TITLE: Effect of sesame flour and eggs on technology and nutritive quality of spelt pasta

AUTHORS: Vladimir Filipović, Jelena Filipović, Jana Simonovska, Vesna Rafajlovska

NOTICE: This is the author's version of a work that was accepted for publication in *Journal of the Serbian Chemical Society.* Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in *Journal of the Serbian Chemical Society*, Volume 82, Issue 10, October 2017, Pages 1097–1109. DOI:10.2298/JSC170405060F

Journal of the Serbian Chemical Society

JSCS-info@shd.org.rs • www.shd.org.rs/JSCS

ACCEPTED MANUSCRIPT

Please cite this article as V. Filipović, J. Filipović, J. Simonovska, Vesna Rafajlovska, *J. Serb. Chem. Soc.* (2017), doi: 10.2298/JSC170405060F

J. Serb. Chem. Soc. *82* (0) 1–13 (2017)
JSCS–4836

UDC
Original scientific paper

Effect of sesame flour and eggs on technology and nutritive quality of spelt pasta

VLADIMIR FILIPOVIĆ[1], JELENA FILIPOVIĆ[2]*, JANA SIMONOVSKA[3] and VESNA RAFAJLOVSKA[3]

[1]*University of Novi Sad, Faculty of Technology, Bul. cara Lazara 1, 21000 Novi Sad, Serbia;* [2]*Institute for Food Technology in Novi Sad, Bul. cara Lazara 1, 21000 Novi Sad, Serbia;* [3]*Ss. Cyril and Methodius University in Skopje, Faculty of Technology and Metallurgy, Department of Food Technology and Biotechnology, Rudjer Boskovic 16, 1000 Skopje, Republic of Macedonia*

(Received 4 April, accepted 8 May 2017)

Abstract: Pasta is suitable for correcting nutrition plan because it is quick and easy to prepare, easily digestible food and it is one of the widespread foods in many countries around the world. The influence of sesame flour on dough characteristics for pasta making was determined by rheological parameters. The effect of the quantity of the sesame flour (0, 10 and 20 g/100g flour) and liquid eggs (0, 12.4 and 24.8 g/100g flour) on the technological and nutritive quality of spelt pasta was investigated. Standard score analysis was applied for evaluation of the contribution of sesame flour and liquid eggs to spelt pasta quality. The significant differences between spelt flour and spelt flour with 10 and 20 g sesame flour on 100g flour was confirmed by application of Post-hoc Tukey's HSD test at 95 % confidence limit. Sesame flour adversely influenced farinograph and mixolab characteristics, while data pointed to higher maximum scores (0.63) for cooking, textural, color and mineral characteristics of pasta with sesame flour and eggs in the quantity of 20 g/100g flour and 24.8 g/100g flour, respectively. This pasta could be good source for satisfying daily needs of minerals recommended by FAO/WHO.

Keywords: sesame flour, eggs, rheology quality, technological quality, mineral content

INTRODUCTION

Sesame (*Sesamum indicum* L.) as one of the most important oilseed crops worldwide has been cultivated since ancient times in Africa, Middle East and Asia for its edible oil and seeds which were used in traditional foods[1]. This oleaginous plant is attributed with a high nutritional value due to high amounts of proteins rich in sulfur-amino acids, essential fatty acids, B-complex vitamins, and

* Corresponding authors. E-mail: jelena.filipovic@fins.uns.ac.rs
https://doi.org/10.2298/JSC170405060F

minerals such as Mn, Cu, Ca, Mg, Fe and P [2, 3]. The health benefits of the sesame seed in terms of reducing LDL-cholesterol in the blood and the blood pressure, decreasing the risks of cancer and cardiovascular diseases and improving DNA synthesis are confirmed by Gerstenmeyer *et al.*[4] and Nikmaram *et al.*[5,6] The sesame seed plays an important role in the human nutrition due to application in culinary, mostly in the bakery products. The medicinal, pharmaceutical, industrial and agricultural uses of the sesame seed are significant, too[3].

Pasta is the most popular foodstuff and its consumption has been observed to rise. The pasta quality depends on the properties of flour raw materials, mainly protein content, while the starch characteristics are less important[7, 8]. Even the durum semolina, which is the best raw material for pasta production through the world, is often produced from common wheat flour (*Triticum aestivum, Triticum vulgare* and *T. aestivum* subsp. *Spelt*) [9,10]. The pasta is characterized by significant amount of complex carbohydrates, low sodium, total fat, fiber, minerals and essential fatty acids. Its nutritional value can be improved with additional functional components [11, 12]. Over the past few decades, to cater health-conscious consumers who prefer having a product rich in protein, healthy lipids and other health benefits, the wheat pasta has been successfully formulated using different ingredients [12,13].

