

EXTRUDED BEAN PRODUCT QUALITY EVALUATION

Liene Strauta¹, Sandra Muizniece-Brasava¹, Ina Alsina², Tatjana Rakcejeva¹

¹ Faculty of Food Technology, Latvia University of Agriculture, Liela street 2, Jelgava, Latvia, e mail: strauta.liene@gmail.com

² Faculty of Agriculture, Latvia University of Agriculture, Liela street 2, Jelgava, Latvia

Abstract

Aim of study was to develop a new type of bean (*Phaseolus vulgaris* L.) products with various additives using one screw extrusion, define their quality (physical and chemical properties) and ascertain people opinion about such products. Research was carried out at Latvia University of Agriculture Faculty of Food Technology. White beans were used in experiments. Beans were boiled, crushed and extruded through one screw extruder. Different additives were used, as bell peppers, tomatoes, spinach, garlic and red beet. Parameters as crude protein content, ash content, pH and colour were determinate. People at international exhibition "Riga Food 2013" were asked to give their opinion about the experimental product.

Average protein content in beans (*Phaseolus vulgaris* L.) extruded products were 25.5±0.4% of dry matter (DM). Average ash content was 4.99±0.05% of DM and pH 5.77. Dry matter was 91.59±0.03% in average. No more than 5% of lignified protein had been found in product.

Keywords: beans, extrusion, protein, ash.

Introduction

Dietary importance of legumes has been well established. Their high content of protein, carbohydrates, fiber, certain minerals and vitamins make them a good source of nutrients. Nowadays research on nutraceutical properties of beans is a very hot topic (Rocha-Guzma et al., 2006).

Kidney bean (*Phaseolus vulgaris* L.) is the most widely produced and consumed food legume not only in Africa, India, Latin America and Mexico (FAO, 1993) but worldwide. These beans have reported to have numerous health benefits, e.g. heart and renal disease risks (Anderson et al., 1999); lower glycemic index for persons with diabetes (Viswanathan et al., 1989); increased satiation (Leathwood, Pollet, 1988) and cancer prevention (Hangen, Bennink, 2002). Furthermore, kidney beans are regarded as an important source of protein and minerals for livestock feed production, as well as, potential raw materials for processing into human food (Gupta, 1987; Salunkhe, 1982; Kahlon et al., 2005).

The low incidence of diseases related to blood circulation in Asian population is ascribed, in part, to a relatively high consumption of legumes (Kahlon et al., 2005).

However, legumes are an underutilised commodity in most regions of the world due to long cooking time (Deshpande et al., 1984; Nasar-Abbas et al., 2008), and the belief that legumes are of low nutritive value due to the presence of flatulence and anti-nutritional factors (Adsule et al., 1989). However, legumes are potentially valuable dietary components due to a protein content between 20% and 50%, and the presence of complex carbohydrates, especially dietary fibre and water soluble polysaccharides, which give them low glycaemic potency (Ravindran et al., 2011).

The antinutrients (e.g. trypsin inhibitors, phytic acid, saponins, phytohemagglutinins and tannins) and α -galactosides (e.g. raffinose, stachyose and verbascose) are some of the undesirable components in beans that could limit their protein and carbohydrate utilization (Shimelis, Rakshit, 2007).

Unfortunately, the antinutritional factors reduce biological activity of several chemical compounds or metabolites (Rocha-Guzma et al., 2006).

All processing methods tend to modify the composition and availability of nutrients in raw materials. Among the various technologies, short-time high-temperature extrusion cooking is a well known cost-effective industrial process. Extrusion combines high pressure with a moderately high-temperature and usually high shear for a short period of time. Extrusion processing completely gelatinises the starch and partially or completely destroys antinutritional factors present in many legumes (Melcion, Poel, 1993; Ravindran et al., 2011). Extrusion-cooking technology is a versatile and efficient method of converting raw materials into finished food products. It can replace many conventional processes in food and feed industries. It has been used to develop various types of snack foods, mainly from corn meal, rice, wheat flour, or potato flour, in many shapes and variety of textures. Application of extrusion process for legume flours is a relatively new area, with the exception of soy bean. Several reports show that bean starches have very good expansive and functional properties under extrusion conditions (Gujska, Khan, 1991). According to Gujska, Czarnecki, and Khan (1996), extrusion cooking has good potential for making desirable bean forms that could be economically available in developing countries. Benefits of beans extrusion-cooking are deactivation of heat labile growth inhibitors (Aguilera et al., 1984). Sosulski (1988) claims that legumes flour has not been used widely in foods because of the poor functionality of starch (Rocha-Guzma et al., 2006).

