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THE INFLUENCE OF EXTRUSION ON CHEMICAL COMPOSITION OF DRY SEEDS OF BEAN (*PHASEOLUS VULGARIS* L.)

Jarosław Korus, Dorota Gumul, Bohdan Achremowicz
Department of Carbohydrates Technology, Agricultural University of Cracow, Poland

ABSTRACT

The aim of present work was to evaluate the influence of extrusion parameters on chemical composition of seeds of five bean cultivars. Milled seeds were moisturized to 14% or 20%, and processed in single screw extruder at 120 or 180°C. On raw material and extrudates the following analyzes were performed: protein, lipids, TDF, SDF and IDF content. Also content of starch, ash and mineral compounds was analyzed. The content of analyzed compounds in 100g of dry basis of not processed bean varied depending on cultivar, in the range: 23.9–29.8 g of protein, 1.54–1.78 g of lipids, 59.9–68.4 g of total carbohydrates, 32.2–39.6 g of starch, 20.6–24.5 g of TDF and 3.81–4.21 g of ash. After extrusion the content of these compounds was as follows: 23.8–30.2 g of protein, 1.41–1.82 g of lipids, 53.1–60.7 g of total carbohydrates, 28.7–35.0 g of starch, 3.64–4.03 g of ash and 19.5–23.8 g of TDF. Extrudates obtained from higher moisture raw material had higher content of lipids, total carbohydrates and insoluble dietary fiber in comparison to extrudates from lower moisture raw material. Except higher moisture also lower temperature of process influenced of better preservation of mentioned above components. There was no significant influence of extrusion parameters on minerals content.

Key words: bean, *Phaseolus vulgaris*, chemical composition, extrusion.

INTRODUCTION

Seeds of legumes, including also common bean *Phaseolus vulgaris* L. are valuable component of diet due to high content of protein, dietary fiber, mineral compounds and B group vitamins [23, 27]. Their chemical composition is subjected to fluctuations, depending on various factors like cultivar and maturity stage, environment (mostly weather conditions), agrotechnics and others [8]. Kahlon et al. [18] ascribed low incidence of blood circulation diseases of Asia inhabitants to, among others, relatively high consumption of legume seeds (110 g daily per person, in USA only about 9 g). In the last decades consumption of legumes in Europe significantly diminished, but increasing number of vegetarians and growing knowledge about healthy nutrition habits slowly caused changes in this tendency [27]. According to author's low consumption of legume seeds is caused by long time needed to prepare meal, and by lack of the new product available on market. The chance to overcome those obstacles it may be an implementation of a new technologies, which up to present time were not used in legumes processing. Submission of milled seeds of bean to extrusion allows to obtain ready to eat snacks, moreover it significantly decreases content of antinutrients present in this product [1, 2, 20, 24], which occurrence in all seeds of legumes is serious factor limiting their consumption.

The aim of present work was to evaluate the influence of extrusion parameters on chemical composition of dry seeds bean extrudates.

MATERIAL AND METHODS

Dry seeds of five polish cultivars of bean, with different color of cover: red-Augusta and Rawela, black–Nigeria, Tip-Top and cream–Toffi were used in this research. They were grown in breeding station and horticulture seed production PlantiCo in Szymanów, Poland. The seeds were disintegrated in pulverisette 14 mill (Fritsch, Idar-Oberstein, Germany) and moisten up to 14 or 20% of humidity. Extrusion was carried out in single screw extruder 20 DN (Brabender, Duisburg Germany). Two temperature profiles were applied: 80ºC/100ºC/120ºC and 120°C/160°C/180°C. Both on raw material and obtained extrudates the following analyses were performed: protein content according to Kjeldahl (AOAC 2.047) in Büchi B 324 (N×6.25), lipids by Soxhlet method in Büchi Universal Extraction System B811 (AOAC 920.39), dietary fiber (AOAC 991.43), sugars (AOAC 32.041), starch according to ICC standard no 122, and ash (AOAC 32.027) [3, 16]. Total carbohydrates content was expressed as sum of starch, dietary fiber and sugars after inversion.

