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SCIENTIFIC PAPER

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FLAKES PRODUCT SUPPLEMENTED WITH SUNFLOWER AND DRY RESIDUES OF WILD OREGANO

Article Highlights

- Sunflower and wild oregano was used to create flakes product with improved chemical properties
- Value added corn flakes has changed physical characteristics
- The sensory properties of flakes product with additional components were changed

Abstract

This paper investigates the effects of simultaneous addition of sunflower (3, 6 or 9 g/100 g of sample) and dry residue of wild oregano (0.5 or 1 of sample), on the physical texture and chemical properties of corn flakes to obtain new products with altered nutritional properties. The chemometric analysis pointed at the versatile beneficial contributions of sunflower in corn flakes enriched with dry residue of wild oregano enabling the optimization of corn flakes formula. The presented data point that addition of milled sunflower in investigated corn flakes products improved nutritive properties while addition of dry residue of wild oregano improved physical characteristics of corn flakes products. Regarding quality (sample CF11, score value of 0.59) maximum scores have been obtained with the addition of 6 g/100 g of sunflower and 1 g/100 g of dry residue of wild oregano per 100 g of sample for corn flakes formulation. Production of corn flakes with addition of wild oregano residues contributed to the food waste valorisation in the food industry.

Keywords: wild oregano, sunflower, corn flakes, physical-texture properties, chemical properties.

Cereals constitute the staple food of the human race. In accordance with the modern nutritionist opinions, cereal products, such as ready to eat breakfast cereals, flakes are the most common food in the daily diet, flakes and snacks. Heat treating of cereals is used for improving their hygiene, nutritional, physicochemical and other properties thus increaseing the nutrient value of some nutrients, improving sensory properties and providing the microbiological safety of the products [1-3]. Extrusion technology makes it possible to apply different sources of ingredients for the enrichment of cereal-based flakes or snack products. Extrusion is a relatively new technological process during which raw material is subjected to high temperature and high pressure during which raw material is also mechanically treated by shear forces (friction). Ingredients and formulation play an important role in developing the texture of the extruded product and ultimately the acceptability of the extruded product to the consumer [3-6]. Nowadays, consumers prefer to eat healthier foods in order to prevent diseases, but fast and easy to prepare. For this reason industry and researchers are involved in optimizing extruded technology to improve the physical and chemical properties, quality, taste, microbiology and functionality of food products such as flakes [2,3,7,8]. The industry, as a whole, faced the need to develop a positive message to consumers on flakes food with improved nutritional value. Among the ingredients that could be included in corn flakes formulation are milled sunflower and wild oregano, which may significantly

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improve its chemical and nutritive properties [3,7]. Sunflower seeds contain around 20% protein, high levels of potassium (710 mg/100 g) and magnesium (390 mg/100 g), respectively and are especially rich in polyunsaturated fatty acids (approximately 31.0%) in comparison to other oilseeds: soy (3.5%), peanut (13.1%), cottonseed (18.1%), flaxseed (22.4%), sesame seed (25.5%) and safflower seed (28.2%) respectively [9]. Wild oregano is a natural source of antioxidants and may be used as an ingredient in food products [10]. The residue after distillation of oil from wild oregano, which is one of the strongest natural antioxidants, certainly belongs to the group of food waste that can be used for developing of functional cereal-based products.

In this study, the effect of varying the proportion of sunflower (3, 6 and 9 g/100 g of sample) and wild oregano dry residue (0.5 and 1 g/100 g of sample) on the physical, texture and chemical properties of corn flakes was studied with the aim to obtain new products with good techological quality along with improved nutritional properties. The waste from distillation of wild oregano, as well as sunflower proteins, add new value to human nutrition.

MATERIAL AND METHODS

Materials

Corn flour used in this study was obtained from the mill Žitoprodukt d.o.o., Bačka Palanka, Serbia, produced in 2014 with following characteristics: moisture content of 13.3%, sugar, protein, cellulose, starch and lipid content (% dry matter basis) of: 0.87, 5.59, 0.98, 79.43 and 1.57, respectively [11]. Sunflower variety “Cepko” was produced in 2014 by “Vitastil” Erdevik, Serbia with following characteristics of samples, protein, starch, lipid and cellulose, content of 26.67, 6.73, 54.05 and 8.21 (% dry matter basis), respectively [11]. Sunflower was dehulled and milled in a Hammer mill 2300 rev/min with 2.5 mm sieve. Wild oregano (*Origanum minutiflorum* O. Schwarz & P.H. Davis) harvest 2013 was produced by Inan tarim ECODAB - Antalia, Turkey.