Aim of this research was to develop a new type of bean (*Phaseolus vulgaris* L.) products with various additives using one screw extrusion, define their quality (physical and chemical properties) and ascertain people opinion about such products.

Materials and Methods

White beans (*Phaseolus vulgaris* L.) were boiled, then crushed with hand meat-grinder and extruded by

L Series Göttfert Werkstoff Single screw laboratory extruder Different additives were added before extrusion (Table 1). Additives used in experiment were as shown in Table 1.

Table 1

Amount of additives to samples			
No	Additive	Amount of additive, %	Amount of salt, %
1	Control (without additive)	0	0
2	Chia seeds	1	2
3	Nettle powder	3	0.3
4	Caraway-seeds	1	0.3
5	Fresh bell pepper	20	0.5
6	Salt	-	2
7	Beetroot	12	0.3
8	Spinach	12	0.3
9	Almond essence	0.5	0.1
10	Lemon essence	0.5	0.1
11	Thyme powder	0.1	0.3
12	Tomato paste	15	0.2
13	Garlic powder	1	0.3

Sample without additives was used as a control.

Extrusion process was performed at temperature regimes 90–95–105 °C. Before extrusion dry matter of samples was measured using dry matter weights *Precisa XM120*.

After extrusion samples (size of one piece – 15×20 mm) were dried in a rotary type oven *SVEBA DAHLIN S400* for 2 hours at 90 °C temperature. Dry samples were packaged in conventional two layer laminated polymer polyethylene/polyamide (PE/PA) pouches (200×300 mm, material thickness 20/45±2 µm) and then hermetically sealed by chamber type machine *MULTIVAC C300*. Mass of the sample in each package was 100±5 g. Quality of the extruded products was analysed at Faculty of Food Technology and Scientific laboratory of Agronomy Research. Some of samples were tested at the international exhibition “Riga Food 2014”, to roughly estimate the consumers’ interest in such products.

The total dry matter content was determined according to ISO 6496, 1999. Container with lid for half an hour was dried at 103±3 °C temperature, then cooled to room temperature in desiccators. Weigh was measured with an accuracy of 1 mg. 5 g of sample weight of to the nearest 1 mg were placed in container and put in the drying oven at 103±3 °C for 4.0±0.1 h. After four hours, the container lid were put on, sample was removed from oven and cooled in a desiccators to room temperature. Sample was weighted with container and absolute dry matter was calculated according to method. All chemical parameters were calculated on absolute dry matter.

Crude protein (CP) was determined using Kjeldahl method. Approximately 0.5 g (to the nearest 0.0001 g) of well crushed sample was weighted. The sample was transferred in a temperature resistant glass flask; where copper catalyst was added and 20 mL of concentrated H₂SO₄. Flask was placed in a preheated *BÜCHI* digest automat K-438 (420±5 °C) and gas vacuum suction cap was fixed on. Wet mineralization went for 1 hour until the solution in flask was colourless and clear. Flask and digested sample was removed from the stove and allowed to cool for 15–20 min. Cooled sample was placed in a distillation unit, 50 mL of water, 80 mL of 40% NaOH were added. Ammonium was distilled in 65 mL of 4% H₃BO₃ solution. The steam distillation was carried out for 220 s. Boric acid solution was titrated with 0.2 M HCl (which concentration was checked with 0.1 M NaOH solution) till pH 4.70. 1 g of sucrose was used as a blank sample. For protein calculations coefficient 6.25 was used (LVS EN ISO 5983-2, 2009).

Ash content was determined according ISO 5984:2002/Cor 1:2005. The sample mass 5±0.0001 g was weighted, placed in the porcelain crucible and placed on *Bomann* stove. After 20 min sample was placed in muffle for 4 hours at 550 °C temperature. When muffle has cooled till 100 °C temperature samples are placed in an exsiccator and cooled till room temperature, then weighted on analytic scale.

Lignified protein content was determinate in two steps. First, acid detergent fibre content was determined according to LVS EN ISO 13906, 2008.

