

Influence of Buckwheat Addition on Physical Properties, Texture and Sensory Characteristics of Extruded Corn Snacks

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The influence of buckwheat addition on physical properties, texture, colour and sensory characteristics of extruded corn snacks are presented in this paper. Snacks were prepared with a single screw extrusion-cooker TS-45 with L:D=12:1, shaped on the circular open die 3 mm, screw speed during processing was set to 120 rpm. Buckwheat flour was added in the amount from 10 to 50% of corn grits mass. Selected physical properties, cutting force and texture with Kramer cell were evaluated. The sensory characteristics and acceptability of buckwheat enriched snacks were evaluated. The expansion ratio lowered, whilst bulk density and durability increased with a higher level of buckwheat addition. Fracturability and hardness lowered with higher buckwheat amount in the recipe. Colour measurements showed lower L^* and higher b^* values with higher buckwheat addition. Higher buckwheat amount influenced lower sensory notes of snacks.

INTRODUCTION

Corn (maize), rice or buckwheat products play an important role in the nutrition of people with gluten intolerance (celiac disease), who cannot consume bakery, pasta or snack products made from commonly used raw materials. Those diseases have been connected with life-long intolerance to a gliadin fraction of wheat and also to other prolamines: rye (secalin), barley (hordein) and possibly oats (avenin) [Counts & Sierpina, 2006; Wronkowska *et al.*, 2008]. Specific physico-chemical properties of raw materials of corn and buckwheat, such as high starch content, proteins with a low content of α -gliadin fraction, dietary lipids, no gluten, hypoallergenic, many valuable compounds (flavonoids, rutin), trace elements, dietary fibre and delicate flavour, make them very desirable in the production of a new generation of products and convenience foods intended for specific audiences [Kreft *et al.*, 2006; Wronkowska *et al.*, 2008]. Protein content in buckwheat flour has been reported in the range from 8.5 to 18.9%, depending on the origin and variety [Krkošková & Mrázová, 2005]. Buckwheat protein is gluten-free, which may increase the assortment of products for consumers suffering from celiac disease [Moroni *et al.*, 2011] and have a high biological value due to the well-balanced amino-acid composition, although their digestibility is relatively low [Wronkowska & Soral-Šmietana, 2008]. The only method of therapy is a gluten-free diet based

on products prepared from corn, rice, potatoes, buckwheat, millet, legumes or soy [Alvarez-Jubete *et al.*, 2010; Kreft *et al.*, 2006; Niewinski, 2008]. A consumption of 100 g of buckwheat grit makes the daily intake of essential amino acids complete [Bonafaccia *et al.*, 2003; Guo & Yao, 2006; Zhang *et al.*, 2010]. Buckwheat is characterised by a specific dietary-nutritive value, which may be useful to develop multicomponent mixtures and a new type of gluten-free assortments [Dziedzic *et al.*, 2010; Wronkowska & Soral-Šmietana, 2008].

Nowadays, consumers are looking for both taste and functional properties of food products, like increased natural body resistance, prevention or therapy support in selected diseases, increase of physical efficiency and beneficial influence on mental condition of the body. There is a new trend in interest in functional foods, including buckwheat products [Ekielski *et al.*, 2007b; Sedej *et al.*, 2011a].

Addition of buckwheat protein extracts is lowering the cholesterol level in blood and in liver, may be used in over-pressure, obesity and constipation treatment. Substances contained in buckwheat have a positive effect on the composition of intestinal microflora and strengthen blood vessels. Tests on animals showed a positive impact of buckwheat in alleviating symptoms associated with gall-stone (cholelithiasis). Buckwheat is also useful in cancer prevention, treating inflammatory conditions and surgical convalescence [Chłopicka, 2008; Yoo *et al.*, 2012; Krkošková & Mrázová, 2005; Prestamo *et al.*, 2003]. The presence of rutin (quercetin-3-rhamnosyl glucoside) – the main buckwheat flavonoid, in seeds (both groat and hull) and sprouts, and suggestion that buckwheat seems to be a source of antioxidants depend on buckwheat species origin [Zielińska *et al.*, 2010].

