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Physical and sensory properties of corn flakes with added dry residue from wild oregano distillation

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Abstract: According to the modern nutritionists, cereal products such as flakes and snacks are the most common foods in the daily diet. The extrusion technology makes it possible to apply different sources of ingredients for the enrichment of cereal-based flakes or snack products. Substances with strong antioxidant properties such as wild oregano have a positive impact on human health. Therefore, they attract the attention of scientists, consumers and food industry experts. This paper investigates the effects of the simultaneous addition of dry residue from wild oregano distillation (0.5 g/100 g sample and 1 g/100 g sample), on the physical- textural and color properties of corn flakes in order to create a new product with improved nutritional properties. The addition of dry residue of wild oregano positively influenced the physical characteristics of the corn flakes (decrease in the bulk density by 30.2 %, and increase in the expansion rate by 44.9 %), as well as led to decrease in their texture hardness and work of compression by 42.8 and 40.3 %, respectively. Also, the oregano significantly changed the color of the flakes. The Tukey's HSD test showed statistically significant differences between most of the mean values of physical-textural, color and sensory attributes of the oregano-added corn flakes and the ones of the control sample. A principal component analysis has been applied to classify the samples according to the differences in the studied parameters. The data showed that the investigated corn flakes with added dry residue from wild oregano distillation is a new food product with good physical-textural and sensory properties due to a higher level of its antioxidant activity. Moreover, this new product may contribute to the valorization of edible industrial waste in food production.

Keywords: flakes products; wild oregano; physical-textural properties; color; sensory properties.

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INTRODUCTION

A sensory analysis is widely used to evaluate the perceived characteristics of dry cellular food products such as extrudates, chips or puffed cereal products. The results are often compared to physical measurements, as first illustrated by Vickers and Christensen for crispness.[1] The crispness is one of the most important sensory quality attributes of low-moisture solid food products such as corn flakes.[2] The actual difficulty in the evaluation of these products, in order to predict their sensory properties, is due to their structural complexity and practical problems of measurement such as sample size, preparation and geometry, which have to be addressed.[3] Moreover, some cereal products, like corn flakes, are particulate solids of irregular shapes, difficult to test individually. A heat treatment of cereals is used for improvement of their nutritional, hygienic, physicochemical and other properties. Additionally, it increases the value of some nutrients, improves sensory properties and provides the microbiological safety of the products.[4,5] The extrusion technology makes it possible to apply different sources of ingredients for the enrichment of cereal-based flakes or snack products.[4,6] The food and agricultural product processing industries generate a substantial quantity of phenolic-rich by-products, which could be used as valuable natural source of antioxidants. Phytochemicals, including phenolic compounds are suggested to be the major bioactive compounds contributing to the health benefits of the fruits, vegetables and grains. The flavonoids are a group of phenolic compounds with antioxidant activity that provide a reducing effect to the risk of major chronic diseases.[7] Among the ingredients that could be included in the corn flakes formulation is the wild oregano, which may significantly contribute to its physico-sensory properties[2] and increase the amount of antioxidants of natural origin.[8] The mechanical resistance of cereal-based expanded products, soft (sponge cakes) or crispy (extruded starches), may directly be related to their apparent density underlying the relevance of the model of cellular solids in this case[3,9]. An uniform soft crisp texture and bright yellow color are the desired features of the corn flakes while maintaining their integrity after putting them in milk.[1] Although the extrusion is conducted at low moisture content, the use of high temperature for a short duration leads to a sudden release of steam, leaving behind an expanded non-collapsing structure. The development of crisp texture and characteristic flavor are an integral part of this operation. Whatever the sensor and data treatment procedures were used, they have put the effect of moisture content on the sensory and physical properties of cereal food foams in a prominent place.[1,2] As noted by Duizer,[10] the relationships between the physical measures and sensory evaluation are established by testing cereal-based food products conditioned under different water activities. The physical and chemical changes in the proteins, occurring during processing of corn flakes, could affect the texture of corn-based ready-to-eat breakfast cereals.[1,11,12]

The dry residue obtained from wild oregano distillation is an edible industrial waste that can be recycled as a high-added value ingredient inside the food chain. In this regard, the paper investigates the impact of its addition (0.5 g wild oregano/100 g sample and 1 g wild oregano/100 g sample) with the aim of making a new product with improved technological characteristics.