Macro- and microelements were measured by weighting of 3.000 g of air dry sample in quartz evaporating dish and incineration for 12 h at 450°C. Then ash was treated with 5 mL of HNO_3 (1:2) and carefully vaporized to dryness at heating place. Remnants of carbon in the sample were burnt in furnace for 3 h at 450°C. The residue was treated with 5 mL of HCl in order to precipitate silica, vaporized to dryness, again was treated with 5 mL of HNO_3 (1:2) and after boiling under cover was filtered through paper filter, washing the deposit with 1% HCl. The content of metals in solution was measured with the means of atomic emission spectrometer (ICP-AES) JY 238 ULTRACE with inductive induced argon plasma (Jobin-Yvon, France).

Obtained results were calculated on dry basis of 100 g sample, and statistically evaluated with the means of F Snedecor and t-Student tests. The least significant difference (LSD) was calculated at p = 0.01 level. All analyses were conducted at least in triplicate.

RESULTS AND DISCUSSION

Raw dry bean seeds

Protein content in 100g dry basis of not processed seeds of bean depended on cultivars and oscillated from 23.9 to 29.8 g (Table 1). Seeds of Augusta, Nigeria and Rawela cultivars had similar protein content, significantly lower was discovered in Tip-Top cultivar, and the highest in Toffi. Similar content of protein in bean was reported by Berrios et al. [4] – 25.9 g and Candela et al [6] – 23.3 g, slightly lower – 22.4 g Granito et al. [11]. Fernández-Quintela et al. [9] discovered in soya bean 36.7 g of this compound, Brand et al. [5] 26.0 g in faba bean, 24.7 g in field pea and 39.3 g in sweet yellow lupine (*Lupinus luteuus*).

Table 1. Chemical composition of raw dry seeds of bean

It1em	Cultivar					LSD p = 0.01
	Augusta	Nigeria	Rawela	Tip-Top	Toffi	
Dry matter g × 100 g^{-1}	88.8	86.7	87.6	88.3	87.5	n.s.
Protein g × 100 g^{-1}d.b.	28.1	28.5	28.4	23.9	29.8	0.68
Lipids g × 100 g^{-1}d.b.	1.78	1.54	1.71	1.67	1.63	0.078
Carbohydrates g × 100 g^{-1}d.b.	64.5	64.1	59.9	68.4	60.9	0.41
Starch g × 100 g^{-1}d.b.	38.5	36.9	32.2	39.6	32.2	n.s.
Total dietary fiber (TDF) g × 100 g^{-1}d.b.	20.6	21.8	20.6	24.5	22.6	2.48
Soluble dietary fiber (SDF) g × 100 g^{-1} d.b.	9.45	9.96	5.95	7.42	8.41	2.471
Insoluble dietary fiber (IDF) g × 100 g^{-1} d.b.	11.16	11.83	14.65	17.13	14.19	1.494

n.s. – not significant.

Cultivars Tip-Top and Toffi had similar content of lipids, significantly higher amount was discovered in Augusta and Rawela cultivars, which had the greatest amount in this compound (1.78 g and 1.71 g respectively). Nigeria had the smallest amount of lipids, and contained it in significantly lower dose – 1.54 g. Berrios et al. [4] and Granito et al. [11] discovered the similar amount of lipids in the investigated cultivars of bean, but Candela et al. [6] reported the value of 3.50 g in bean. Grela et al. [12] discovered in grass pea 0.8 g of this compound, Brand et al. [5] 1.4 g in faba bean, 1.2 g in field pea and 5.4 g in sweet yellow lupin.

Seeds of legumes are important source of carbohydrates in diet. Their content in 100 g of dry matter varied from 59.9 g in Rawela to 68.4 g in Tip-Top. This range covers values reported by Vargas-Torres et al. [30] and Berrios et al. [4]. On other hand Candela et al. [6] showed significantly lower level of carbohydrates as 43.2 g. Fernández-Quintela et al. [9] determined 59.4 g and 52.1 g of carbohydrates in pea and faba bean respectively. Among seeds of legumes the lowest content of carbohydrates was noted in soya bean 35–39 g [26].

