found in pea and of copper, which was greatest in broad beans. In the following part of the work the results obtained at all the stages of the investigation will be given in 100 g fresh matter. This form of presenting the results makes it possible to establish whether the investigated changes in the methods of freezing and preparation for consumption had a beneficial effect on the retention of mineral constituents in the material prepared for consumption, that is, in fresh matter.

Table 1
Moisture content in raw, blanched, cooked then prepared for consumption vegetables

Sample	Broad bean		Pea		French-bean	
	g/100 g	%	g/100 g	%	g/100 g	%
A	72.7 ± 0.16	100	76.6 ± 0.02	100	90.8 ± 0.03	100
B	75.0 ± 0.18	103	75.5 ± 0.02	99	90.5 ± 0.05	100
C	71.5 ± 0.18	98	75.8 ± 0.02	99	89.0 ± 0.03	98
D	77.1 ± 0.14	106	76.6 ± 0.03	100	90.4 ± 0.01	100
E	69.6 ± 0.14	96	73.7 ± 0.09	96	88.4 ± 0.03	97

A – raw material, B – blanched material before freezing, C – cooked material before freezing, D – product after frozen storage prepared from blanched material before freezing by cooking and E – product after frozen storage prepared from cooked material before freezing by defrosting and heating in microwave oven.

The loss in mineral constituents brought about by blanching depended on the species. The smallest loss of most constituents was recorded in broad bean seeds (Table 2). A small loss in phosphorus, potassium, iron, zinc, copper and manganese during the blanching of broad bean was also reported by Kmiecik et al. (2000). The greatest loss was found in pods of French-bean, with the exception of sodium and nickel, whose content decreased the most in broad bean seeds and of calcium, potassium and chromium, where the greatest decrease was in pea seeds. Cooking of the same batch of the material, compared with the material after blanching, resulted in an increase in the content of ash and sodium due to the addition of table salt to the cooking water. The recorded decrease in the content of the remaining elements, due to cooking, was only slightly greater than that caused by blanching. Losses greater than the 13–14%, recorded in the blanched material, were found only in French-bean pods in the case of iron and in broad bean seeds in the case of chromium. As for the remaining constituents, the difference between the loss due to blanching and to cooking ranged from 0% to 10%. According to Santos, Abreu, and Carvalho (2003), the leaching of mineral constituents depended, as in the presented investigation, on the time of thermal processing in water and on the species. According to Kimura and Itokawa (1990) prolonging the thermal processing did not always lead to increased losses. However, Bressani, Turcios, Ruiz, and Palomo (2004) showed, that depending on the element, prolonging the thermal processing could result in increased, decreased or fluctuating loses. Kimura and Itokawa (1990) and Latunde-Dada (1990) reported that the addition of salt or other substances to water during cooking limited the losses, as was confirmed in the presented work.

Table 2
Content of selected minerals in raw, blanched, cooked and frozen then prepared for consumption broad bean

Sample	Ash g/100 g fresh matter	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu	Cr	Ni
		mg/100 g fresh matter										
A	1.13 ± 0.13	151 ± 19	230 ± 25	35.6 ± 6.2	33.1 ± 3.0	4 ± 0.6	1.61 ± 0.21	2.10 ± 0.24	0.329 ± 0.026	0.278 ± 0.024	0.007 ± 0.001	0.039 ± 0.007
B	0.98 ± 0.15	137 ± 18	201 ± 27	35.7 ± 4.2	32.3 ± 4.6	3 ± 0.6	1.50 ± 0.21	1.65 ± 0.14	0.283 ± 0.027	0.270 ± 0.037	0.007 ± 0.002	0.028 ± 0.005
C	1.49 ± 0.14	134 ± 11	196 ± 23	34.4 ± 3.8	30.4 ± 4.0	272 ± 52.6	1.49 ± 0.18	1.64 ± 0.25	0.282 ± 0.030	0.257 ± 0.026	0.006 ± 0.002	0.025 ± 0.002
D	1.38 ± 0.19	132 ± 19	170 ± 20	36.6 ± 2.5	26.4 ± 2.9	229 ± 20.6	1.42 ± 0.23	1.49 ± 0.19	0.270 ± 0.024	0.255 ± 0.031	0.007 ± 0.002	0.028 ± 0.003
E	1.55 ± 0.25	135 ± 21	197 ± 33	35.9 ± 1.9	30.8 ± 4.8	282 ± 41.3	1.52 ± 0.15	1.67 ± 0.17	0.296 ± 0.020	0.263 ± 0.027	0.006 ± 0.002	0.027 ± 0.002
LSD												
$p = 0.01$	0.371	ns	ns	ns	ns	65.21	ns	0.420	ns	ns	ns	0.0094
$p = 0.05$	0.268	ns	ns	ns	ns	47.15	ns	0.304	0.0385	ns	ns	0.0068

A – raw material, B – blanched material before freezing, C – cooked material before freezing, D – product after frozen storage prepared from blanched material before freezing by cooking and E – product after frozen storage prepared from cooked material before freezing by defrosting and heating in microwave oven.