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One of the most substantial reasons for its limited use, as well as for search of the new applications for buckwheat grains, arises from its specific flavour [Wronkowska *et al.*, 2008]. A growing interest in buckwheat is possible by involving it as raw material or additive in preparing ready-to-eat products, like crisps, snack or instant grits [Ekielski, *et al.*, 2007c; Sedej *et al.*, 2011b]. Products made by extrusion-cooking have a long shelf-life, good nutritional value and digestibility of food components [Sensoy *et al.*, 2006]. The most popular extrudates are cereal snacks and breakfast cereals, which should be characterised by a uniform shape, crispy but not hard texture, uniform porosity and nice flavour, specific for raw materials used [Mościcki *et al.*, 2007; Moscicki, 2011].

Extrusion-cooking process causes a complete or partial destruction of the crystalline structure of starch due to gelatinization process as well as protein denaturation and the formation of complexes between starch and lipids, and proteins and lipids [Brennan *et al.*, 2004; Bryant *et al.*, 2001; Mercier *et al.*, 1998]. Owing to these interactions, the extrusion-cooking may be used to produce a wide range of products, such as snacks, modified starches, breakfast cereals, instant food and dietetic products [Counts & Sierpina, 2006; Moscicki, 2011; Wójtowicz & Baltyn, 2006].

The aim of this study was to evaluate physical properties, colour, texture and sensory characteristics of buckwheat-enriched corn snacks processed by extrusion-cooking.

MATERIALS AND METHODS

Corn grits (Vegetus, Lubartów Poland) were used as the base raw material. Buckwheat dehulled seeds (Sante, Sobolew, Poland) ground to flour (up to 0.5 mm) were used in the amount of 10, 20, 30, 40 and 50% as the corn grits replacements. Recipes with varying ratios of corn and buckwheat were moistened to the moisture content of 16% and processed using a single screw extrusion-cooker TS-45 (ZMCh Metalchem, Gliwice, Poland) with L:D=12:1 and a screw compression ratio of 3:1. Thermal treatment was in the range of 125–145°C, products were shaped on the open die of 3 mm. The screw speed during the extrusion-cooking was set to 120 rpm. After cooling (moisture content of snacks was 7.0%) snacks were stored at room temperature before tests.

Physical properties of the extrudates

The expansion ratio of directly expanded extrudates is an important factor of its quality and should be as great as possible, according to the consumers' preferences. The radial expansion index was evaluated as a ratio of extrudates diameter to the diameter of forming die [Wójtowicz, 2007]. Measurements were done in 10 replications for each recipe. Bulk density and durability of the products were tested according to ASAE Standard [ASAE S269.3:1989] as mass of the snacks volume (kg/m³) and their resistance to damage (%) during shaking test in the Pfast apparatus, respectively.

Textural properties

Universal testing machine Zwick BDO-FB0.5TH (Zwick GmbH & Co., Germany) was used for texture evaluation. Cutting force (N) was tested with Warner-Bratzler steel blade

with 3 mm thick and 60 mm long, double-face truncated at an angle 45° as mean of 10 replications. Test head speed was 500 mm/min. Selected texture parameters of buckwheat-enriched snacks were analyzed using 5-blade Kramer cell by shearing 10 g of snacks with a head speed 500 mm/min under double-compression test cycle. Fracturability (N), crispness (N), hardness (N), adhesion (mJ) and springiness (-) were calculated with *testXpertIII@v3.3* from data recorded during the tests as means of triple measurements.