Dry residue of wild oregano

Dry residue of wild oregano was prepared as follows: distillation of wild oregano (*Origanum minutiflorum*) was carried out in the pilot plant distiller based on water vapor principle in the Institute of Medicinal Plant Research "Dr Josif Pančić" in Pančevo, Serbia. For distillation mini distiller was used. The distillation duration time was 2.5 h. Residue from distillation was dried with naturally air flow on to place protected from sun, milled at a facility Repro Trade d.o.o., Temerin, Serbia, on the hammer mill (2300 rpm, sieve hole diameter 1.5 mm) and prepared for further research.

Methods

Extrusion of flakes

The flakes were obtained by extrusion in a twin-screw extruder (Yuninan Daily Extrusion, Republic of China) in industrial conditions on Repro Trade d.o.o. Extrusion parameters were as a follows: length of monolit screws 140 cm, screw speed of 180 rpm, temperature profile: 114/125/131 °C. A triple die 6 mm diameter aperture was used and a knife rotating at 1300 rpm cut the emerging product into pelets about 5 mm in length. The moisture of raw material mixture prior extrusion was adjusted to 22%. Corn flour, was replaced by milled sunflower in the quantity 3, 6 or 9 g/100 g of sample, and dry residue of wild oregano added in the quantity of 0, 0.5 or 1 g/100 g of sample based on corn flour and milled sunflower. Table 1 describes corn formulation enriched with different quantities of milled sunflower and dry residue of wild oregano. Obtained extrudates were dried in drying unit at temperature of 84 °C, cooled for 30 min at controlled temperature 25±1 °C and stored at 4 °C in sealed plastic bags until required for analyses.

Texture analysis

Texture properties of flakes were measured by Texture Analyzer TA.HD plus (Stable Micro System, UK) equipped with a 50-kg load cell. Hardness and work of compression of flakes product were measured using a 45 mm cylinder probe (P/45R) by compressing 10 individual flakes at one turn. The maximum force and work of compression correlate to the hardness of the sample. The following settings were used: pre-test speed: 2 mm s^{-1}; test-speed: 2 mm s^{-1}; post-test speed: 10 mm s^{-1}; distance: 2.5 mm; trigger force: 10 g. The tests were performed on 5 replicates per batch.

Flakes color

Flakes color attributes were measured instrumentally using a Chroma meter (CR-400, Konica, Minolta, Tokyo, Japan) tri-stimulus colourimeter. The results were expressed in terms of L^* - brightness (from 0 (black) to 100 (white)), a^* - greenness/redness (from $-a^*$ (green) to $+a^*$ (red)), b^* - blueness/ /yellowness (from $-b^*$ (blue) to $+b^*$ (yellow)), W - whiteness, C - differences in coloration, h - differences in tone, DW - dominant wavelength as per CIELab system. The measurements were observed under constant lighting conditions, at 28 °C, using a white control (L^* = 98.76, a^* = -0.04, b^* = 2.01) [8].

Table 1. Flakes formulation with different quantities of milled sunflower and dry wild residue oregano

Sample	Quantity of corn g/100 g flour	Quantity of sunflower g/100 g flour	Quantity of dry wild oregano residue g/100 g sample	Quantity of salt g/100 g sample
CF0	100	0	0	0
CF1	100	0	0	2
CF2	97	3	0	2
CF3	94	6	0	2
CF4	91	9	0	2
CF5	100	0	0.5	2
CF6	97	3	0.5	2
CF7	94	6	0.5	2
CF8	91	9	0.5	2
CF9	100	0	1	2
CF10	97	3	1	2
CF11	94	6	1	2
CF12	91	9	1	2

Physical characteristics

Bulk density (*BD*) was measured by a bulk density tester (Tonindustrie, West und Goslar, Germany). It was determined by loose pouring the flakes samples into a 1000 ml measuring-cylinder. The inner diameter of the steel cylinder was 53 mm. The flakes samples were subsequently transferred to a funnel with a valve mounted in the bottom. The measuring cylinder was placed underneath at the center and the valve opened. Filling of the cylinder continued until a pile of flakes had developed on the top. Then excess flakes were gently removed by pulling a scrape one time over the edge of the cylinder. The sample was weighed on an electronic scale, and the bulk density was recorded (g ml^{-3}). The results are presented as means of six measurements.