EXPERIMENTAL

Materials

In this experimental study, the following materials were used for corn flake production:

- The corn flour used in this study was obtained from Žitoprodukt d.o.o. mill, Bačka Palanka location, Serbia. It was produced in 2014 and has the following characteristics: sample moisture content of 13.3%, sugar, protein, cellulose, starch, and lipid content (% dry matter sample) of 0.87, 5.59, 0.98, 79.43, and 1.57, respectively.[13]
- Wild oregano (*Origanum minutiflorum*), harvest 2013, produced by İnan Tarım Ecodab – Antalia, Turkey.
- 2,2´-Diphenyl-1-picrylhydrazyl (DPPH), 2,4,6-tripyridyltriazine (TPTZ), Folin–Ciocalteu phenol reagent, ferric chloride and monobasic potassium phosphate were obtained from Sigma–Aldrich. All of the other reagents and chemicals used were of analytical grade.

Preparation of dry residue of wild oregano

The dry residue from wild oregano was prepared as follows: the distillation of wild oregano was carried out in the production plant of the Institute of Medicinal Plant Research "Dr Josif Pančić" from Pančevo, Serbia. The distillation was conducted in a mini distiller based on the water vapor principle. The duration of the distillation process was 2 h and 30 min. The waste in the process of distillation (trope) is naturally cooled and dried by air flow in place, protected from the sun and prepared for further research: milled at a facility Repro Trade d.o.o. on a hammer mill "Sever" Subotica (2300 rpm, sieve hole diameter 1.5 mm, particle size < 12 mm).

Preparation of corn flakes

The flakes product was obtained by extrusion in a twin-screw extruder (Yuninan Daily Extrusion, Yunnan, Republic of China) in industrial conditions in Repro Trade d.o.o. factory, Temerin, Serbia. The extrusion parameters were as follows: length of the screw, 140 cm, diameter, 6 mm, rotor speed, 180 rpm, temperature profile, 131/125/114 °C. The moisture of the corn flour, with or without milled dry residue from wild oregano in a mixer, was adjusted to 22% humidity of flour. The corn flour was replaced by dry residue from wild oregano added in quantity of 0.5 g/100 g sample or 1 g/100 g sample. Three formulations of corn flakes were tested: CF 1 (control sample without wild oregano), CF 2 (0.5 g wild oregano/100 g sample) and CF 3 (1 g wild oregano/100 g sample). The obtained extrudates were dried in a dry unit at temperature of 84 °C, cooled for 30 min at controlled temperature of 25±1 °C, and stored in plastic bags until used for analysis.

Physical analyses

The bulk density (*BD*) was measured by a bulk density tester, Tonindustrie, West und Goslar, Germany. The moisture content during the pelleting process was determined by a rapid moisture analyzer (OHAUS MB 45, Nänikon, Switzerland). The expansion ratio (*ER*) was determined according to Kaludjerski and Filipović[14] and Kannadhason *et al.*,[15] where it was calculated as follows: *ER* = flakes volume/crude flakes volume.

Corn flake texture – texture analysis

The textural properties of the flakes product were measured by a texture analyzer TA.HD plus (Stable Micro System, Godalming, Surrey, UK) equipped with a 50 kg load cell. The hardness, work of compression, crispiness and crunchiness of the flakes product were measured using a 45 mm cylinder probe (P/45R) by compressing 10 individual flakes at one turn. The hardness is defined as the maximum force during the sample compression. The maximum force and work of compression correlate to the hardness of the sample. The crispness is defined as the number of force peaks during the sample compression. The crunchiness is defined as the linear distance in the selected region of the compression curve, which actually represents an imaginary line joining all points of the multi-peak compression curve. The longer the linear distance the crunchier the product. 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×*g*. The tests were performed by making 10 replicates per batch.

Corn flake color

The flake color was measured by objective colorimeter Chroma meter (CR-400, Konica, Minolta, Tokyo, Japan) and was determined according to the procedure previously described by Filipović *et al*.[16]

Sensory analysis

In this study, the test to assess the quality and acceptability was performed by using 57 inexperienced tasters. The tasters were asked to evaluate the following sensory properties of corn flakes with 0, 0.5 and 1 % of wild oregano (WO): taste, odor, chewability and overall acceptability using a 9-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely).