Colour profile measurements

Colour of snacks enriched with buckwheat flour was tested using Colour and Appearance Measurements System Lovibond CAM-System 500 (The Tintometer Ltd., UK). CIE-Lab scale was used for evaluation of L^* for brightness, a^* for (+)redness-(-)greenness and b^* for (+)yellowness-(-)blueness, accordingly [Farris & Piergiovanni, 2009]. ΔE was calculated as a colour change index according to the equation (1) [Carini *et al.*, 2010].

$$\Delta E = \sqrt{(L_{sample}^* - L_{control}^*)^2 + (a_{sample}^* - a_{control}^*)^2 + (b_{sample}^* - b_{control}^*)^2} \quad (1)$$

Measurements were performed in 20 replications for each sample. Background colour values were: $L^*=94.0$, $a^*=2.7$ and $b^*=-0.4$. Colour parameters for reference sample (corn snacks) were as follows: $L^*=91.88$, $a^*=-1.92$, $b^*=17.21$.

Sensory evaluation

Sensory characteristics of corn-buckwheat snacks: taste, shape, colour, flavour, crispness, and overall quality of snacks were evaluated according to Polish Standards [PN-A-88034:1998; PN-A-88036:1998; PN-ISO 11036:1999; BN-91/8070-14:1991]. A 15-member semi-trained panel judged snacks products in a 5-point scale (1—for weak, 5—for very good).

Overall acceptability of each sample was evaluated in relation to the sensory preferences in a nine-point hedonic scale, where: 1 = dislike extremely, and 9 = like extremely. Snacks were considered as acceptable if their mean scores for overall acceptability were above 5 [Bustos *et al.*, 2011].

Statistical analysis

The results were analysed by statistical software Statistica 6.0. Differences in means of results, due to buckwheat addition, were tested and correlations between functional properties of snacks were determined. The analysis of variance ANOVA was conducted at a confidence level of 95% ($p=0.05$); the significance of differences between means was assessed by Duncan's multiple range test.

RESULTS AND DISCUSSION

Physical properties of buckwheat-enriched snacks

Results of the radial expansion index for corn snacks enriched with buckwheat flour are presented in Figure 1. The increased amount of buckwheat in the recipe was found to lower snacks expansion with a high correlation coefficient

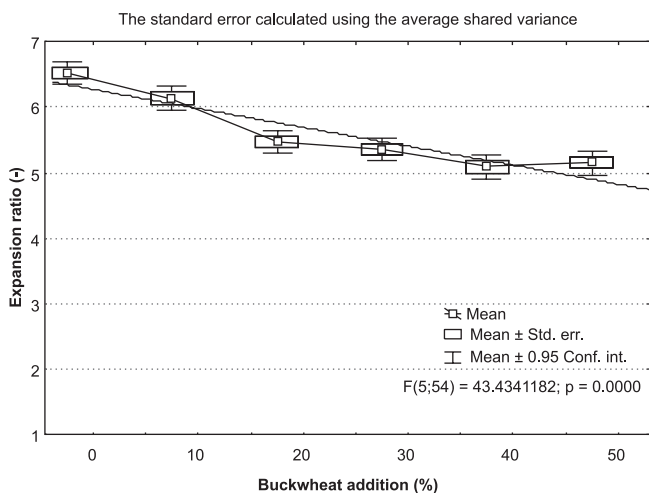


FIGURE 1. The expansion ratio results of corn snacks enriched with buckwheat.

of $r=0.932$. The difference between the expansion of a reference corn snack sample and snacks with the highest buckwheat addition was 26%, which may be affected by higher protein and fat contents in final products. Ekielski *et al.* [2007a] processed the maize-buckwheat extrudates in single-screw autogenic extruder (L/D=6.5) with the screw speed of 200 rpm and found an increase in the volumetric expansion ratio for both die hole diameters used: 12 and 14 mm, when buckwheat content was increased. The main reason of these differences may be the effect of different design of the extruder and baro-thermal conditions applied. All these factors may affect the expansion of extrudates, which offers a wide choice to snack producers [Moscicki *et al.*, 2011].