Table 3
Content of selected minerals in raw, blanched, cooked and frozen then prepared for consumption pea

Sample	Ash g/100 g fresh matter	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu	Cr	Ni
		mg/100 g fresh matter										
A	0.97 ± 0.10	153 ± 20	175 ± 17	56.5 ± 5.5	33.2 ± 2.7	8 ± 1.0	2.03 ± 0.27	1.93 ± 0.27	0.445 ± 0.024	0.215 ± 0.025	0.016 ± 0.005	0.050 ± 0.006
B	0.75 ± 0.09	149 ± 15	136 ± 10	52.5 ± 8.2	31.4 ± 4.1	6 ± 0.8	1.88 ± 0.19	1.51 ± 0.23	0.439 ± 0.041	0.200 ± 0.033	0.011 ± 0.004	0.042 ± 0.005
C	1.22 ± 0.08	142 ± 19	124 ± 12	52.7 ± 8.0	28.7 ± 1.4	206 ± 18.2	1.69 ± 0.20	1.50 ± 0.23	0.395 ± 0.055	0.185 ± 0.023	0.011 ± 0.005	0.041 ± 0.004
D	1.17 ± 0.07	139 ± 21	106 ± 15	54.3 ± 4.8	25.3 ± 3.5	210 ± 14.8	1.55 ± 0.24	1.45 ± 0.21	0.401 ± 0.028	0.183 ± 0.018	0.011 ± 0.004	0.028 ± 0.005
E	1.26 ± 0.09	143 ± 9	130 ± 15	54.6 ± 4.7	29.5 ± 4.1	212 ± 15.0	1.76 ± 0.20	1.52 ± 0.22	0.417 ± 0.035	0.194 ± 0.024	0.012 ± 0.002	0.043 ± 0.005
LSD												
$p = 0.01$	0.186	ns	28.9	ns	ns	26.00	ns	ns	ns	ns	ns	0.0109
$p = 0.05$	0.134	ns	20.9	ns	5.02	18.80	ns	ns	ns	ns	ns	0.0079

A – raw material, B – blanched material before freezing, C – cooked material before freezing, D – product after frozen storage prepared from blanched material before freezing by cooking and E – product after frozen storage prepared from cooked material before freezing by defrosting and heating in microwave oven.

Table 4
Content of selected minerals in raw, blanched, cooked and frozen then prepared for consumption French-bean

Sample	Ash g/100 g fresh matter	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu	Cr	Ni
		mg/100 g fresh matter										
A	0.79 ± 0.10	60 ± 8	230 ± 22	60.6 ± 6.7	29.5 ± 4.0	7 ± 1.1	1.05 ± 0.19	0.63 ± 0.08	0.221 ± 0.025	0.084 ± 0.015	0.017 ± 0.004	0.014 ± 0.004
B	0.60 ± 0.09	53 ± 6	195 ± 24	59.1 ± 6.2	23.1 ± 2.5	6 ± 0.9	0.81 ± 0.07	0.50 ± 0.07	0.157 ± 0.020	0.058 ± 0.013	0.016 ± 0.003	0.013 ± 0.003
C	1.15 ± 0.06	50 ± 9	181 ± 21	58.4 ± 3.2	22.1 ± 2.2	138 ± 7.1	0.68 ± 0.08	0.48 ± 0.05	0.165 ± 0.019	0.055 ± 0.009	0.015 ± 0.003	0.012 ± 0.003
D	1.13 ± 0.08	47 ± 8	135 ± 18	55.8 ± 7.9	17.3 ± 1.6	161 ± 25.3	0.56 ± 0.04	0.46 ± 0.05	0.147 ± 0.017	0.052 ± 0.002	0.014 ± 0.004	0.011 ± 0.002
E	1.17 ± 0.09	52 ± 9	183 ± 26	59.9 ± 3.3	22.7 ± 2.2	143 ± 19.4	0.69 ± 0.08	0.48 ± 0.06	0.170 ± 0.021	0.059 ± 0.007	0.015 ± 0.003	0.013 ± 0.002
LSD												
$p = 0.01$	0.181	ns	46.8	ns	5.48	30.40	0.217	ns	0.0426	0.0213	ns	ns
$p = 0.05$	0.131	ns	33.9	ns	3.96	21.98	0.157	0.095	0.0308	0.0154	ns	ns

A – raw material, B – blanched material before freezing, C – cooked material before freezing, D – product after frozen storage prepared from blanched material before freezing by cooking and E – product after frozen storage prepared from cooked material before freezing by defrosting and heating in microwave oven.

Statistical analysis showed that while blanching did not significantly affect the level of phosphorus, calcium, sodium or chromium, it significantly decreased the content of ash (Tables 2–4). As regards the remaining constituents, the effects in the investigated species varied, since either the level of a given constituent was significantly lowered or no significant effect on its content was observed. In broad bean seeds, the content of zinc and nickel, as well as of manganese (but only at the significance level $p = 0.05$), was reduced, as was that of potassium and nickel in pea seeds ($p = 0.05$). In pods of French-bean the content of a greater number of constituents, namely magnesium, iron, manganese and copper, was significantly reduced, as was that of potassium and zinc at the significance level of $p = 0.05$.