There were no significant differences in starch content among investigated cultivars. The most of starch was in Tip-Top seeds – 39.6 g, the least of all in Rawela and Toffi cultivars 32.2 g. Similar amount of starch, at level of 33.6 – 36.7 g, was reported by Vargas-Torres et al. [30] in five cultivars of bean, and by Granito et al. [11]. On other hand Lisiewska et al. [22] and Korus et al. [19] reported 48.2–50.8 g × 100 g^{-1} db of starch in grass pea.

Compared in this work cultivars of bean significantly differed in total dietary fiber content and its soluble fraction. The most abundant in total dietary fiber (TDF) was seeds of Tip-Top cultivar – 24.5 g, but significantly the smallest amount was in Augusta and Rawela 20.6 g. The highest amount of soluble fraction (SDF) was in Nigeria – 9.96 g, the lowest once again Rawela – 5.95 g. However the highest amount of insoluble dietary fiber fraction (IDF) was discovered in Tip-Top – 17.13 g, the lowest in Augusta – 11.16 g. Martín-Cabrejas et al. [23] recorded similar amount of TDF, SDF and IDF in bean of Carilla cultivar – 24.5 g, 7.7 g, 17.1 g respectively. Considerably higher amounts were discovered by Granito et al. [11] and Candela et al. [6] – respectively in case of TDF 31.76 g and 32.11 g, IDF fraction-28.50 g and 27.18 g, but lower in case of SDF fraction-3.26 g and 4.93 g.

Total ash content was on similar level in Augusta and Nigeria cultivars (average 3.82 g), and in the remaining cultivars was about 10% higher (Table 2). Similar values were reported in bean by Granito et al. [11], slightly higher 4.65 g was given by Berrios [4] and 4.87 g by Candela et al. [6]. However Lisiewska et al. [22] determined in grass pea 3.4 g of total ash, Brand et al. [5] 2.79 g in faba bean, 3.01 g in pea and 4.52 g in sweet yellow lupine. Seeds of legumes are source of many valuable nutritional components, including among others minerals. The most deficient in theses compounds was Augusta cultivar, which contained the smallest amounts of Fe, Zn, Mn and Cu. In Nigeria cultivar there was found the lowest level of K, P and Mg, but the highest of Ca, Fe, Zn and Mn. Investigated dry bean seeds were characterized by potassium and magnesium level close to value determined by Granito et al. [11], phosphorus and iron levels were higher 32% and 60% respectively, but calcium level was about 38% lower (Table 2). In turn Lisiewska et al. [22] noted in grass pea similar to investigated beans amount of potassium and magnesium, and lower amount: of calcium (about 70%), iron-32%, and 20% less of phosphorus. Wang and Daun [31] found, that field pea had similar level of K, Zn and Mn, lower about 17% amount of P, 33%-Ca and 42% Fe, but content of Mg was 10% higher and Cu–17%.

Table 2. Contents of total ash and minerals in raw seeds of bean (on dry basis)

Cultivar	Item									
	Ash g × 100 g^{-1}	K mg × 100 g^{-1}	P mg × 100 g^{-1}	Mg mg × 100 g^{-1}	Ca mg × 100 g^{-1}	Fe mg × 100 g^{-1}	Zn mg × 100 g^{-1}	Na mg × 100 g^{-1}	Mn mg × 100 g^{-1}	Cu mg × 100 g^{-1}
Augusta	3.81	999	556	122	103	8.7	2.6	1.9	1.11	0.53
Nigeria	3.83	933	521	151	123	11.1	4.5	1.6	1.48	0.66
Rawela	4.07	1014	578	144	95	9.4	3.5	2.0	1.14	0.72
Tip-Top	4.21	1275	629	163	152	10.7	2.9	1.5	1.36	0.49
Toffi	4.05	1175	648	166	105	10.6	3.5	1.5	1.33	0.61
LSD $p = 0.01$	0.191	74.7	39.6	7.5	9.9	1.25	1.11	n.s.	n.s.	n.s.

n.s. – not significant.