Antioxidant activity

The antioxidant activity of a sample of WO, dry residue from WO (DR) and corn flakes (CF 1 – 0 g/100 g sample, CF 2 – 0.5 g/100 g sample and CF 3 – 1 g/100 g sample) was determined. The material was grinded and extracts were obtained by subjecting 1 g (WO, DR) and 2 g (CF 1, CF 2 and CF 3) of the powdered material to maceration in 100 ml 80 % ethanol (in water) for 24 h at ambient temperature in the dark. The extracts were filtered using filter paper (Whatman No. 1) followed by centrifugation (U-320 R, Boeco, Germany) at 4750 g (4 °C) for 15 min and after that were kept refrigerated. These extracts were used for determination of the total phenolic content (*TPC*), antiradical power (*DPPH ARP*) and ferric reducing antioxidant power (*FRAP*). In all of the assays, the absorbance was measured using Thermo Scientific Evolution 220 spectrophotometer.

The total phenolic content (*TPC*) was determined using the Folin–Ciocalteu method and the results are expressed as milligram of gallic acid equivalents (GAE) per g of extract sample.[17] The assay mixture contained 1 ml of Folin–Ciocalteu phenol reagent (previously diluted in the ratio of 1:10 with distilled water) and 200 µl of the sample solution. The mixture was neutralized with 7.5 % sodium carbonate solution after 10 min. For each sample three replicates were carried out and also a control one, where 1 ml of dH_2O was added instead of Folin–Ciocalteu phenol reagent. The absorbance was determined after 60 min at 760 nm.

The DPPH free radical scavenging activity was evaluated according to the method of Sánchez-Moreno *et al.*[18] with minor modifications. The following assay procedure was used: 15.7 mg of DPPH was weighed and dissolved in absolute ethanol. A working solution of 90 µM DPPH was prepared by diluting 22 ml of the primary DPPH solution to a volume of 100 ml in methanol. The assay mixture contained 2 ml working solution and different volumes of the sample solution. In the control sample, the exact amount of the extract was substituted with solvent (80% ethanol), and in the blank sample, only methanol and extract were mixed. The mixture was shaken vigorously on a Vortex mixer, then incubated for 60 min at 25 °C water-bath in the dark. The absorbance of the remaining DPPH was determined at 515 nm. For each sample, three replicates were measured. The radical percentage of inhibition of DPPH radical was calculated by the following equation:

$$I = 100(A_0 - A_1)/A_0$$

where A_0 and A_1 are the absorbance of the control and the sample solution, respectively. The concentration of the extract that inhibits the DPPH radical formation by 50% is defined as IC_{50} / μg ml^{-1}. Finally, the results were presented in form of DPPH antiradical power (*DPPH ARP*) defined as:

$$DPPH\ ARP = 1/IC_{50}$$

The total antioxidant capacity was estimated according to the FRAP assay.[19] The reduction potential of the extracts was calculated using the calibration curve of a standard solution of ascorbic acid ($R^2 = 0.99$). The working FRAP reagent was prepared by mixing an acetate buffer (300 mM, pH 3.6), 2,4,6-tripyridyltriazine reagent (10 mM in 40 mM HCl) and $FeCl_3 \cdot 6H_20$ (20 mM) in volume ratio of 10:1:1. The absorbance of the assay mixture containing sample and 2 ml of the working FRAP reagent was measured at 593 nm, after 6 min incubation in the dark at room temperature. Due to the coloration of the extracts, it was necessary to prepare a control sample (sample and dist. H_2O instead of the FRAP reagent) and a blank sample (FRAP reagent and 80 % ethanol instead of the sample). All the samples were prepared in triplicate and the mean values of reducing power were expressed as mg ascorbic acid equivalents (AAE) per gram sample extract, and were calculated according to the standard calibration curve.

Statistical analyses

The descriptive statistical analyses for the all of the obtained technological parameters were expressed as a mean ± standard deviation (*SD*). The evaluation of the analysis of variance (ANOVA) and principal component analysis (PCA) analyses of the obtained results were performed using StatSoft Statistica 10.0® software. The collected data were subjected to ANOVA for a comparison of the means, and significant differences are calculated according to the post-hoc Tukey's HSD (honestly significant differences) test at $p < 0.05$ significance level, 95 % confidence limit. Furthermore, PCA was applied successfully to classify and discriminate the different samples, according to the technological parameters.