A comparison of the content of analysed constituents in blanched and cooked material prepared for freezing, showed that the cooked material contained significantly more ash and sodium. Differences in the levels of the remaining elements were non-significant (Tables 2–4). In their investigation of pea, Koplik et al. (2004) found that, in spite of a decrease in the level of the investigated elements there were no significant differences between the fresh, blanched or cooked seeds in the content of phosphorus, manganese, iron, nickel or copper. Puupponen-Pimiä et al. (2003) also report statistically non-significant losses of mineral constituents during pea blanching. Neither did Kala and Prakash (2004) find any significant decrease in the level of mineral compounds during the cooking of various vegetable species.

The morphological structure of the raw material was certainly a factor in the difference in losses between the species. Pea seeds are smaller than those of broad beans, hence the surface/weight ratio makes them more susceptible to the leaching of constituents. Peas also have a less dense seed coat than broad beans. In the case of French-bean pods the surface exposed to the action of water was much greater than that of the seeds. Amaro, Moreno, and Zurera (2004) have reported similar observations.

The cooking of frozen products, obtained from blanched material, increased the loss of all the analysed constituents except for ash and sodium. This increase was due to the addition of salt to water during cooking. The greatest losses resulting from cooking frozen products were noted in potassium, magnesium and iron and – except for broad bean – in nickel. In frozen products obtained from material cooked before freezing and prepared for consumption the results were different. The content of the analysed constituents increased slightly and, consequently, compared with the raw material the loss was 0–5% smaller than directly after cooking, that is, in the material before freezing. In both kinds of frozen products, the observed changes in the content of the analysed compounds brought about by culinary processing should be regarded as small, except for ash and sodium. Analysis of the different products in terms of retention of the analysed elements, showed that in both kinds of

products, when compared with the raw material, the greatest retention was in broad bean seeds (Table 2) and the smallest in French-bean pods (Table 4). Nickel was the exception in that its greatest retention occurred in French-bean pods. In frozen broad beans, obtained using the traditional method, Kmiecik et al. (2000) found significantly less potassium and zinc in the cooked product compared with the raw material, no changes being noted in the levels of phosphorus, iron, copper and manganese. These authors also observed an increased content of calcium. Increased amounts of calcium in cooked products – compared with the content in the material before cooking – are commonly observed, as a result of the content of this element in the water used for cooking in the preparation of the product for consumption (Bressani et al., 2004; Kimura & Itokawa, 1990; Lisiewska, Korus, Kmiecik, & Gębczyński, 2006).

In comparison with the product prepared for consumption using the traditional method, the product prepared for consumption using the modified technology contained greater amounts of all the analysed elements, with the exception of chromium and nickel in broad bean and sodium in the French-bean product. The greatest differences, depending on species, were found in potassium 16–36%; magnesium 17–31%; iron 7–23%; manganese 4–16% and in nickel from −4% to +54%. Comparing the product obtained using the modified method with that obtained using the traditional technology, statistical analysis showed the former type to have a significantly greater content of nickel only in peas; of potassium in French-beans; of sodium at $p = 0.05$ in broad beans; of potassium in peas; and of magnesium in French-beans.

Augustin, Beck, Kalbfleisch, Kagel, and Matthews (1981b) found the retention of mineral constituents within the range 39–100% in cooked fresh French-bean. However, according to Lopez and Williams (1985), in frozen but not cooked French-beans the content of mineral constituents was 73–171% of that found in the raw material. The amounts of iron, potassium and phosphorus being smaller than in fresh French-beans; of calcium, sodium and zinc being greater; while the level of copper, magnesium and manganese unchanged. In contrast, Blumenthal, Meier, and Känel (1981) and Polo, Lagarda, and Farré (1992) postulate that fresh and frozen seeds of peas and pods of French-beans supply similar amounts of mineral constituents. According to Augustin, Beck, Kalbfleisch, and Kagel (1981a) and Lyimo, Mugula, and Elias (1992) the better retention of some elements could be due to their resistance to leaching *inbathing medium*. Moreover, due to changes in weight after blanching and cooking in water (Kmiecik et al., 2000).

4. Conclusions

The effect of the two methods of pretreatment before freezing (blanching and cooking in 2% brine) on the retention of the investigated elements was similar, a slightly smaller content of all the elements, except for ash and sodium, being found in the cooked vegetables. In the product prepared for consumption after frozen storage, obtained using the modified method (cooking–freezing–defrosting and heating in a microwave oven) the amounts of all the investigated elements were almost always greater than in the product obtained using the traditional method (blanching–freezing–cooking). However, statistical analysis only showed a greater content of nickel in pea and potassium in French-beans and at the significance of $p = 0.05$, also of sodium in broad bean; of potassium in pea and of magnesium in French-beans.

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