Extrudates from dry bean seeds

Protein content in bean extrudates was in range 23.8 g – 30.2 g (Table 3). Although average for different extrusion parameters was similar 27.4 g – 27.8 g, the differences were statistically proved. In comparison to raw material it was discovered slightly decrease in protein content, the most obvious in extrudates from Augusta cultivar (14%/120°C) and Toffi (20%/180°C), average about 3%. Increase about 4%, was noted in extrudate from Rawela (20%/120°C). Basing on obtained results there is no chance to state about unequivocal tendency concerning the influence of extrusion temperature and raw material moisture on protein content. It may be only assessed, that extrusion process in most cases decreased the protein content. Findings of other author about influence of extrusion process on protein content are divergent. Marzo et al. [24] discovered the increase about 7% of protein content in extruded bean. Lipiec et al. [21] observed lack of influence of extrusion temperature and moisture of raw material on protein content in extruded lupine. Prakrati et al. [25] discovered the increase of protein content in faba bean during extrusion, the highest at low temperature (75°C) and 20% moisture. But Cardoso-Santiago and Arêas [7] observed the decrease of protein content in chickpea after extrusion, about 19%. Besides quantative changes of total protein many authors indicate on oscillation of amino acids composition occurring as a result of extrusion process [7, 14, 25]. Moreover reduction of antinutrients, in this case mostly trypsine inhibitors, influences the increase of digestibility legumes seeds after extrusion [1, 2, 17, 29].

Table 3. Chemical composition of bean extrudates

Cultivar	Extrusion parameters				average for cultivar	LSD* p = 0.01
	14%/120°C	20%/120°C	14%/180°C	20%/180°C		
Dry matter [g × 100 g^{-1}]						
Augusta	91.7	90.9	92.0	91.2	91.5	I – n.s. II – 0.40 III – n.s.
Nigeria	91.7	90.7	92.3	91.0	91.4	
Rawela	91.8	90.7	91.9	91.2	91.4	
Tip-Top	91.6	90.9	92.3	91.4	91.6	
Toffi	91.9	90.7	92.4	91.3	91.6	
Average for extrusion parameters	91.7	90.8	92.2	91.2	X	
Protein [g × 100 g^{-1}d.b.]						
Augusta	27.1	27.8	27.8	27.8	27.6	I – 0.11 II – 0.01 III – 0.22
Nigeria	28.3	29.0	28.0	28.2	28.4	
Rawela	27.9	29.4	28.3	28.1	28.4	
Tip-Top	24.0	23.8	24.1	24.4	24.0	
Toffi	30.2	28.9	29.1	28.9	29.3	
Average for extrusion parameters	27.5	27.8	27.4	27.5	X	
Lipids [g × 100 g^{-1}d.b.]						
Augusta	1.57	1.78	1.57	1.76	1.67	I – 0.053 II – 0.048 III – 0.107
Nigeria	1.53	1.59	1.48	1.55	1.54	
Rawela	1.62	1.82	1.63	1.69	1.69	
Tip-Top	1.70	1.71	1.69	1.78	1.72	
Toffi	1.52	1.44	1.52	1.41	1.47	
Average for extrusion parameters	1.59	1.67	1.58	1.64	X	
Carbohydrates [g × 100 g^{-1}d.b.]						
Augusta	56.0	56.8	53.5	56.0	55.6	I – 0.35 II – 0.31 III – 0.70
Nigeria	55.8	59.4	53.1	57.1	56.4	
Rawela	56.0	60.7	54.1	57.5	57.1	
Tip-Top	59.0	59.6	58.1	58.8	58.9	
Toffi	56.7	58.2	56.4	56.5	56.9	
Average for extrusion parameters	56.7	58.9	55.1	57.2	X	
Starch [g × 100 g^{-1}d.b.]						
Augusta	32.0	32.2	28.8	31.9	31.2	I – 0.08 II – n.s. III – n.s.
Nigeria	30.2	33.2	28.7	32.4	31.1	
Rawela	31.0	35.0	28.8	32.6	31.8	
Tip-Top	30.8	33.0	30.2	31.0	31.3	
Toffi	29.3	30.8	29.3	30.9	30.1	
Average for extrusion parameters	30.7	32.8	29.2	31.7	X	