RESULTS AND DISCUSSION

Quality of corn flakes with dry residue of wild oregano

The effect of the added dry residue from wild oregano on the bulk density is shown in Table I. The bulk density of the flakes varies from 150 to 215 g dm^{-3}. With the addition of wild oregano the bulk density statistically significantly decreased, but the addition of wild oregano (WO) contributed to statistically significant increase in the expansion ratio of the corn flakes. The explanation for this was found in the interaction of the added dry residue from wild oregano with the starch. Also, the residue could rupture the pore walls and prevent air bubbles from expanding to their maximum potential.[16]

One of the most important quality parameters of the flake products is the time during which, when soaked in milk, their texture is still acceptable for consumers. The texture of the food depends on its underlying microstructure and its corresponding mechanical properties. The textural characteristics (hardness, work of compression, crispiness and crunchiness) of the flake product with the added dry residue from wild oregano are presented in Table I.

TABLE I. Physical and texture attributes of corn flakes with added dry residue from wild oregano distillation compared to a control sample; the results are presented as mean ± *SD*; different letters (a, b, c) within the same row indicate the significant difference in mean values ($p < 0.05$) according to Tukey's test. Number of repetitions: $n = 10$. CF 1 – control (sample without wild oregano), CF 2 – 0.5 g wild oregano/100 g sample and CF 3 – 1 g wild oregano/100 g sample. *BD* – bulk density, *ER* – expansion ratio, *HD* – hardness, *WOC* – work of compression, *CI* – crispiness, *CN* – crunchiness

Characteristics		Sample		
		CF 1	CF 2	CF 3
Physical	*BD* / g ml^{-1}	215.00±3.60^{c}	161.60±1.60^{b}	150.2±1.2^{a}
	ER / ml g^{-1}	6.46±2.89^{a}	8.60±0.0^{b}	9.36±5.77^{c}
Textural	*HD* / g	15510±2^{b}	14350±3^{b}	8880±4^{a}
	WOC / g s^{-1}	8270±2^{b}	7790±2^{b}	4940±2^{a}
	CI	20.20±1.92^{ab}	17.80±5.17^{a}	23.60±2.07^{b}
	CN / g·s^{-1}	59338±27368^{a}	59369±10327^{a}	62094±2771^{a}

The highest value for hardness (15510 g) was observed in sample CF 1 while the lowest hardness value was recorded for sample CF 3 (8880 g). These results are in accordance with the data reported by Anton *et al.*,[20] who concluded that texture properties that are highly influenced by the expansion ratio had lower hardness. The content of dry residue from WO contributed to statistically insignificant decrease in the hardness (CF 2 and CF 3), where the presence of fibers in WO caused the decrease of the product hardness due to reduction of the pore wall thickness.[21–23] The addition of dry residue from WO statistically insignificantly decreased the work of compression (CF 2 and CF 3), in comparison to sample CF 1. Many texture studies on crispness and crunchiness have been published because of the great interest of consumers towards corn flakes. The sensations "crisp" and "crunch" are difficult to describe, especially when different food products are involved.[24] The micro- and macrostructure in corn flakes during the production process influence the crunchiness and crispness. Actually, the addition of dry residue from wild oregano increased the crunchiness and crispness (Table I). The crispy and crunchy textures are desirable characteristics and contribute to the appreciation of the extruded products.[24]

Most of the antioxidant potentials in plant foods are due to the properties of phenolic compounds, which can act as reducing agents, free radical scavengers and hydrogen donors.[7,25] Dietary phenolic antioxidants have shown a potential to play an important role in delaying the development of many oxidative-stress related chronic diseases such as cardiovascular diseases, cancer, inflammatory bowel syndrome, neurodegenerative diseases and ageing processes.[26,27] It is known that the oregano possesses high antioxidant capacity.[28,29] Furthermore, our study showed that the dry residue from WO (*DR*, Table II), is also a very powerful antioxidant source (*DPPH ARP* = 4.98 (1/IC_{50}), *FRAP* = 8.45 mg AAE/g sample), and has a high content of phenolic compounds (23.55 mg GAE/g sample), which completely changes the aspect of its usage. Until now, the residues from WO were considered a waste material, but it turns out that they could be used as a food supplement. The content of phenolic compounds was significantly lower in the CF 1 (control sample) than in the samples with addition of DR. The level of phenolic compounds observed in CF 1 was in the range observed by other authors in cereal based foods.[30,31] The antioxidant activity of corn flakes (CF 1) was relatively low (*DPPH ARP* = 0.13 (1/IC_{50}), *FRAP* = 0.45 mg AAE/g sample). Although DR was added in small amounts, its addition strongly influenced the antioxidant activity of the corn flakes. Additionally, it statistically significantly increased the *DPPH ARP* (CF 2 and CF 3) and *FRAP* (CF 3), Table II. These results are in line with some of the previously published results, which showed that phenolic compounds could contribute to the antioxidant activity mainly due to their redox properties and chemical structure, which can play an important role in neutralizing of free radicals and chelating transitional metals.[32]