The results of bulk density measurements of the enriched snacks showed a significant influence of increasing buckwheat addition on higher bulk density of corn-buckwheat snacks (Figure 2). The values increased from 123 kg/m³ for corn snacks to 141 kg/m³ when 40% of buckwheat was used in the recipe. The negative correlation coefficient ($r=-0.845$) was obtained between the expansion ratio and bulk density.

Resistance for mechanical disruption is one of the most important factors during crispy foods transport and storage.

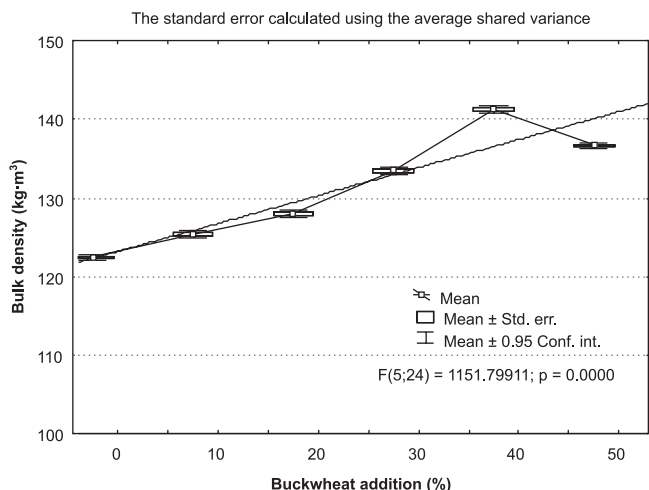


FIGURE 2. Bulk density of corn snacks enriched with buckwheat.

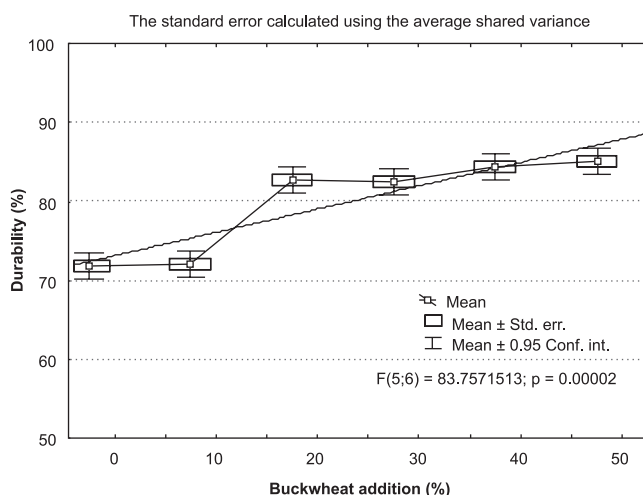


FIGURE 3. Durability of corn snacks enriched with buckwheat.

It was noticed that snacks durability was significantly dependent on buckwheat addition ($r=0.893$). The increased level of buckwheat in the recipe improved snacks durability, measured values varied from 72% for corn snacks to even 85% of undamaged samples with 50% of buckwheat (Figure 3). Durability of the analysed products was highly correlated with its expansion ratio (cor. coeff. -0.974) and bulk density of snacks ($r=0.834$).

Texture of corn-buckwheat snacks

The textural properties of snacks play an important role in terms of quality and consumer acceptability [Szczeniak, 2002]. Texture of snack samples evaluated with the cutting test as the maximum cutting force showed the force required for permanent deformation of the sample. Analysing the results of the cutting tests, it was observed an increased cutting force of snacks with the higher amount of buckwheat in the recipe. Values of cutting forces ranged from 18.4 to 23.3 N, differences between samples reached 5 N with increased buckwheat content. The cutting force was negatively correlated with the expansion ratio values (-0.66).

Texture profile of foods may be evaluated on the basis of texturograms obtained during double compression tests (Figure 4). As shown in this Figure, different peaks and areas under the curves were obtained depending on tested sample recipe. The upper line represents the first compression cycle and the bottom is for the second one. Due to the large sample destruction after the first compression, the second cycle graphs resulted in low values of peaks. On the basis of these data *testXpert*® software is able to calculate specific texture properties.