Expansion ratio (*ER*) was determined according to Kaludjerski and Filipović [12], where expansion ratio was calculated as:

ER = volume flakes (ml)/crude flakes prior flaking volume (ml)

Basic chemical analyses

Basic chemical analyses (protein, starch, lipid, sugar and moisture) of flakes were determined according to the official methods of AOAC [11]. Measurements of all analysed responses are done in triplicates.

Statistical analyses

Descriptive statistical analyses for all obtained results were expressed as the mean ± standard deviation (*SD*). Post-hoc Tukey's HSD test was evaluated for comparison of physical and textural attributes with color attributes and chemical composition for different formulations of corn flakes.

Principal component analysis (PCA), used as the pattern recognition technique, was applied within assay descriptors to characterize and differentiate various analyzed samples. The PCA analyses of the obtained results were performed using StatSoft Statistica® 10.0 (StatSoft Inc., 2010, USA) software.

Score analysis

Score analysis uses min-max normalization of corn flakes quality parameter responses and transfer them from their unit system in new dimensionless system which allows further mathematical calculation of different types of responses [13]. The maximum value of normalized score presents the optimum value of all analyzed responses [14] and indicates the optimum quantity of added sunflower flour and wild oregano residue in corn flakes formulation.

RESULTS AND DISCUSSION

Physical and texture characteristics of flakes product

The bulk density of flakes product is important in relation to their packaging requirement and the ability to float or sink when poured into water or milk [1]. Effect of sunflower and dry residue of wild oregano addition on bulk density is shown in Table 2. The bulk density of flakes varies from 150 to 323 g dm^{-3}. With addition of sunflower (3, 6 and 9 g/100 g sample) bulk density of extruded product statistically significantly increased and addition of dry residue of wild oregano (0.5 and 1 g/100 g sample) statistically significantly decreased bulk density of extruded product. With addition of sunflower (3, 6 and 9 g/100 g sample)

Table 2. Characterisation of corn flakes with sunflower flour and wild oregano; the results are presented as mean ± SD; different letter within the same column indicates significant differences ($p < 0.05$), according to Tukey's test. Number of repetitions: $n = 3$. Experimental cases (samples) are detail explained in Table 1