Eggs added to pasta contribute to better mechanical properties and quality of the product and increase the nutritive and biological value of the product, which is reflected in the increase of lysine, ω-3 fatty acids and lecithin [14,15,16].

This paper investigates the rheology properties of the pasta dough enriched with sesame flour. Additionally, with aim to obtain new functional product with good quality and improved mineral composition, the effects of sesame flour (10 and 20 g/100g flour) and liquid eggs (12.4 and 24.8 g/100g flour) on the technological quality and mineral properties of spelt pasta were studied.

EXPERIMENTAL

Material

The stone milled spelt wholemeal flour (200 to 300 µm particle size) obtained from spelt wheat "Austria" cultivar, grown in the year 2015 in Serbia at Bačko Gradište location (45.5333° N, 20.0333° E) was supplied by a local producer "Jeftić"-Bačko Gradište. The sesame seed with organic production origin was purchased in an organic food store in Novi Sad and grinded at Institute for Food Technology in Novi Sad (Serbia) on the hammer mill type "Sever-Subotica" (2300 rpm, sieve hole diameter 1.5 mm, particle size < 12 mm). Mineral content of sesame flour was: zinc: 51.30 mg/100g, calcium: 22.38 mg/100 g, manganese: 26.05 mg/100 g, iron: 86.72 mg/100 g, calcium: 20305 mg/100 g determined by AOAC[17]. The eggs were supplied from a local food market.

Dough rheology tests

The doug behavior during development and mixing was tested with Farinograph with 300g bowl (Brabender, Germany). Standard procedure[18] and the methods prescribed by the Regulations on the physical and chemical methods of analysis for quality control of grain, milling and bakery products, pasta and deep frozen dough [19] were used in the determination of the following parameters: water absorption, development time, 15 min drop time, quality number and quality class.

The dough rheology of the spelt wheat flour with sesame flour in the quantity of 0%, 10% or 20% was studied by Mixolab (Chopin, Tripette et Renaud, Paris, France). The required quantity of the flour in the analysis was calculated by Mixolab Software according to the input values of flour mixtures moisture, as well as water absorption. The test conditions used were in accordance with the literature data published by Filipović *et al.*[9] (8 min holding period at 30 °C, 4 °C /min temperature increasing until the mixture reached 90 °C, hold at 90 °C for a period of 7 min, temperature decreasing of 4 °C /min to 50 °C, and then 5 min holding at 50 °C. The mixing speed was set at 80 rpm). The results obtained for each blend, as well as, for the control are the averaged of six readings.

Preparation of pasta

The pasta was prepared using the device "La Parmigiana D45" type MAC 60 (Firenza, Italy) according the procedure reported by Filipović *et al.*[11, 20] In a paddle mixer, by adding water in quantity of 31.5 g water per 100 g flour, the moisture of wholemeal flour, with or without sesame flour and liquid eggs, was adjusted. The wholemeal spelt flour was replaced by sesame flour in the quantity of 10 or 20 g/100g flour, and liquid eggs were added in the quantity of 12.4 g /100g or 24.8 g 100/g of samples based on total mass of flour and sesame flour. In Table 1 are given the pasta formulations. The two pasta batches of 1.5 kg were prepared for each formulation, for the total of 3 kg, which were needed for production of enough samples to be tested. The wholemeal pasta was tested as a control sample.

Table 1. Pasta formulations with sesame flour and liquid eggs: experimental design and actual level of independent variables

Exp. No.	Independent variable*			
	Coded level		Actual level	
	x_1	x_2	X_1 / (g/100 g)	X_2 / (g/100 g)
S1	-1	-1	0	0
S2	0	-1	10	0
S3	+1	-1	20	0
S4	-1	0	0	12.4
S5	0	0	10	12.4
S6	+1	0	20	12.4
S7	-1	+1	0	24.8
S8	0	+1	10	24.8
S9	+1	+1	20	24.8

*sesame flour (x_1,X_1); liquid eggs (x_2,X_2).

Pasta cooking quality

The pasta quality was evaluated in terms of cooking characteristics i.e. cooking time, volume increasing and cooking losses, according to the method described by Kaluđerski and Filipović[21].