The results of selected texture characteristics of corn snacks enriched with buckwheat in the recipe are presented in Table 1. Texture of the extrudates measured with Kramer cell showed an influence of an increasing additive level on lower snacks fracturability and hardness ($r=-0.82$ and $r=-0.85$, respectively). Both of these textural properties were dependent on expansion ratio, bulk density and durability. The correlation coefficient for the expansion ratio and fracturability was $r=0.63$ and for hardness was $r=0.69$. Negative correlations were noted for fracturability and hardness *versus*

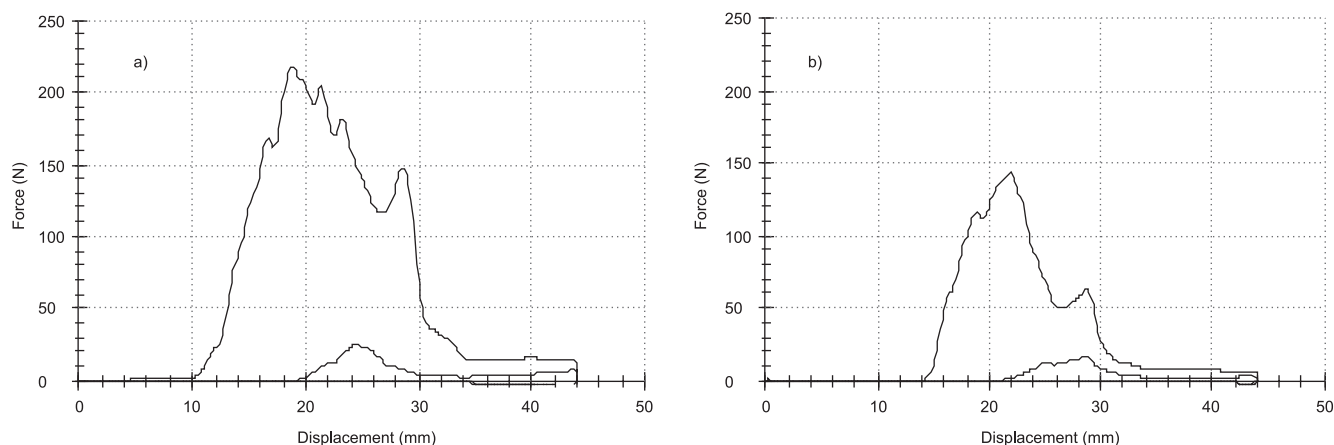


FIGURE 4. Results of texture measurement of corn snacks enriched with buckwheat: a) corn snacks, b) snacks with 50% of buckwheat.

bulk density ($r=-0.81$ and $r=-0.86$, respectively) and snacks durability ($r=-0.64$ and $r=-0.65$, respectively). A high correlation of $r=0.93$ was determined between hardness and fracturability. Springiness of the extrudates was low and highly correlated ($r=0.77$) with the adhesiveness and the expansion ratio ($r=0.60$). The results of crispness and adhesiveness of buckwheat-enriched extrudates showed inconclusive correlations of these characteristics with the increasing level of buckwheat in the recipe.

Colour evaluation

Colour measurements showed lower L^* values of snacks with higher buckwheat addition ($r=-0.93$) (Table 2). For corn

snacks processed without additives the L^* value was the highest and reached 91.9. This was confirmed during sensory assessment by semi-trained panel. Greenness-redness balance for buckwheat-enriched snacks varied from -1.92 for control samples without additives to -2.70 for 20% and -1.78 for 50% of buckwheat content in products, respectively (Table 2). The nature of buckwheat used in the experiments may be the key factor of high yellowness improved with the increasing buckwheat addition ($r=0.98$). The b^* values varied from 17.2 for control corn snacks to 35.6 for snacks enriched with 50% of buckwheat. Yellowness of snacks was observed in all samples because of the presence of carotenoids in corn grits and in buckwheat.