Borosilicate crucible is dried for 4 hours at 103±3 °C, and weighted to the nearest 0.1 mg. Sample is taken 1000±2 mg. Crucible is placed in the analyzer. 100 mL of the ADF solution is added and cooling water is switched on after 5–10 min. After 60±5 min the hardware glass walls are washed with less than 5 mL of ADF solution. The heater was turned off and solution filtered off. The sample was washed 3 times with 30 mL of hot (90–100 °C), distilled water allowing it to stay on sample for 3–5 min. After washing crucible with the sample was transferred to the cold extraction unit and washed with 25 mL of acetone and filtered. Then crucible with the sample was placed in the drying oven at 103±3 °C for more than 5 hours or 130±3 °C for more than 2 hours (LVS EN ISO 13906, 2008).

Second, after determining the ADF fraction, dried sample was transferred in high temperature resistant glass flask and proceeded the same as crude protein. For lignified protein determination sample weigh before ADF determination is used in calculations (Undersander et al., 1993).

Sodium and iron was determined according to LVS EN ISO 6869. After ash content was determined, ash was transferred in to volumetric flask and added 10 mL 6 M HCl solution. Solution was dried on hot plate. Then residue dissolved in 5 mL 6 M HCl and transferred with some 5 mL portions of hot water in 50 mL volumetric flask. Cooled and diluted to the mark with

water. After particles had settled quantity of test samples is diluted with water, 100 mL of lanthanum nitrate solution, 5 mL of caesium chloride solution and 5 mL of 6 M HCl acid solution. Then atomic absorbance is measured. Solution is diluted as much is needed to obtain absorbance in the linear part of calibration curve, which is made from known sodium or iron quantity solution. Blank sample is made using water instead of the test sample.

pH was determined according to GOCT 26180-84. 10 g of well crushed sample was placed in a volumetric flask. Water was added till 100 mL. After 5 hours pH was measured.

Colour of product was measured in CIE $L^*a^*b^*$ colour system using *Tristimulus* Colorimeter, measuring Hunter colour parameters by Colour Tec PCM/PSM. Colour values were recorded as L^* (brightness) – the vertical co-ordinate runs from $L^* = 0$ (black) through grey to $L^* = 100$ (white); a^* (-a, greenness, +a, redness) – the horizontal co-ordinate, that runs from - a^* (green) through grey to + a^* (red) and b^* (-b, blueness, +b, yellowness) – another horizontal co-ordinate, that runs from - b^* (blue) through grey to + b^* (yellow) (Papadakis et al., 2000). Samples were crushed and bolted through 1 mm sieve. Samples were densely pressed in a Petri plate with diameter 5 cm and colour was measured at least ten times at randomly selected locations of each sample.

Colour difference (ΔE^*) of bean products from control sample was calculated using the following equation 1:

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (1)$$

where ΔE^* – colour difference of the product, L^* – products colour intensity value, L_0^* – control samples colour intensity value, a^* – products value of colour component green – red, a_0^* – control samples value of colour component green – red, b^* – products value of colour component blue – yellow, b_0^* – control samples value of colour component blue – yellow.

During international exhibition “Riga Food 2013” 150 exhibition visitor as potential consumer opinion about such products were asked using 5 point scale for likeness. Where score 1 means “does not like at all” and score 5 – “likes very much”.

Data were analysed with correlation, ANOVA single factor analyses using Microsoft Excel 2007, Data Analysis, confidence level was taken 95% ($\alpha=0.05$).

Results and Discussion

The dry matter content of prepared samples before extrusion was $38.0 \text{ g } 100 \text{ g}^{-1}$ in average (Figure 1). Sample with bell peppers contained only $34.6 \pm 0.5 \%$ of dry matter, while samples with chia seeds and nettles – $38.8 \pm 0.5 \%$ of dry matter each. The largest dry matter $39.30 \pm 0.5 \%$ was detected in a sample with spinach additive.