Pasta texture

Textural properties of cooked pasta were measured with Texture Analyzer TA.HD plus (Stable Micro System, U.K.) equipped with a 5 kg load cell using the procedure described by

Filipović *et al.*[11]. The tests were performed 6 times per batch. The two spaghetti strands were held close together and positioned centrally under the sample during testing.

Pasta colour

The pasta color was measured using a tri-stimulus colorimeter type CR-400 (Konica, Minolta, Tokyo, Japan) equipped with D65 illuminant. The results were expressed as per CIELab system in terms of coordinates: L*- lightness (0, black to 100, white), a*- redness (-100, green to +100, red), and b*-yellowness (-100, blue to +100, yellow). The measurements were observed under constant lighting conditions, at 28 ºC, using a color attributes of white control plate[11], L*=98.76, a*=-0.04 and b*=2.01.

Mineral content of pasta

The content of calcium, zinc, copper, magnesium and iron was determined by atomic absorption spectroscopy using standard procedure (No. 985.29) given by AOAC[17].

Statistical analysis

Second order polynomial models (SOP) were developed using Response Surface Methodology (RSM) to evaluate the influence of sesame flour quantity (X_1) and liquid eggs (X_2) on the values of cooking parameters (cooking time – CT, volume increase - VI, cooking loss – CL), textural (hardness - HAR, adhesiveness - ADH, work of shear - WS), colour attributes (brightness/ligtness - L*, greenness/redness - a*, blueness/yellowness – b*), and mineral composition (zinc - Zn, copper - Cu, magnesium - Mg, calcium - Ca, iron – Fe). Measuring results were collected using 3 × 3 experimental design plan, with 9 runs (1 block), as presented in Table 1.

The SOP model given by Eq. 1 was fitted to the experimental data. Fourteen models were developed to relate 14 responses (*Y*) and two process variables (*X*):

$$Y_k = \beta_{k0} + \sum_{i=1}^{2} \beta_{ki} X_i + \sum_{i=1}^{2} \beta_{kii} X_i^2 + \beta_{k12} X_1 \cdot X_2 \qquad k=1\text{-}14, \qquad (1)$$

where: β_{k0}, β_{ki}, β_{kii}, β_{k12} are constant regression coefficients; Y_k – cooking (CT, VI, VL), textural (HAR, ADH, WS), colour attributes (L^*, a^*, b^*), mineral composition (Zn, Cu, Mg, Ca, Fe); X_1 – sesame flour content and X_2 – liquid eggs content.

The obtained results were expressed as the mean ± standard deviation (SD). Analysis of variance (ANOVA) was utilized to show relations between applied assays, while the following post-hoc Tukey's HSD test at the 5 % significance level ($p<0.05$) for comparison of different pasta formulations.

StatSoft Statistica 10.0 software [22] was used in the statistical analysis of the obtained results.

Score analysis

Score analysis utilizes min-max normalisation of pasta quality parameter responses and migrate them from their original unit system in new dimensionless system which allows further mathematical calculation of different types of responses[23]. Maximum value of normalised score presents optimum value of all combined analysed responses and indicates on optimum quantity of added sesame flour and liquid eggs in pasta formulation.

$$S_{ki} = \frac{(x_{ki} - x_{k\min})}{(x_{k\max} - x_{k\min})} \quad (2)$$

where x_k is: CT, VI, HAR, WS, L*, a*, b*, Zn, Cu, Mg, Ca, Fe.

$$S_{ni} = 1 - \frac{(y_{ni} - y_{n\min})}{(y_{n\max} - y_{n\min})} \quad (3)$$

where y_n is: CL, ADH.

$$S_i = \frac{\sum_{i=1}^{k} S_{ki} + \sum_{i=1}^{n} S_{ni}}{k+n} \quad (4)$$

$$\max[S_i] \rightarrow \text{optimum} \quad (5)$$

RESULTS AND DISCUSSION

Rheology of whole meal spelt flour with sesame flour

The farinograph parameters measured for the whole meal spelt flours with added sesame flour are presented in Table 2. The values for water absorption, 15 min drop, quality number and quality class decreased with adding 10 and 20 g of sesame flour per 100g of flour. The decreasing is a result of reduced protein content because part of flour was replaced with sesame flour as non protein raw material[24]. The quality number of the whole meal spelt flour (48.8) correlated with the strong gluten flour. Increasing the quantity of sesame flour in meal spelt flour from 10 to 20 g/100 g of flour, the flour quality number and quality class decreased from 41.2 to 36.3. The adverse influence of sesame flour on gluten network forming was confrimed by the statistically significantly increased values of the farinograph parameters: development time, dough stability and 15 min drop.