TABLE II. Total phenolic content (*TPC*) and antioxidant activity of corn flakes with added dry residue from wild oregano distillation compared to a control sample; the results are presented as mean ± *SD*; different letter (a, b, c) within the same row indicates the significant difference in mean values ($p < 0.05$), according to Tukey's test. Number of repetitions: $n = 10$. WO – wild oregano, CF 1 – control (sample without wild oregano), CF 2 – 0.5 g wild oregano/100 g sample and CF 3 – 1 g wild oregano/100 g sample. DR – dry residue from wild oregano. *TPC* – total phenolic content, *DPPH ARP* – antiradical power, *FRAP* – ferric reducing antioxidant power

Parameter	Sample				
	WO	DR	CF 1	CF 2	CF 3
TPC, mg GAE/g sample	42.87±0.85	23.55±0.75	0.98±0.03^{a}	1.18±0.01^{b}	1.30±0.01^{c}
DPPH ARP (1/IC_{50})	8.25±0.32	4.98±0.06	0.13±0.00^{a}	0.14±0.00^{b}	0.16±0.02^{c}
FRAP, mg AAE/g sample	8.69±0.08	8.45±0.03	0.45±0.01^{a}	0.46±0.01^{a}	0.50±0.01^{b}

The color characteristics of flakes product are important for the sensory evaluation of the product and play an essential role in the consumer acceptability. Different values in various color coordinates were observed for different flakes formulations, Table III. These attributes are very important in creating sensory

TABLE III. Color attributes of corn flakes with added dry residue from wild oregano distillation compared to a control sample; the results are presented as mean ± *SD*; different letter (a, b, c) within the same row indicates the significant difference in mean values ($p < 0.05$), according to Tukey's test. Number of repetitions: $n = 10$. CF 1 – control (sample without wild oregano), CF 2 – 0.5 g wild oregano/100 g sample and CF 3 – 1 g wild oregano/100 g sample; DR – dry residue wild oregano. L^* – brightness, a^* – share of green colour, b^* – share of yellow color, W – whiteness, C – the differences in coloration, h – difference in tone

Parameter	Sample			
	DR	CF 1	CF 2	CF 3
L^*	53±0.74	85.50±0.85[a]	83.15±0.45[b]	82.51±0.64[b]
a^*	–2.63±0.09	–1.06±0.11[a]	–1.12±0.21[a]	–1.05±0.16[a]
b^*	1.78±0.34	34.06±2.19[a]	30.95±0.80[b]	27.26±1.00[c]
W	49.44±0.59	62.97±2.34[a]	64.74±0.83[a]	67.59±1.10[b]
C	19.95±0.34	34.08±2.18[a]	30.97±0.80[b]	27.28±1.00[c]
h	82.41±0.27	91.80±0.30[a]	92.08±0.39[a]	92.2±0.34[a]

expectations for consumers, which could affect their perception and acceptability of the product.[16] Compared to CF 1 (control sample), DR has lower values for: brightness (L^*), share of yellow color (b^*), whiteness (W), the difference in coloration (C) and a higher value in share of green color (a^*). Statistically significant differences between flake samples without and with oregano addition were found for L^* coordinate (brightness) due to the low L^* value for DR. The highest L^* value (85.50) was observed for sample CF 1, while the lowest L^* value (82.51) was observed for sample CF 3 with composition 1 g WO/100 g sample. The addition of DR contributed to the decrease in L^*, which led to the formation of a darker flakes product, similarly to the results obtained by Jozinović *et al.*[6] The share of green color (a^*) coordinate was found to have no statistically significant difference among all samples. Statistically significant differences in yellow color (b^*) were observed in samples CF 1, CF 2 and CF 3, which indicated that the content of wild oregano reduced the yellow tone in the sample. The whiteness (W) of the flakes increased with the addition of DR, and the highest value (67.59) was observed in sample CF 3. The highest C value, indicating the differences in coloration (34.08), was measured for sample CF 1 and the lowest one (27.28) for sample CF 3. The content of DR statistically significantly contributed to a decrease in the coloration (C), at $p < 0.05$ level. The whiteness of the flakes was also statistically significantly increased by the addition of DR at $p < 0.05$ level. No difference in the tone was found between the samples. The maximum value of h, indicating the difference in tone, was observed in sample CF 3 (92.2) and the lowest one (91.80) was found in sample CF 1.