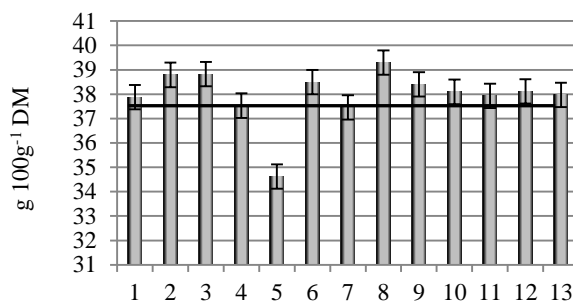


Figure 1. Dry matter of samples before extrusion

1 – control 2 – chia seeds; 3 – nettle; 4 – caraway seeds; 5 – bell peppers; 6 – salt; 7 – beetroot; 8 – spinach; 9 – almond essence; 10 – lemon essence; 11 – thyme; 12 – tomato; 13 – garlic; — line for control sample

Dry matter in extruded bean products is shown in Figure 2. The highest dry matter content was in samples with bell peppers, $93.13 \pm 0.01 \text{ g } 100 \text{ g}^{-1}$, and samples with salt $93.07 \pm 0.03 \text{ g } 100 \text{ g}^{-1}$ but the lowest in a sample with almond essence – $88.45 \pm 0.02 \text{ g } 100 \text{ g}^{-1}$ and in control sample it was $95.13 \pm 0.05 \text{ g } 100 \text{ g}^{-1}$ of product, that could be explained with vaporization of essence.

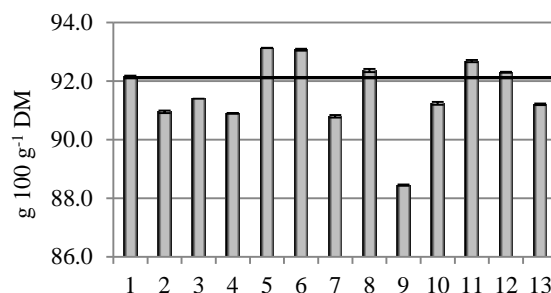


Figure 2. Dry matter in extruded bean products

1 – control 2 – chia seeds; 3 – nettle; 4 – caraway seeds; 5 – bell peppers; 6 – salt; 7 – beetroot; 8 – spinach; 9 – almond essence; 10 – lemon essence; 11 – thyme; 12 – tomato; 13 – garlic; — line for control sample

Significant differences were found in protein content (Figure 3) among extruded products ($p=3.2 \times 10^{-6}$). The highest protein content was found in garlic containing products – $26.7 \pm 0.3 \text{ g } 100 \text{ g}^{-1}$ of product, but the less in those ones with tomato – $23.2 \pm 0.2 \text{ g } 100 \text{ g}^{-1}$ of product. They were the ones that made the changes significant. Mathematical analysis showed that there was no significant difference among other investigated sample protein content on dry matter. Protein content in a control sample was $26.2 \pm 0.2 \text{ g } 100 \text{ g}^{-1}$. Relatively high protein content of samples with spinach can be explained by fact that fresh, raw spinach contains till 30% protein of dry matter. So the crude protein loss was not significant despite fresh material.

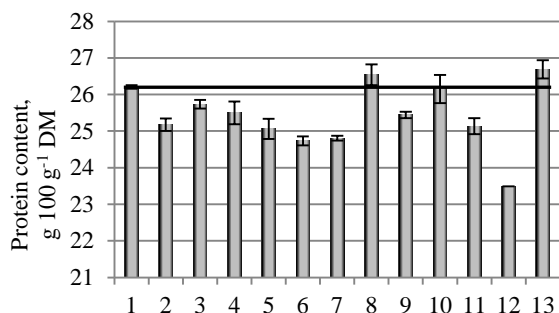


Figure 3. Protein content in extruded bean products

1 – control 2 –chia seeds; 3 –nettle; 4 –caraway seeds; 5 – bell peppers; 6 – salt; 7 –beetroot; 8 – spinach; 9 – almond essence; 10 – lemon essence; 11 – thyme; 12 – tomato; 13 – garlic — line for control sample

The content of ash in extruded been products is shown Figure 4. The lowest ash content is determined in control sample – 3.46±0.07 g 100 g⁻¹ of products dry matter, sample with lemon essence – 3.49±0.04 g 100 g⁻¹ of products dry matter and almond essence – 3.52±0.01 g 100 g⁻¹ of products dry matter.