Lower values of water absorption and speed of weakening protein network due to warming (p<0.05) for samples with sesame flour compared to spelt flour was measured using mixolab. The influence of the sesame flour on the time of dought development, dough elasticity, dough stability, and speed of starch gelatinization was unsignificant. Statistically significant (p<0.05) decrease of values of maximum torque, speed of enzymatic degradation, warm pasta stability and retrogradation of starch were oberved in samples with sesame flour (10 and 20 g/100 g of flour). Incorporating sesame in the flour formulation, the speed of starch gelatinization was reduced which led to the decreasing stability of starch network. It can be expected that pasta dough would need some corrections related to the gluten network strengthening.

Table 2. Rheology data* of whole meal spelt flour with added sesame flour

	Quantity of sesame flour, (g/100 g)		
	0	10	20
Farinograph data			
Water absorption / %	56.20±0.59^{a}	52.91±0.54^{b}	50.20±0.51^{c}
Dough development time / min	2.51±0.09^{a}	3.02±0.1^{b}	3.01±0.11^{b}
Dough stability / min	0.00±0.00^{a}	0.50±0.01^{b}	0.51±0.05^{b}
15 min drop / Fu	100±10^{a}	115±20^{ab}	150±15^{b}
Quality number/Quality class	48.8/ B 2	41.2/ C 1	36.3/ C 1
Mixolab data			
Water absorption of mixolab, %	53.11±1.08^{a}	46.14±2.10^{b}	42.21±1.75^{b}
Dough development, min	1.06±0.05^{a}	1.14±0.41^{a}	1.12±0.25^{a}
Dough elasticity, Nm	3.65±0.71^{a}	3.00±0.45^{a}	2.32±0.61^{a}
Dough stability, min	0.07±0.04^{a}	0.06±0.05^{a}	0.05±0.04^{a}
Speed of weakening protein networks at warming, Nm/min	5.28±0.17^{a}	3.17±0.26^{b}	1.67±0.09^{c}
Maximum torque, Nm	0.32±0.04^{a}	0.27±0.03^{ab}	0.19±0.07^{b}
Speed of starch gelatinization, Nm/min	1.88±0.80^{a}	1.26±0.54^{a}	1.04±0.36^{a}
Speed of enzymatic degradation, Nm/ min	1.61±0.17^{a}	1.51±0.25^{a}	0.88±0.30^{b}
Warm pasta stability, Nm	2.91±0.61^{a}	2.51±0.45^{ab}	1.32±0.49^{b}
Retrogradation of starch, Nm	-0.068±0.004^{a}	-0.054±0.001^{b}	-0.048±0.005^{b}

*Data are expressed as mean±standard deviation (n=6).
^{a,b,c} Values with different superscripts within the row are significantly different (Tukey test, p<0.05).

Quality of spelt pasta with sesame flour and eggs

In production of pasta enriched with sesame flour and liquid eggs the most important goal was to maintain the quality and sensory properties of the product. An improtant pasta characteristic is the cooking quality expressed as cooking time, volume increase and cooking loss. The obtained results presented in Table 3 showed that cooking time was affected by the amount and type of supplements. The cooking time ranged from 4.04 min to 5.51 min. In the pasta formulations with sesame flour (S2, S3, S5, S6, S8 and S9), the cooking time significantly increased (p<0.05) in comparison to the pasta without sesame flour (S1, S4 and S7), probably due to sesame lipids incorporation[9]. Statisically significant differences in cooking time (p<0.05) were determined in pasta samples with eggs (S4-S9), which indicated that protein and fatty substances from eggs reinforced and strengthened the gluten structure of the product[8] and lessen the adverse influence of sesame supplementation as was indicated by farinograph and mixolab data. The volume increasing as pasta quality parameter, represents the ability of starch to swell. In general, the high contents of sesame flour and eggs in dough statistically decreased pasta volume during cooking (p<0.05), since part of the flour was replaced by non starch constituent. These data were in agreement with mixolab data, Table 2. Increasing the quantity of the sesame flour in pasta dough significantlly increased the cooking loss

(p<0.05) which was consistent with cooking time. The positive influence of liquid eggs in decreasing pasta cooking losses was statistically significant, which indicated that liquid eggs helped in strenghtening the structure of pasta dough.