Sample	Physical and texture attributes				Color attributes							Chemical composition			
	BD g ml^{-1}	*ER* ml g^{-1}	*H* kg	*WOC* kg s^{-1}	L^*	a^*	b^*	*W*	*C*	*h*	*DW*	*P*	*Lip*	*St*	*S*
CF0	176.30 ±1.86^{a}	7.86 ±1.77^{ab}	26.46 ±4.59^{a}	10.62 ±2.19^{ab}	85.018 ±0.88^{a}	-0.99 ±0.26^{a}	36.36 ±1.69^{ab}	60.66 ±1.87^{abcd}	36.38 ±1.69^{ade}	91.57 ±0.46^{a}	575.69 ±0.14^{a}	5.40 ±0.09^{a}	2.15 ±0.02^{a}	78.76 ±0.05^{a}	0.56 ±0.01^{a}
CF1	215.00 ±3.60^{b}	6.46 ±1.89^{ab}	14.35 ±2.68^{ab}	8.27 ±1.17^{abc}	85.50 ±0.85^{a}	-1.06 ±0.11^{a}	34.06 ±2.19^{ac}	62.97 ±2.34^{bcd}	34.08 ±2.18^{ab}	91.80 ±0.30^{a}	575.62 ±0.09^{abc}	5.48 ±0.20^{a}	2.0 ±0.02^{b}	78.72 ±0.03^{a}	0.69 ±0.02^{b}
CF2	227.51 ±2.14^{c}	6.21 ±0.00^{ab}	15.63 ±5.8^{ab}	8.86 ±1.18^{abc}	82.23 ±0.12^{b}	-1.17 ±0.11^{ab}	38.54 ±0.95^{b}	58.86 ±1.60^{bc}	38.55 ±0.95^{d}	91.74 ±0.14^{a}	575.62 ±0.05^{abc}	5.92 ±0.03^{b}	3.85 ±0.03^{c}	78.52 ±0.09^{b}	0.69 ±0.03^{b}
CF3	242.34 ±6.06^{d}	6.00 ±0.00^{ab}	17.22 ±7.99^{ab}	10.10 ±2.30^{abc}	81.80 ±0.43^{b}	-1.26 ±0.13^{ab}	36.88 ±1.58^{ab}	58.61 ±2.27^{abd}	36.90 ±1.58^{ad}	91.98 ±0.28^{a}	575.55 ±0.09^{abc}	6.31 ±0.09^{c}	5.30 ±0.06^{d}	78.07 ±0.08^{c}	0.58 ±0.01^{a}
CF4	323.41 ±3.00^{e}	4.20 ±0.00^{a}	20.64 ±7.85^{ab}	11.40 ±3.27^{b}	79.26 ±0.87^{c}	-1.52 ±0.14^{b}	35.78 ±2.14^{ab}	57.55 ±0.484^{a}	35.82 ±2.13^{acde}	92.45 ±0.37^{a}	575.39 ±0.11^{bc}	6.42 ±0.23^{c}	6.72 ±0.02^{e}	77.82 ±0.09^{d}	0.62 ±0.01^{a}
CF5	161.60 ±1.60^{f}	8.60 ±0.00^{b}	15.51 ±1.51^{ab}	7.79 ±1.91^{abc}	83.15 ±0.45^{ab}	-1.12 ±0.21^{ab}	30.95 ±0.80^{cd}	64.74 ±0.83d^{e}	30.97 ±0.80^{b}	92.08 ±0.39^{a}	575.54 ±0.12^{abc}	5.27 ±0.02^{a}	2.06 ±0.03^{ab}	78.36 ±0.05^{e}	0.68 ±0.01^{b}
CF6	194.67 ±0.46^{g}	7.01 ±1.31^{ab}	16.42 ±5.36^{ab}	8.42 ±1.97^{abc}	82.20 ±0.47^{b}	-1.12 ±0.12^{ab}	33.05 ±1.29^{ac}	62.44 ±1.33^{bcd}	33.07 ±1.28^{abf}	91.95 ±0.27^{a}	575.57 ±0.08^{abc}	5.35 ±0.09^{a}	3.72 ±0.02^{f}	78.30 ±0.06^{e}	0.74 ±0.03^{b}
CF7	222.41 ±0.29^{ch}	5.82 ±1.89^{ab}	18.53 ±4.14^{ab}	9.17 ±2.57^{abc}	79.05 ±0.75^{c}	-1.37 ±0.20^{ab}	33.52 ±0.57^{ac}	60.45 ±0.76^{abc}	33.55 ±0.57^{ab}	92.34 ±0.70^{a}	575.44 ±0.12^{abc}	5.72 ±0.22^{ab}	5.8 ±0.06^{g}	77.80 ±0.06^{d}	0.86 ±0.00^{c}
CF8	302.41 ±1.27^{i}	4.43 ±0.00^{a}	23.76 ±2.70^{a}	12.17 ±1.01^{b}	78.13 ±0.28^{c}	-1.44 ±0.05^{ab}	32.40 ±0.15^{ac}	60.88 ±0.18^{abcd}	32.43 ±0.15^{be}	92.55 ±0.10^{a}	575.37 ±0.03^{c}	6.19 ±0.05^{bc}	6.81 ±0.01^{e}	77.65 ±0.06^{f}	0.85 ±0.01^{c}
CF9	150.20 ±1.21^{j}	9.36 ±1.77^{b}	8.88 ±3.95^{b}	4.94 ±0.40^{c}	82.51 ±0.64^{b}	-1.05 ±0.16^{a}	27.26 ±1.00^{d}	67.59 ±1.10^{e}	27.28 ±1.00^{f}	92.20 ±0.34^{a}	575.52 ±0.10^{abc}	5.71 ±0.05^{ab}	2.10 ±0.03^{a}	78.38 ±0.05^{e}	0.87 ±0.01^{c}
CF10	197.51 ±0.52^{gk}	7.10 ±1.29^{ab}	9.62 ±1.79^{b}	5.35 ±1.69^{ac}	80.74 ±0.35^{bc}	-1.00 ±0.04^{a}	29.68 ±1.28^{cd}	64.60 ±1.23^{de}	29.70 ±1.28^{bf}	91.93 ±0.10^{a}	575.59 ±0.03^{abc}	5.93 ±0.02^{b}	3.90 ±0.01^{c}	78.28 ±0.03^{e}	0.84 ±0.00^{c}
CF11	213.17 ±0.17^{bl}	6.36 ±1.23^{ab}	14.15 ±2.17^{ab}	7.00 ±1.09^{abc}	77.85 ±0.59^{c}	-1.00 ±0.16^{a}	32.44 ±0.69^{ac}	60.70 ±0.31^{abcd}	32.46 ±0.40^{ab}	91.76 ±0.27^{a}	575.63 ±0.08^{abc}	6.24 ±0.02^{bc}	5.25 ±0.01^{d}	77.78 ±0.02^{d}	0.83 ±0.02^{c}
CF12	253.71 ±2.60^{d}	5.86 ±1.47^{ab}	28.34±3 .74^{d}	17.68 ±1.00^{d}	74.25 ±0.88^{d}	-0.96 ±0.13^{a}	32.04 ±1.60^{c}	59.44 ±1.42^{abc}	32.06 ±1.60^{bc}	91.72 ±0.28^{a}	575.64 ±0.08^{abc}	7.21 ±0.01^{d}	6.78 ±0.04^{e}	77.76 ±0.05^{d}	0.84 ±0.03^{c}