TABLE 1. Texture properties of corn snacks enriched with buckwheat.

Buckwheat addition (%)	Cutting force (N)	Fracturability (N)	Crispness (N)	Hardness (N)	Adhesiveness (mJ)	Springiness (-)
0	18.5 ^a ±2.70	172.36 ^{ab} ±3.90	3.94 ^d ±1.87	202.82 ^{ab} ±11.28	42.31 ^{ab} ±1.61	1.51 ^{ab} ±0.79
10	21.5 ^b ±5.06	196.90 ^a ±7.70	8.27 ^{bc} ±6.77	226.14 ^a ±10.16	16.20 ^b ±1.71	1.20 ^b ±0.15
20	23.3 ^c ±3.91	169.77 ^{ab} ±30.02	4.41 ^d ±2.83	216.44 ^{ab} ±21.21	18.68 ^b ±8.65	2.33 ^a ±1.34
30	22.1 ^b ±4.45	157.04 ^b ±17.25	28.75 ^a ±12.75	157.25 ^b ±17.00	22.50 ^b ±10.23	1.71 ^{ab} ±0.39
40	22.8 ^{bc} ±5.10	114.77 ^c ±32.31	14.20 ^b ±13.86	152.34 ^b ±2.69	53.98 ^a ±12.32	1.71 ^{ab} ±0.39
50	20.5 ^{ab} ±1.66	123.86 ^{bc} ±11.40	6.79 ^c ±2.14	144.36 ^b ±1.04	48.53 ^a ±24.70	1.54 ^{ab} ±0.44

^{a,b,c} – the same letters in columns mean that there are no significant differences between mean values at $p=0.05$ (Duncan's test).

TABLE 2. Colour values in $L^*a^*b^*$ scale of corn snacks enriched with buckwheat.

Buckwheat addition (%)	Colour parameter			ΔE
	L^*	a^*	b^*	
0	91.88 ^a ±0.79	-1.92 ^a ±1.31	17.21 ^a ±5.78	ref
10	91.41 ^a ±1.09	-3.07 ^b ±1.71	23.30 ^b ±7.62	6.21
20	91.57 ^a ±2.40	-2.70 ^b ±1.36	25.39 ^b ±6.32	8.23
30	88.67 ^{ab} ±3.65	-2.63 ^b ±1.49	30.92 ^c ±6.01	14.10
40	85.33 ^b ±3.21	-2.04 ^a ±1.92	32.63 ^c ±4.01	16.75
50	81.65 ^c ±3.81	-1.78 ^a ±1.31	35.65 ^d ±5.04	21.09

L^* – brightness, a^* (+)redness, (-)greenness, b^* (+)yellowness, (-)blueness values are means of 20 replications ± standard deviations. ^{a,b,c} – the same letters in columns mean that there are no significant differences between mean values at $p=0.05$ (Duncan's test).

TABLE 3. Sensory properties of buckwheat-enriched corn snacks.

Buckwheat addition (%)	Shape	Colour	Flavour	Taste	Crispness	Overall notes
0	4.0 ^a ±0.02	4.3 ^a ±0.10	3.5 ^{ab} ±0.25	3.7 ^a ±0.30	5.0 ^a ±0.67	4.10 ^a
10	4.0 ^a ±0.05	4.3 ^a ±0.10	3.8 ^a ±0.20	3.7 ^a ±0.50	4.5 ^{ab} ±0.50	4.06 ^a
20	4.0 ^a ±0.05	4.3 ^a ±0.14	3.8 ^a ±0.15	3.7 ^a ±0.50	3.8 ^b ±0.68	3.92 ^{ab}
30	4.0 ^a ±0.08	4.2 ^a ±0.25	3.8 ^a ±0.15	3.5 ^{ab} ±0.68	4.2 ^b ±0.46	3.94 ^{ab}
40	4.0 ^a ±0.10	4.0 ^{ab} ±0.30	3.7 ^a ±0.30	3.2 ^b ±0.73	3.0 ^c ±0.79	3.58 ^b
50	3.3 ^b ±0.15	3.7 ^b ±0.50	3.3 ^b ±0.50	2.8 ^c ±0.84	3.2 ^c ±0.73	3.26 ^c

^{a,b,c} – the same letters in columns mean that there are no significant differences between mean values at $p=0.05$ (Duncan's test).