* LSD for: factor I – cultivar, factor II – extrusion parameters, factor III – interaction (IxII)
n.s. – not significant.

In most cases lipid content after extrusion was lower or remained unchanged. In Tip-Top cultivar content of this component increased at all extrusion parameters average 3% (Table 3) in comparison to raw material. Moreover increase of lipids content was observed in extrudates obtained from Nigeria and Rawela cultivars at 120°C, 20% initial moisture. The highest increase of lipid content, about 7%, was noted in extrudates obtained from Tip-Top cultivar (20%/180°C), the greatest decrease – 14% in Toffi cultivar extruded at the same conditions. It can be seen from data published in Table 3, that samples moisturized before extrusion up to 20% kept more lipids than samples with 14% initial moisture. Only in Toffi extrudates reverse tendency occurred. Grela et al. [12] discovered, that moisturization of grass pea seeds before extrusion, maximally up to 22% caused about 17% increase of lipid content in extrudates, in comparison to raw material. Further increase of humidity caused decrease of lipids content in extrudates about 32%. Applying by these authors low extrusion temperature (not exceeding 100°C) caused increase of lipids content in extrudates about 12%, but higher temperatures of the process caused decrease in content of lipids. Moreover they found positive effect of greater moisturization of raw material on lipid fraction composition. At water content in range 14-30% they reported the decrease in content of saturated fatty acids and concomitant increase of polyunsaturated fatty acids. Marzo et al. [24] discovered almost 50% decrease of lipids content in bean extrudated at 150°C and 25% moisture level. These authors attributed this phenomenon to high temperature action, causing partial decomposition and volatilization of lipid components. On other hand Lipiec et al. [21] found in extruded lupine the decrease of lipids content, maximally about 27%, that resulted from creation of amylose-lipid and lipid-protein complexes under conditions of temperature, moisture and pressure. Similarly, the decrease of lipids content during extrusion of faba bean were discovered by Prakrati et al. [25] and about 54% by Cardoso-Santiago and Arêas [7] in chickpea.

After extrusion total carbohydrate and starch content were lower. The greatest decrease of starch content-25% was observed in extrudates from Toffi cultivar (14%/180°C). In case of total carbohydrates content the greatest decrease was noted in extrudates obtained from cultivars Nigeria and Augusta, (14%/180°C), about 17%, the smallest in Toffi (14%/180°C) about 8%. Extrusion parameters: 14% humidity and temperature of 180°C caused in all analyzed bean cultivars the greatest decrease of starch and total carbohydrate content. Again, it can be noticed, that in samples moisturized before extrusion to 20%, more this constituents were preserved than in samples with lower humidity. Cardoso-Santiago and Arêas [7] noted, that after extrusion of chickpea level of total carbohydrates was higher about 8%. Guillon i Champ [13] noted that, due to high amylose content, starch from legumes is less absorbed in digestive tract than starches of other botanical origin: cereal or tuber. However, Alonso et al. [2] observed, that extrusion process increased in vitro digestibility of starch and proteins from faba bean and kidney bean. Increase in digestibility after extrusion was greater than in case of dehulled, moisturized and sprouted seeds.