expansion ratio of extruded product statistically significantly decreased, the addition of wild oregano residue (0.5 and 1 g/100 g sample) statistically significantly increased expansion ratio of flakes product, probably due to the interaction of wild oregano with starch. Besides that, the cellulose component can rupture cell walls and prevent air bubbles from expanding to their maximum potential [16]. The results of bulk density are inversely proportional to the results for the expansion ratio (Table 2), *i.e.*, flakes products with added sunflower had higher bulk density statistically significantly lower expansion ratio proportionally to sunflower share [16,17] also confirmed that sunflower share in the corn flour for flakes product decreased expansion of products.

One of the most important quality parameters of flakes is the time during which, when soaked in milk, their texture is still acceptable for consumers. The textural characteristics hardness and work of compression of flakes product with sunflower and wild oregano residue addition are presented in Table 2. The highest value for hardness (28.34 g) was observed for sample CF12, while the lowest hardness value was noticed for sample CF9 (8.88 g). Statistically significant differences in hardness were not observed between following samples CF0, CF1, CF2, CF3, CF4, CF5, CF6, CF7, CF8, CF11 and CF12, while other samples (CF9 and CF10) were statistically different. Addition of sunflower results in increasing hardness. These results are in accordance with data reported by Jozinović *et al.* [17], who concluded that texture properties are highly influenced by expansion ratio, *i.e.*, extrudates with higher expansion ratio had lower hardness and work of compression. Sunflower also influenced mechanical and microstructural properties of flakes product obtained from high amylose corn starch and sunflower protein concentrate and hardness increased as also observed by Zhu *et al.*

[18]. Share of wild oregano contributes to increased hardness (CF5, CF6, CF7, C8 and CF12) where presence of fibers in oregano caused the increase of product hardness probably due to their cell wall thickness as stated by Yanniotis *et al.* [19], Lazou and Krokida [20] and Nascimento *et al.* [21]. Addition of sunflower (3, 6 or 9 g/100 g sample) contributes to a higher value of work of compression as compared to the flakes without sunflower. Addition of wild oregano (0.5 or 1 g/100 g sample) caused continual of the work of compression decreased (CF1, CF2, CF3, CF5, CF6, CF7, C9, CF10 and CF11) contrary to samples CF4, CF8 and CF12 with maximum share of sunflower probably due to corn proteins and starch complexing with sunflower lipids.