Sensory properties

The sensory attributes results, like appearance, shape, colour, taste and crispness, of corn-buckwheat snacks are presented in Table 3. The best results of crispness were noted for corn snacks; the increasing level of buckwheat in the recipe lowered crispness of the tested snacks ($r=-0.88$). Also notes given to taste and colour decreased significantly with the increased amount of buckwheat in snacks ($r=-0.90$ and $r=-0.88$, respectively). The panellists noted that the increased level of buckwheat induced greenish tint of snacks as confirmed with instrumental colour measurements. Flavour and shape of the tested samples were similar and insignificant differences between the samples were noticed. Good sensory properties were revealed for snacks with addition of buckwheat up to 30% with the overall sensory notes of 3.92–4.10. The higher additive level lowered the sensory notes to values of 3.58 and 3.26 for snacks with 40 and 50% of buckwheat, respectively. The preliminary sensory evaluation of gluten-free breads with 30% of buckwheat flour showed significant improvement of the sensory quality in comparison with control breads, which obtained very low notes in total score [Wronkowska & Soral-Śmietana, 2008].

Higher buckwheat amount in the recipe lowered the overall acceptability notes ($r=-0.95$) (Figure 5). That was associated with a darker colour, higher adhesiveness of snacks and specific taste according to buckwheat addition. The over-

all quality of snacks enriched with buckwheat lowered, especially for those with higher than 20% buckwheat content and acceptability results were below 6.0 (Figure 5).

CONCLUSIONS

The presented results showed buckwheat as useful and valuable raw material for snacks obtained by extrusion-cooking. The application of the proposed process parameters allows achieving good quality corn snacks enriched with buckwheat. The addition of buckwheat lowered the expansion ratio of snacks and enlarged its bulk density and durability. Increased buckwheat addition lowered fracturability and hardness of the extrudates and their sensory notes. Also the lightness of snacks decreased significantly with the higher level of buckwheat used. The best acceptability was concluded for corn snacks enriched with buckwheat at a level not exceeding 30%, the higher dose of the additive gave specific buckwheat flavour to snacks. Corn-buckwheat snacks may be an attractive type of appetizer with increased nutritional properties.

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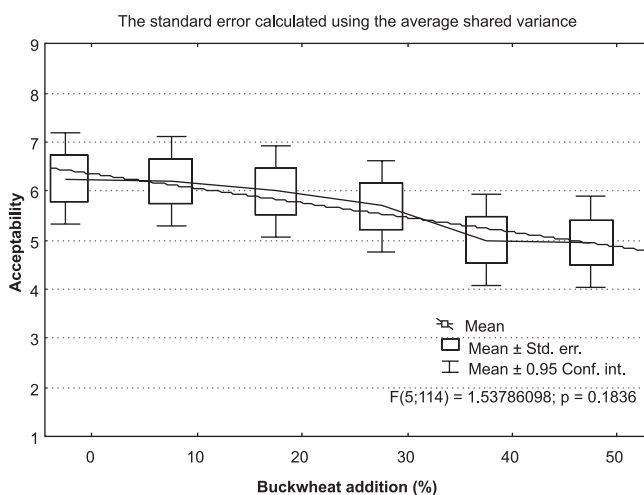


FIGURE 5. Acceptability of corn-buckwheat snacks depending on additive amount in a hedonic scale.

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