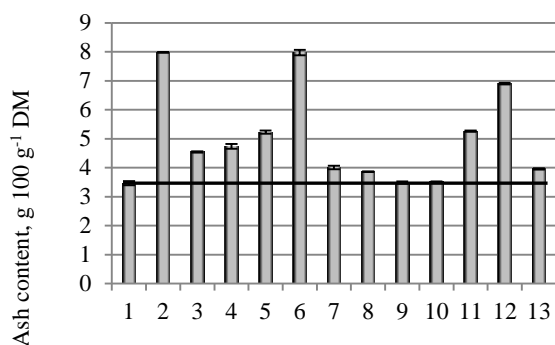


Figure 4. The content of ash in extruded bean products

1 – control 2 –chia seeds; 3 –nettle; 4 –caraway seeds; 5 – bell peppers; 6 – salt; 7 –beetroot; 8 – spinach; 9 – almond essence; 10 – lemon essence; 11 – thyme; 12 – tomato; 13 – garlic — line for control sample

However the highest ash content was detected in samples with salt and chia seed addition 7.98±0.01 g 100 g⁻¹ and 7.97±0.09 g 100 g⁻¹ of product, respectively. Significant differences were found between all samples ($p=3.54 \times 10^{-17}$) ash content, except for samples with almond and lemon essence who had no significant differences form control.

Lignified protein content of crude protein (CP) in samples was 3.40±0.04 g 100 g⁻¹, however in beans lignified protein of CP can be even 8.2 g 100 g⁻¹, as it is indicated in feed database (Interactive, 2014), so we can conclude, that no significant amount of lignified protein has been formed in extrusion process.

Sodium content in control sample was 0.02530±0.0002 g 100 g⁻¹, but with chia seeds – 1.93±0.03 g 100 g⁻¹ and in the sample with salt 2.09±0.07 g 100 g⁻¹ of product. Thus we can see control sample contains only little traces of sodium.

Figure 5 shows iron content of samples that had additives with elevated iron content.

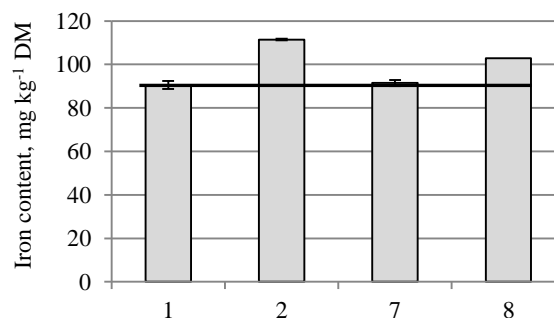


Figure 5. The content of iron in selected extruded bean products

1 – control 2 – chia seeds; 7–beetroot; 8 – spinach — line for control sample

Control sample and sample with beetroot had no significant differences. Control sample contained 90±2 mg kg⁻¹ iron in dry matter of and sample with beetroot contained 91.4±0.3 mg kg⁻¹ iron in dry matter. Samples with chia seeds and spinach had higher iron content 111±2 mg kg⁻¹ and 103±1 mg kg⁻¹, respectively.

The values of extruded bean sample colour components L* a* b* are summarised in Table 2.

Table 2

Colour components of extruded bean products

Added additive	Value		
	L*	a*	b*
Control (without additive)	82.9±0.3	-1.5±0.1	15.9±0.3
Chia seeds	78.6±0.2	-1.1±0.3	14.3±0.4
Nettle	63.2±0.4	-1.7±0.1	16.6±0.4
Caraway-seeds	75.4±0.7	-1.5±0.3	17.5±0.4
Bell peppers	71.8±0.4	2.6±0.3	24.7±0.6
Salt	76.4±0.6	-1.1±0.3	15.5±0.8
Beetroot	55.9±0.5	16.8±0.4	1.1±0.2
Spinach	69.7±0.3	-2.0±0.2	19.9±0.4
Almond essence	77.8±0.3	-1.4±0.1	17.2±0.3
Lemon essence	78.0±0.2	-1.7±0.2	16.4±0.6
Thyme	74.7±0.2	-1.5±0.3	15.5±0.4
Tomato	74.7±0.3	-0.8±0.2	22.2±0.3
Garlic	76.0±0.4	-1.3±0.2	16.3±0.5

Sample with added beetroot was darker, described by the lowest L* value 55.9±0.5 as well as the highest red one – 16.8±0.4 and the smallest b* value 1.1±0.2. While the lightest one was found control sample without additives described by colour components as follows: L*=82.9±0.3; a*=-1.5±0.1 and b*=15.9±0.3. The changes of colour components compared to a control sample are summarized in Table 3.

The colour of sample with beetroot differs from other extruded products.