The color characteristics of corn flakes are important sensory characteristics of a product. These attributes are significant in creating sensory expectations of consumers, which could affect their perception and acceptance of the product [8]. Different values in various color coordinates were observed for different flakes formulations (Table 2). Statistically significant differences between all flakes samples were found for L^* coordinate (brightness) due to sunflower and dry residue of wild oregano content which contributed to the decrease of the brightness value L^*. The highest L^* (85.50) was observed for sample CF1, while the lowest L^* value (74.25) was noticed for sample CF12, with the greatest shares of sunflower and wild oregano. Content of sunflower and wild oregano contributed to decrease of brightness L^*, which led to the formation of darker flakes product. Similar results were observed by Jozinović *et al.* [17]. The share of green colour (a^*) coordinate was found to have no statistically significant difference among all samples. Statistically significant differences in yellow color (b^*) were observed in samples with increasing share of sunflower thus positively contributing to favorable yellow color of flakes product. The addition of wild oregano influenced statistically significant ($p < 0.05$) decrease of yellow (b^*). Additon of sunflower influenced statistically significant decrease of colour attribute of whiteness (W), while addition of wild oregano in flakes samples caused statistically insignificant increase of whiteness (W). The highest the differences in coloration C (38.55) were measured in sample CF2 and the lowest C (27.28) for sample CF9. Share of sunflower contributed to statistically insignificant increased coloration (C) but share of wild oregano addition contributed to statistically significant decreased coloration (C) leading to a more intensive coloration of flakes product. The difference in tone (h) was statistically insignificantly different for most of the samples indicating that there were no influences of addition of sunflower flour and dry residue of wild oregano on difference in tone. The maximum value of h was observed in sample CF8 (92.55) and the lowest value of h (91.57) was found in sample CF0. Values of dominant wavelength ranged between 575.37 (sample CF8) and 575.69 (sample CF0), thus indicated that sunflower and wild oregano addition were not statistically significantly affecting the dominant wavelength. Influence of various raw materials on the color of extruded products was attributed to the diverse reactions that basically include the Maillard reaction [3].

Flakes products are complex multi-component systems consisting of biomacromolecules such as proteins, carbohydrates and lipids. Carbohydrates (78.07-80.19%) dominated in corn flakes (Table 2). There were great possibilities for the improvement of functional characteristics of flakes products [8,22]. The addition of sunflower flour to flakes product improved proteins and nutritive properties (Table 2).

Investigated corn flakes were characterized by low crude protein content in the sample without sunflower (CF0, CF1, CF5 and CF9). The minimum (5.27±0.02% d.m.) was observed in CF5. The addition of sunflower statistically significantly contributed to the increase of protein in corn flakes because a part of the corn flour was replaced with constituent richer in proteins. Statistically significant differences in lipid content were observed for almost all flakes samples, Table 2. As expected, the maximum of lipid content (6.78± 0.04% d.m.) was obtained for CF12 (maximum sunflower and maximum of wild oregano addition), while the minimum of 2.15±0.02% was observed in CF0. Lipid content in corn flakes depended only on the content of sunflower, since wild oregano was a non-lipid constituent. Starch content reached maximum value (78.76% d.m.) in CF0 and, as expected, the minimum of starch 77.65% d.m. was observed in CF8, where addition of sunflower flour statistically significantly decreased starch content in samples of flakes product. Statistically significant differences in sugar content were not observed between following group of samples: group I (CF0, CF3 and CF4), group II (CF1, CF2, CF5 and CF6), group III (CF7, CFCF8, CF9, CF10, CF11 and CF12) while other samples were statistically different.

Score calculation

Score analysis quantifies different responses of corn flakes quality parameters in dimensionless values that represent score values which were comparable between samples of corn flakes with different formulations. In that way, score values allow the possibility of comparing total quality of the analyzed samples, and optimization of its formulation.

Figure 1 shows score values of corn flake samples with different quantity of added sunflower flour and wild oregano residue, where it can be seen that increase of quantity of dry wild oregano residue increased total quality of the corn flake samples while addition of medium quantities of sunflower flour resulted in optimum total quality parameters. Corn flakes sample CF11 achieved the maximum score value of 0.59, indicating on optimal combination of added quantities of sunflower flour and dry wild oregano residue.

PCA

The PCA allows a considerable reduction in the number of variables and the detection of structure in the relationship between measuring parameters and different samples of corn flakes formulations that give complementary information [23]. The full auto scaled data matrix consisting of corn flakes samples with 0, 3, 6 and 9 g/100g of added sunflower flour and 0, 0.5 and 1 g/100g of added wild oregano residue was submitted to PCA. For visualizing the data trends and for the discriminating efficiency of the used descriptors a scatter plot of samples using the first two principal components (PCAs) from PCA of the data matrix was obtained (Figure 2).

As can be seen, there was a neat separation of the 12 samples of corn flakes formulation, according to physical and texture attributes, color attributes and chemical composition Samples were grouped according to quantity of added sunflower flour (samples are connected with tin line) and quantity od added wild oregano residue (samples were encircled with tin line border).