The sensory parameters of corn flakes with different compositions (0 g WO/ /100 g sample, 0.5 g WO/100 g sample and 1 g WO/100 g sample) used in the present study were affected significantly due to the supplementation levels of

WO into the corn flakes, Table IV. The results of the present study showed that the addition of WO in the corn flakes caused significant changes in their taste, odor, chewability and overall acceptability. Interestingly, the overall acceptability of WO-added corn flakes actually increased in comparison to the control sample, probably due to the protective effect of the antioxidants added against an eventual lipid oxidation. The latter phenomenon, indeed, could be the cause of off-flavors, as reported in a similar study where rosemary extract or other natural antioxidants were added to corn-flakes to prevent the formation of off-flavor-responsible volatile compounds.[8] From the present study could be concluded that to the corn flakes with composition 1 g WO/100 g sample were assigned scores of above 8.67 (like very much) for their chewability and overall acceptability. The supplementation of WO into the corn flour could produce corn flakes not only acceptable from a sensory standpoint, but ones with more antioxidant activity and health benefits.

TABLE IV. Sensory analysis of corn flakes with added dry residue distillation from wild oregano distillation compared to a control sample; the results are presented as mean ± *SD*; different letter (a, b, c) within the same row indicates the significant difference in mean values ($p < 0.05$), according to Tukey's test. Number of repetitions: $n = 3$

Property	Sample		
	CF 1	CF 2	CF 3
Taste	7.33 ± 0.05^a	7.83 ± 0.12^b	8.5 ± 0.01^c
Odor	6.33 ± 0.10^a	7.00 ± 0.31^b	7.8 ± 0.09^c
Chewability	8.00 ± 0.18^a	7.83 ± 0.26^a	8.67 ± 0.27^b
Overall acceptability	7.67 ± 0.04^a	8.00 ± 0.03^b	8.67 ± 0.29^c

Principal component analysis (PCA) and standard score analysis

The PCA allows a considerable reduction in the number of variables and the detection of structure in the relationship between the measuring parameters and samples of flake products with different formulations that give complementary information.[33] The full auto scaled data matrix consisting of flakes with 0, 0.5 and 1 % oregano content in their formulations were submitted to the PCA.

For visualization of the data trends and for discriminating of the efficiency of the used descriptors a scatter plot of the samples using the first two principal components (PCs) from PCA of the data matrix were obtained (Fig. 1). The first two principal components were marked as PC 1 and PC 2, while the percentage of the variance description was written in the continuation of the text. As can be seen, there is a neat separation of the three samples of flakes, according to the observed physical, textural, antioxidant, color and sensory characteristics. Sample CF 1 is located on the upper right part of the figure with pronounced color attributes (*C*, L^*, a^* and b^*) and mechanical characteristics (*BD*, *HD* and *WOC*). Sample CF 3 showed the most acceptable antioxidant capacity (regarding the *FRAP* and DPPH tests), sensory score (regarding the taste, odor, chewability and overall acceptability) and also good color attributes regarding the *a** coordinate.