Total dietary fiber (TDF) content in all samples after extrusion was smaller in the range 3 – 9%, the most in case of Tip-Top extrudates (14%/180°C), the least in obtained from Augusta (14%/180°C) – Table 4. Mentioned above extrusion parameters caused the greatest decrease of TDF in case of Augusta, Nigeria and Rawela cultivars. Influence of extrusion temperature and raw material moisture was not so obvious as in case of starch and total carbohydrates. Similarly in all extrudates the content of non-soluble dietary fiber decreased. The greatest decrease was observed in extrudates obtained from seeds of Tip-Top (14%/120°C) – 22%, and the smallest (and comparable) in Nigeria (14%/120°C) and Augusta (14%/180°C) – 11%. Once again in samples with higher initial humidity, the content of the investigated component was higher than in samples with lower initial humidity. Level of SDF increased in all extrudates. In extrudate obtained from Rawela (14%/180°C) it increased about 33%, the smallest increase – 4% was observed in Nigeria extrudate (14%/120°C). Hughes [15] indicates bean as rich and cheap source of dietary fiber, both soluble and non-soluble. Dietary fiber is important component of foodstuff in respect of their nutritional value. The role in prevention of circulation system diseases, in regulation of intestine work, in maintaining the proper blood glucose level and others is attributed to this components.

Table 4. Total dietary fiber (TDF), soluble fiber (SDF) and insoluble fiber (IDF) contents in bean extrudates (in dry basis)

Cultivar	Extrusion parameters				average for cultivar	LSD* p = 0.01
	14%/120°C	20%/120°C	14%/180°C	20%/180°C		
Total dietary fiber (TDF) [g × 100 g^{-1}]						
Augusta	20.5	20.4	20.0	20.6	20.4	I – 0.82 II – n.s. III – n.s.
Nigeria	21.0	21.0	20.8	21.3	21.0	
Rawela	19.7	20.0	19.5	20.1	19.8	
Tip-Top	22.5	23.5	22.4	23.8	23.1	
Toffi	21.5	21.9	21.5	21.4	21.6	
Average for extrusion parameters	21.0	21.4	20.8	21.4		
Soluble dietary fiber (SDF) [g × 100 g^{-1}]						
Augusta	10.01	9.89	10.02	9.98	9.98	I – 0.446 II – n.s. III – n.s.
Nigeria	10.36	9.97	10.01	10.21	10.14	
Rawela	7.92	7.55	7.93	7.58	7.75	
Tip-Top	9.17	9.03	8.50	9.59	9.07	
Toffi	9.40	8.59	8.92	9.10	9.00	
Average for extrusion parameters	9.37	9.01	9.08	9.29	X	
Insoluble dietary fiber (IDF) [g × 100 g^{-1}]						
Augusta	10.49	10.55	9.98	10.62	10.41	I – 0.601 II – 0.538 III – n.s.
Nigeria	10.59	11.01	10.74	11.06	10.85	
Rawela	11.82	12.40	11.61	12.49	12.08	
Tip-Top	13.29	14.50	13.92	14.20	13.98	
Toffi	12.10	13.32	12.58	12.28	12.57	
Average for extrusion parameters	11.66	12.36	11.77	12.13	X	

* LSD for: factor I – cultivar, factor II – extrusion parameters, factor III – interaction (IxII)
n.s. – not significant.

Ash content in extrudates was lower or similar as in raw material (Table 5). The greatest decreased – 11% was observed in extrudate from Rawela moisturized to 20% and extruded at 120°C. Extrudates from Augusta, Nigeria and Rawela were characterized by similar level of ash–average 3.73 g, significantly higher was in Toffi and Tip-Top respectively 3.86 g and 4.00 g. Lack of significance of extrusion parameters on ash content was observed by Marzo et al. [24], which discovered about 4% increase of this component content in bean extrudates. Lipiec et al. [21] notice about 4% decrease of this component when investigated lupine extrudates. Slightly higher losses caused by extrusion were discovered by Cardoso-Santiago and Arêas [7], the ash content in chickpea was 10% lower. In most cases in extrudates there was significant diversification in mineral compounds content caused by extrusion parameters, greater influence could be attributed to cultivar (Tables 5 and 6).