Samples located on the bottom part of the graphic had added dry wild oregano residue in their formulations, while samples located on the right half of the graphic had added increased quantity of sunflower flour (6 and 9%). Samples that were located in lower right quadrant of the graphic (CF11, CF7, CF12 and CF8) were characterized by increased protein and lipid contents and increased antioxidant activity. Corn flakes samples located in upper right corner, which do not have added dry wild oregano residue while having added increased quantity of sunflower flour in formulations (CF3 and CF4) had increased texture parameters of hardness, work of compression and bulk density. Samples located in upper left quadrant of the graphic (CF0, CF1 and CF2, which had no added dry wild oregano residue and 0 or 3% of added quantity of sunflower flour in their formulations) were characterized with increased starch content, dominant wavelength and brightness. Corn flakes samples with added quantity of dry wild oregano residue (0.5 and g/100 g) and 0 and 3 of added quantity of sunflower flour (CF5, CF6, CF9 and CF10), which were located in lower left quadrant of the graphic were characterized by increased expansion ratio, whiteness and share of green color.

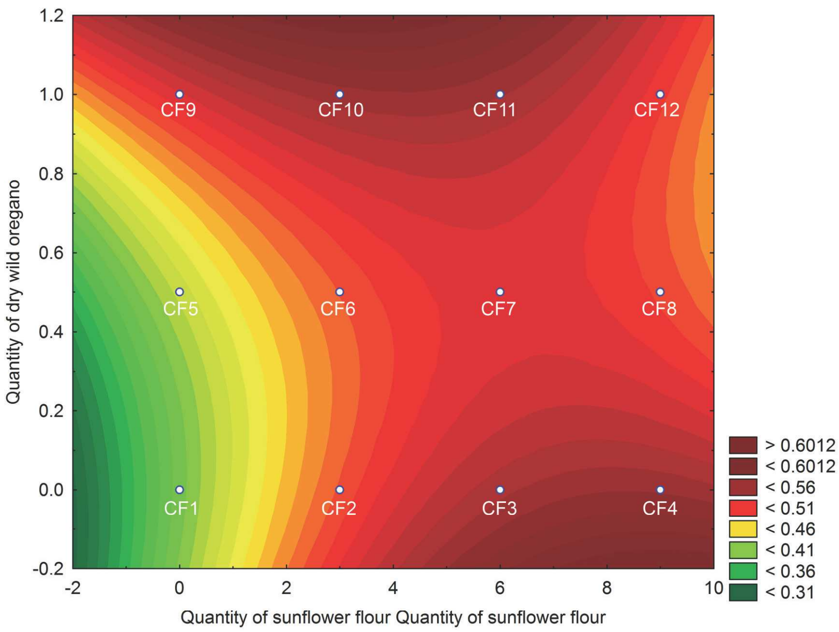

Figure 1. Score values contour plots of corn flakes samples with different quantities of added dry wild oregano residue and sunflower flour.