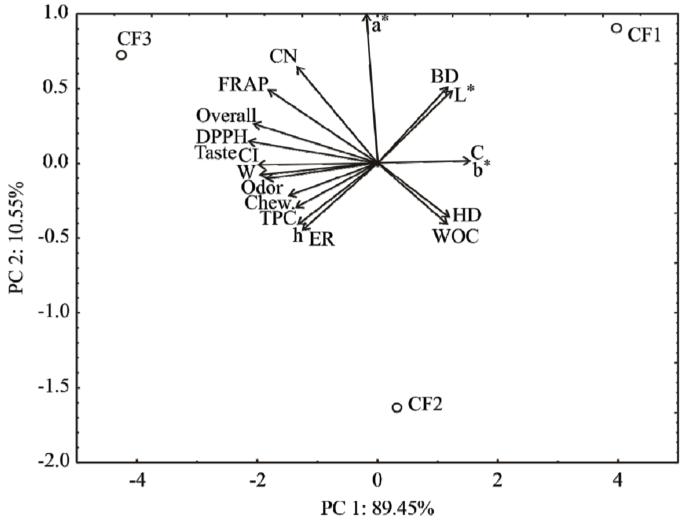

Fig. 1. Biplot diagram of flake product formulations, regarding physical, textural, antioxidant, color and sensory characteristics. B*D* – bulk density, *ER* – expansion ratio, *HD* – hardness, *WOC* – work of compression, *CI* – crispiness, *CN* – crunchiness, *TPC* – total phenolic contents, L^* – brightness, a^* – share of green color, b^* – share of yellow color, *W* – dominant wavelength, *C* – the differences in coloration, *h* – hue angle, Chew. – Chewability, Overall – overall acceptability.

Regarding the obtained characteristics, all variables (except *a**) showed almost equal contribution (based on correlations) to the first factor calculation (between 4.8–5.9 %). The contributions of *BD*, *CN* and *L** to the first factor calculation were 8.3, 9.4, and 6.9 %, respectively. The *a** variable contributed mostly to the second factor coordinate calculation.

CONCLUSIONS

In this study the effect of the addition of dry residue from wild oregano distillation on the physical and sensory properties of corn flakes was investigated. The results showed that the addition of dry residue from wild oregano had a positive effect on the physical characteristics of the corn flakes – a decreased bulk density (30.2 %) and an increased expansion ratio (44.9 %). The dry residue from wild oregano positively affected the corn flake texture. It decreased the hardness and work of compression (the minimum values of 8.88 kg and 4.94 kg s^{-1}, respectively were obtained by adding 1 % of dry residue of wild oregano) and increased the crispiness and crunchiness (the maximum values of 23.6 and 62094 $g\cdot s^{-1}$ were obtained for the sample with composition 1 g wild oregano/100 g sample). The addition of dry residue from wild oregano distillation significantly changed the color of the flakes product. It decreased the brightness, share of yellow color and differences in coloration, while increased their whiteness. The corn flakes with composition 1 g wild oregano/100 g sample is a new product with good physical and sensory properties due to its higher level of antioxidant activity and higher content of phenolic compounds (*TPC* = 1.30 mg GAE/g sample, *DPPH ARP* = 0.16 ($1/IC_{50}$), *FRAP* = 0.50 mg AAE/g sample) in comparison to the control sample. Additionally, this new product may contribute to the better valorization of the industrial edible waste. The PCA proved to be a useful tool for a neat separation of the flake samples according to their quality, physical, textural, antioxidant, color and sensory characteristics.

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ИЗВОД

ВАЛОРИЗАЦИЈА СУВОГ ОСТАТКА ДИВЉЕГ ОРИГАНА КРОЗ ПОБОЉШАЊЕ ФИЗИЧКИХ И СЕНЗОРНИХ СВОЈСТАВА „CORN FLAKES“

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У складу са савременим ставовима нутрициониста, производи од житарица, као што су флекс и снек производи, су најчешћа храна у свакодневном животу. Екструзиона технологија омогућава примену различитих извора додатака за обогаћивање екструдираних производа на бази житарица. Супстанце са јаким антиоксидативним својствима, као што је дивљи оригано имају позитиван утицај на људско здравље, што привлачи пажњу научника, потрошача и експерата из прехрамбене индустрије. Овај рад истражује ефекте додавања сувог остатка дивљег оригана заосталог после дестилације (0,5 g/100 g узорка и 1,0 g/100 g узорка) на физичке особине и боју љуспичастих производа у циљу добијања новог производа са измењеним хранљивим својствима. Додавање сувог остатка дивљег оригана је позитивно утицало на физичке карактеристике (насипна маса 30,2 %, повећан степен експанзије, 44,9 %), као и на смањење тврдоће (38,1 %) и рада компресије (40,3 %). Уједно је знатно измењена боја производа. Tukey's HSD тест је показао статистички значајне разлике између боје, физичко-текстуралних и сензорних особина посматраних узорака. PCA је примењена за класификацију производа на основу посматраних параметара. На основу добијених резултата може се закључити да “corn flakes” са додатком сувог остатка дивљег оригана представља нови производ, са добрим физичким и сензорним особинама, као и са повећаном антиоксидативном активношћу. Овим поступком производње се доприноси бољој употреби индустријских споредних производа.

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