Table 3. Quality of pasta[**] with sesame flour and liquid eggs

Exp. No.	Pasta cooking attributes			Texture attributes			Colour attributes		
	CT, min	VI, %	CL, % d.m.	HAR, g	ADH, gsec	WS, gsec	L*, D65	a*, D65	b*, D65
S1	4.04 ±0.01[a]	3.25 ±0.10[a]	6.52 ±0.36[a]	2590.0 ±42.5[a]	11.31 ±4.12[a]	154.11 ±15.41[a]	79.05 ±0.45[a]	2.34 ±0.05[a]	11.92 ±0.35[a]
S2	4.54 ±0.05[ab]	2.81 ±0.20[abcd]	7.84 ±0.25[b]	3200.3 ±146.2[b]	19.73 ±3.59[b]	141.23 ±25.64[a]	75.41 ±0.51[b]	2.08 ±0.09[abc]	14.27 ±0.21[bc]
S3	5.01 ±0.10[bc]	2.63 ±0.20[bcd]	9.21 ±0.14[c]	3585.9 ±151.4[bc]	21.07 ±2.19[b]	121.43 ±10.17[a]	74.91 ±0.36[b]	2.03 ±0.04[abc]	14.71 ±0.36[c]
S4	4.53 ±0.23[ab]	3.13 ±0.10[ab]	5.92 ±0.21[a]	2594.8 ±167.9[a]	3.16 ±0.15[c]	132.61 ±22.21[a]	77.62 ±0.29[d]	2.19 ±0.08[ab]	12.31 ±0.11[a]
S5	5.07 ±0.49[bc]	2.71 ±0.30[bcd]	6.21 ±0.25[a]	3231.9 ±152.7[b]	5.81 ±2.78[ac]	125.82 ±10.9[a]	77.27 ±0.15[cd]	1.92 ±0.13[abc]	15.6 ±0.21[d]
S6	5.24 ±0.36[bc]	2.51 ±0.10[cd]	8.53 ±0.17[d]	3653.9 ±199.3[bc]	10.83 ±1.30[a]	114.61 ±9.6[a]	74.89 ±0.31[b]	1.71 ±0.11[c]	16.66 ±0.13[e]
S7	5.01 ±0.09[bc]	2.88 ±0.15[abc]	4.44 ±0.19[e]	3316.3 ±247.1[b]	2.72 ±1.04[c]	138.55 ±16.5[a]	77.06 ±0.51[cd]	2.20 ±0.21[ab]	13.64 ±0.47[b]
S8	5.32 ±0.43[bc]	2.36 ±0.21[cd]	4.84 ±0.23[e]	3549.5 ±208.5[bc]	3.44 ±1.21[c]	137.01 ±12.45[a]	76.57 ±0.14[c]	1.82 ±0.15[bc]	16.11 ±0.51[de]
S9	5.51 ±0.17[c]	2.29 ±0.19[d]	7.31 ±0.18[b]	4140.3 ±400.9[c]	8.55 ±3.2[ac]	130.06 ±11.3[a]	75.24 ±0.26[b]	1.78 ±0.36[bc]	16.82 ±0.14[e]

CT-Cooking time, VI-volume increase, CL-cooking loss, HAR- hardness, ADH-adhesiveness, WS- work of shear, L*- brightness, a*- greenness/redness, b*-blueness/yellowness. [**]Data are expressed as mean ±standard deviation (n=6). [a,b,c] Values with different supercripts within the column are significantly different (Tukey test, p<0.05).

The texture parameters are the critical point to ensure the acceptance of products by consumers. In the case of pasta quality, the textural properties were mainly affected by matrix structural network of starch and gluten and other included ingredients in formulations such as meat, ω-3 fatty acids, inulin, *etc.*[12,11]. The highest value for hardness (4140.3 g) was determined for the sample with the highest content of added sesame flour and eggs (S9), while the lowest hardness (2590.3 g) was determined for sample without ingredients (S1). The increase of the sample hardness was statistically significant with addition of the sesame flour and the eggs (p<0.05), due to the influence of the sesame flour and the eggs on the gluten matrix, that was confirmed by Filipović *et al.*[8, 13], also. With increasing content of sesame flour and increasing content of eggs, the adhesiveness of pasta (ADH) significantly increased and decreased (p<0.05) respectively (Table 3). The egg lipids, phospholipids and triglycerides had positive influence on adhesiveness of cooked pasta, according to Raina *et al.*[25] and Filipović *et al.*[8]

The sesame flour adversely affected adhesiveness, which resulted in higher values. In the samples with sesame flour (S2, S3, S5, S6, S8 and S9) decreasing of the work of shear (WS) was determined, due to adverse influence on gluten structure of pasta dough. Also, the work of shear was decreased in the samples with eggs in pasta formulation (Table 3).