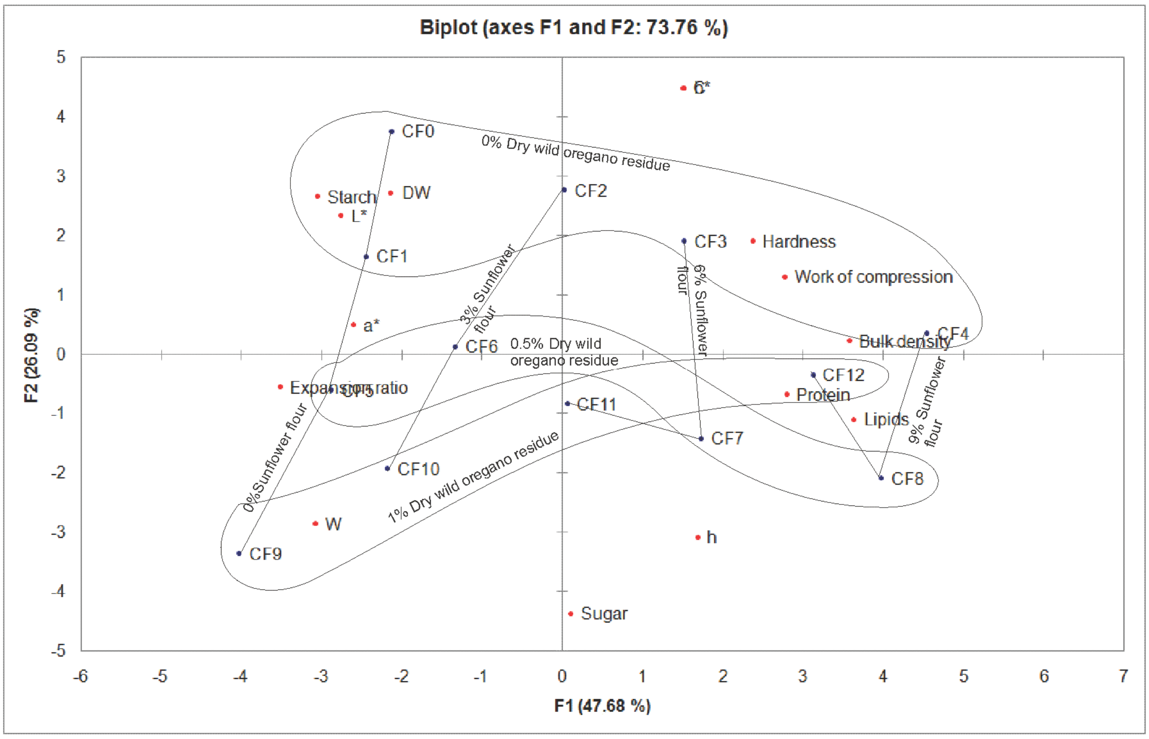

Figure 2. Biplot diagram of corn flakes samples regarding dry wild oregano residue and sunflower flour content.

Quality results showed that the first two principal components account for 73.76% of the total variance and could be considered sufficient for data representation. Concerning physical and texture attributes, color attributes and chemical composition, bulk density (with 12.25% contribution based on correlation), expansion ratio (11.79%) and lipid content (12.61%) mostly contributed to the first factor calculation, while share of yellow (19.29%) and difference in coloration (19.26%) contributed more to the second factor coordinate calculation.

CONCLUSIONS

Based on data resulting from the investigations it can be concluded:

1. Addition of sunflower adversely influenced corn flakes physical characteristics and addition of dry residue wild oregano positively influenced physical characteristics.

2. Sunflower and dry residue of wild oregano have affected corn flakes texture by increasing hardness and work of compression.

3. Addition of sunflower and dry residue wild oregano significantly changed the color of flakes product.

4. Addition of sunflower insignificantly increased the content of protein and lipids.

5. Application of PCA, as the multivariate method of analysis, has provided better visualization in differentiation of the samples. Properties of physical, texture and chemical attributes are the dominant variable in the first principle component, while the color attributes were the most dominant variable in the second principle component, thus stressing the role of share of sunflower and dry residue of oregano.

6. Score analysis was used to calculate total quality of tested samples and to point at optimal formulation of corn flakes as a functional food. Corn flakes sample CF11 achieved maximum score value of 0.59 indicating on optimal combination of added quantities of sunflower flour and dry residue of wild oregano.

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FIZIČKO-HEMIJSKE KARAKTERISTIKE KORN FLEJKSA OBOGAĆENOG KONZUMNIM SUNCOKRETOM I DIVLJIM ORIGANOM

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NAUČNI RAD

U ovom radu je ispitan uticaj dodatka konzumnog suncokreta (3, 6 ili 9 g/100 g po uzorku) i suvog ostatka divljeg origana (0.5 ili 1 g/100 g po uzorku), u skladu sa primenjenim eksperimentalnim planom 3x4, na fizičke, teksturalne i hemijske osobine korn fleksa za dobijanje novog proizvoda poboljšanih nutritivnih karakteristika. Metod odzivne površine je odabran za procenu uticaja konzumnog suncokreta i divljeg origana na kvalitet korn fleksa. Hemometrijska analiza je ukazala na doprinos konzumnog suncokreta i suvog ostatka divljeg origana na optimizaciju sirovinskog sastava fleks proizvoda. Prikazani podaci pokazuju da dodavanje mlevenog suncokreta imalo uticaj na poboljšanje nutritivnih svojstava dok je dodatak suvog ostatka divljeg origana uticao na poboljšanje fizičkih karakteristika korn fleksa. Uzorak KF 11 ima maksimalnu vrednost ocene 0.59 što ukazuje na optimalnu kombinaciju dodatih količina suncokretovog brašna (6 g / 100g uzorka) i suvog ostatka divljeg origana (1g / 100g uzorka). Proizvodnja korn fleksa sa dodatkom suvog ostatka divljeg origana doprinosi valorizaciji sporednih proizvoda u prehrambenoj industriji.

Ključne reči: divlji origano, suncokret, korn flejks, fizičko-teksturalne karakteristike, hemijski sastav.