Positively the poorest in mineral compounds (K, P, Mg, Ca and Fe) were extrudates obtained from Augusta and Rawela cultivars, but the most abundant–Nigeria and Tip-Top. Extrudates obtained from Toffi cultivar contained the greatest amounts of P, Mg and Cu, and the least of Ca. Average content in all extrudates of particular major and minor compounds was similar to non-processed seeds of appropriate cultivar. There is lack of information about influence of extrusion process on mineral components in bean extrudates. Besides quantity of particular mineral compounds, also their bioavailability is important. One of anti-nutritive factor in bean seeds is fitic acid, which creates insoluble salts with K, Mg, Ca, Mn Zn and Fe ions, that limits their bioavailability [10, 28]. Abd El Hady and Habiba [1] noticed, that extrusion decreased content of fitic acid in faba bean, pea and kidney bean. The level of this compound was decreasing alongside with increase of raw material humidity and process temperature.

Table 5. Contents of total ash and macroelements in bean extrudates (in dry basis)

Cultivar	Extrusion parameters				average for cultivar	LSD* p=0.01
	14%/120°C	20%/120°C	14%/180°C	20%/180°C		
Ash [g × 100 g^{-1}]						
Augusta	3.73	3.68	3.79	3.76	3.74	I – 1.188 II – 1.063 III – 2.377
Nigeria	3.80	3.64	3.76	3.68	3.72	
Rawela	3.80	3.64	3.75	3.78	3.74	
Tip-Top	4.03	3.96	3.97	4.02	4.00	
Toffi	3.94	3.88	3.85	3.76	3.86	
Average for extrusion parameters	3.86	3.76	3.82	3.80	X	
K [mg × 100 g^{-1}]						
Augusta	987	974	950	1052	991	I – 44.8 II – 40.0 III – 89.5
Nigeria	948	1205	1327	1351	1208	
Rawela	951	948	870	847	904	
Tip-Top	1309	1369	1241	1294	1303	
Toffi	1190	1246	1255	1244	1234	
Average for extrusion parameters	1077	1148	1129	1158	X	
P [mg × 100 g^{-1}]						
Augusta	542	529	519	583	543	I – 16.8 II – 15.0 III – 33.5
Nigeria	560	565	658	654	609	
Rawela	571	569	497	512	537	
Tip-Top	638	681	632	659	652	
Toffi	660	671	709	705	686	
Average for extrusion parameters	594	603	603	623	X	
Mg [mg × 100 g^{-1}]						
Augusta	122	121	121	127	123	I – 3.1 II – 2.8 III – 6.2
Nigeria	151	139	158	157	151	
Rawela	143	145	131	134	138	
Tip-Top	162	172	162	169	166	
Toffi	163	165	171	174	168	
Average for extrusion parameters	148	148	149	152	X	
Ca [mg × 100 g^{-1}]						
Augusta	97	91	97	103	97	I – 18.8 II – n.s. III – n.s.
Nigeria	117	114	133	133	124	
Rawela	99	108	93	95	99	
Tip-Top	150	159	158	154	155	
Toffi	96	111	104	121	108	
Average for extrusion parameters	112	117	117	121	X	

* LSD for: factor I – cultivar, factor II – extrusion parameters, factor III – interaction (IxII)
n.s. – not significant.

Table 6. Contents of microelements in bean extrudates (in dry basis)