Table 3

The changes of colour components compared to control sample

Added additive	Value			ΔE
	L*	a*	b*	
Chia seeds	-4.3	0.4	-1.6	4.6
Nettle	-19.7	-0.2	0.7	19.7
Caraway-seeds	-7.5	0.0	1.6	7.7
Bell peppers	-11.1	4.1	8.8	14.7
Salt	-6.4	0.4	-0.4	6.5
Beetroot	-27.0	18.3	-14.8	35.8
Spinach	-13.2	-1.2	3.9	13.8
Almond essence	-5.1	0.1	1.3	5.3
Lemon essence	-4.9	-0.2	0.5	4.9
Thyme	-8.2	0.0	-0.4	8.2
Tomato	-8.2	0.7	6.2	10.3
Garlic	-6.9	0.2	0.4	6.9

So we can see that beetroot gives samples the darkest colour, followed by nettle and spinach. Red colour is more in samples with bell peppers too, but not as much as in one with beetroot. Green colour can be obtained with nettle, spinach and lemon essence additives but yellow with bell peppers, tomato and spinach additives. pH was measured and significant differences were found ($p=1.15 \times 10^{-20}$). All samples can be divided in four groups, according to pH (Fig. 6).

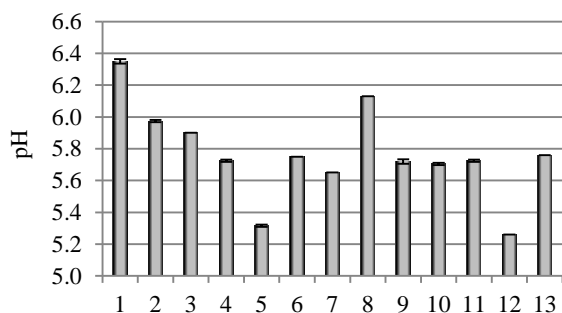


Figure 6. pH of extruded bean products

1 – control 2 – chia seeds; 3 –nettle; 4 –caraway seeds; 5 – bell peppers; 6 – salt; 7 – beetroot; 8 – spinach; 9 – almond essence; 10 – lemon essence; 11 – thyme; 12 – tomato; 13 – garlic

Products with $pH > 6.0$ relates to the first group including control sample as well as sample with spinach additive, the second one with $pH 5.8-6.0$ would contain samples with nettle and chia seeds, the third one with $pH 5.6-5.8$ would be the largest one including samples with garlic, salt, thyme, caraway seed, almond an lemon essences and beetroot additives. In last group with $pH < 5.6$ would be samples with bell peppers and tomato additives. The average pH value of all samples was 5.77 ± 0.01 , but for control sample it was 6.35 ± 0.01 .

Correlation was observed between Na and Fe content $r=0.98$; negative correlation between Na and pH $r=0.96$; dry matter and Fe content $r=0.88$; Na and dry matter content $r=0.86$; negative correlation between protein and Na – $r=-0.68$ and protein and pH content $r=0.64$.

The visitors in International exhibition “Riga Food 2014” were surveyed for their opinion of extruded bean products. Most likable to respondents seemed product with bell peppers and salt (3.6 and 3.3 points on average in 5 point scale), but the least they liked products with caraway seeds and lemon essence (2.6 and 2.8 in 5 point scale). Other tasted products were valued approximately by 3 points in 5 point scale.

Conclusions

Dry matter content of extruded bean products was in range from $88.45 \text{ g } 100 \text{ g}^{-1}$ to $93.13 \text{ g } 100 \text{ g}^{-1}$, in a control sample it was $92.15 \text{ g } 100 \text{ g}^{-1}$. Protein content was in range $23.49 \text{ g } 100 \text{ g}^{-1}$ till $26.69 \text{ g } 100 \text{ g}^{-1}$, in control sample – $26.21 \text{ g } 100 \text{ g}^{-1}$, and ash content 3.46 till $7.98 \text{ g } 100 \text{ g}^{-1}$. Highest iron content was in samples with chia seeds $111 \pm 2 \text{ mg kg}^{-1}$ on dry matter and spinach and $103 \pm 1 \text{ mg kg}^{-1}$ on dry matter.

pH value was in range from 5.26 to 6.35. The highest pH has a control sample, all samples with additives had lower pH, except form lemon and almond essences. As expected high correlation have been observed between ash and sodium and iron content ($r=0.98$) and sodium and pH ($r=-0.96$). Not so close correlation was observed between dry matter and iron content ($r=0.88$), protein and sodium content ($r=-0.68$), protein and pH content ($r=0.64$) and sodium and dry matter content before extrusion ($r=0.86$).

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