Cultivar	Extrusion parameters				average for cultivar	LSD* p=0.01
	14%/120°C	20%/120°C	14%/180°C	20%/180°C		
Fe [mg × 100 g^{-1}]						
Augusta	9.2	9.5	9.0	9.6	9.3	I – 0.35 II – n.s. III – 0.71
Nigeria	11.6	11.5	11.9	11.3	11.6	
Rawela	10.7	11.2	11.0	10.4	10.8	
Tip-Top	11.7	12.5	11.4	11.7	11.8	
Toffi	11.0	10.6	10.9	10.7	10.8	
Average for extrusion parameters	10.8	11.1	10.9	10.7	X	
Zn [mg × 100 g^{-1}]						
Augusta	3.2	2.7	2.5	2.9	2.8	I – 0.22 II – n.s. III – 0.71
Nigeria	4.3	4.6	4.5	4.0	4.4	
Rawela	3.8	4.3	4.4	4.0	4.1	
Tip-Top	3.4	3.9	3.2	3.6	3.5	
Toffi	3.6	3.2	3.6	3.3	3.4	
Average for extrusion parameters	3.7	3.7	3.6	3.6	X	
Na [mg × 100 g^{-1}]						
Augusta	2.2	1.9	1.9	2.8	2.2	I – 0.20 II – n.s. III – 0.41
Nigeria	2.0	1.9	2.6	2.8	2.3	
Rawela	2.0	2.4	1.4	1.4	1.8	
Tip-Top	2.0	2.2	1.6	2.1	2.0	
Toffi	1.6	1.5	1.6	1.7	1.6	
Average for extrusion parameters	1.9	2.0	1.8	2.2	X	
Mn [mg × 100 g^{-1}]						
Augusta	1.15	1.13	1.12	1.10	1.13	I – 0.036 II – n.s. III – 0.073
Nigeria	1.57	1.53	1.52	1.48	1.52	
Rawela	1.26	1.29	1.25	1.25	1.26	
Tip-Top	1.43	1.56	1.42	1.51	1.48	
Toffi	1.34	1.23	1.35	1.36	1.32	
Average for extrusion parameters	1.35	1.35	1.33	1.34	X	
Cu [mg × 100 g^{-1}]						
Augusta	0.54	0.52	0.53	0.50	0.52	I – 0.021 II – 0.019 III – 0.042
Nigeria	0.60	0.60	0.57	0.56	0.58	
Rawela	0.71	0.69	0.64	0.65	0.67	
Tip-Top	0.51	0.56	0.59	0.56	0.55	
Toffi	0.67	0.73	0.78	0.67	0.71	
Average for extrusion parameters	0.60	0.62	0.62	0.59	X	

* LSD for: factor I – cultivar, factor II – extrusion parameters, factor III – interaction (IxII)
n.s. – not significant.

CONCLUSIONS

Wang and McIntosh [32] discovered in rat employed trials, that extrusion of chickpea and pea improved the nutrition value of leguminous in the same extent as traditional boiling, that allowed to use this technique in broadening of this product range available on market, and increasing the consumption of leguminous seeds. As it was mentioned above, information presented by some authors on extrusion parameters influence on selected food chemical components were significantly differed. However, Ismail and Zahran [17] described the most efficient conditions of soya bean and chickpea extrusion as 20% humidity and 160°C–relatively high raw material humidity and low temperature of process. Also in present work, extrudates obtained from raw bean seeds with higher moisture exhibited higher content of lipids, starch, total carbohydrates and insoluble dietary fiber in comparison to extrudates obtained from raw material with lower initial moisture. Except higher moisture also lower extrusion temperature influenced on better preservations of these compounds. Among all extrudates, the most of total carbohydrates contained these obtained at 20% moisture and 120°C. Also the highest amount of starch was discovered in extrudates obtained from four cultivars of bean processed at the same parameters. On other hand applying of lower humidity and higher temperature (14%/180°C) caused the greatest losses of starch, carbohydrates and total dietary fiber. There was no significant influence of extrusion parameters on minerals content.

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Jarosław Korus
Department of Carbohydrates Technology,
Agricultural University of Cracow, Poland
Balicka 122, 30-149 Cracow, Poland
tel/fax +48 12 6624747
email: rrkorus@cyf-kr.edu.pl

Dorota Gumul
Department of Carbohydrates Technology,
Agricultural University of Cracow, Poland
Balicka 122, 30-149 Cracow, Poland
fax: (+4812662474, 6624771)
email: dgum@interia.pl

Bohdan Achremowicz
Department of Carbohydrates Technology,
Agricultural University of Cracow, Poland
Balicka 122, 30-149 Cracow, Poland