The statistically significant differences (p<0.05) between pasta samples with and without sesame flour and eggs were found for color attributes (Table 3). The highest L^* (79.05) was observed for sample S1, while the lowest L^* value (74.89) for sample S6. The sesame flour and eggs contributed to decreased brightness (L^*) or darker pasta. The influence of the sesame flour and eggs is insignificant on the red color (a*). The higher a* values (2.34) was observed for the sample S1, and a* decreased in the pasta with sesame flour and eggs. The yellowness (b*) of the pasta sample significantly increased (p<0.05) with the increasing quantity of sesame flour and quantity of eggs in pasta formulation. The egg pasta color attributes were consistent with previous research of Filipović *et al.*[8,13] Traditionally, durum semolina containing pasta are light yellow colored, derived from carotenoids, namely from b-carotene[26]. In addition to their role as an important aesthetic parameter, the carotenoids have important nutritional and health roles. These pigments provide protection from ocular diseases[8, 27] as well as, due to the antioxidant capacity, they positively contributed to prevent the risk of chronic degenerative diseases.

The effect of sesame flour and eggs on pasta mineral content is shown in Table 4. The zinc content of pastas varied from 19.49 to 28.24 mg kg^{-1}. The zinc (Zn) content was significantly affected by the sesame flour content in pasta, while the effect of eggs was insignificant (p<0.05). The determined Zn quantities in pasta increased by increasing quantity of the sesame flour. The sesame flour (20 g/100 g of flour) significantly influenced the increasing of the copper (Cu) content (S3, S6, S9), while the eggs that was added in the pasta samples caused insignificant decreasing of Cu quantities. Compared to the pasta without sesame flour (S1, S4, S7), the addition of sesame flour contributed to a statistically significant higher values of magnesium (Mg) (S2, S3, S5, S6, S8, S9). In case of the effect of eggs, statistically significant decreasing (p<0.05) in Mg contents were determined in the pasta (S4, S5, S6, S7, S8, S9) compared to pasta samples without eggs (S1, S2 and S3). The statistically significant differences in calcium (Ca) content were determined for all pasta formulation, except for the formulation S5 and S8. The maximum value of Ca (731.59± 12.56 % d.m) was measured for sample S9, while the minimum of 267.01 ± 5.45 % in pasta without sesame flour and eggs (S1). These data indicate that eggs and sesame flour were good sources of calcium. ANOVA test showed statistically significant differences (p<0.05 level) in iron content among the values of pasta samples without sesame flour (S1, S4, S7) and pasta with 10 and 20 g of sesame flour per 100 g of flour, (S2,S5, S8) and (S3, S6, S9), respectively. These results were in accordance with data reported by

Filipović *et al.*[20], where have been concluded that mineral composition had been highly influenced by quantity of added sesame flour. In the nutrition, the daily intake of 100 g pasta with added higher level of sesame flour and eggs is a good opportunity to achieve the recommended daily intake in zinc, copper, magnesium, calcium and iron content (28.24; 5.33; 1254.0; 731.59; 38.10 mg/kg) necessary for the optimal mineral status and normal body functioning, recommended by FAO/WHO[28].

Table 4. Mineral content of pasta with sesame flour and liquid eggs

Exp.	Zn contet, mg/kg	Cu contet, mg/kg	Mg contet, mg/kg	Ca contet, mg/kg	Fe contet, mg/kg
S1	19.49±1.15^{a}	4.93±0.13^{a}	709.15±12.50^{a}	267.01±5.45^{a}	31.19±1.05^{a}
S2	22.07±0.95^{abc}	5.85±0.48^{abc}	1008.36±17.09^{b}	433.12±7.05^{b}	35.04±0.75^{bc}
S3	25.65±2.05^{cde}	7.22±0.53^{c}	1301.0±15.48^{c}	663.29±11.36^{c}	39.24±0.96^{d}
S4	19.46±0.85^{a}	4.68±0.32^{a}	630.94±16.85^{d}	308.15±8.91^{d}	28.74±1.08^{a}
S5	23.75±1.75^{bcd}	5.63±0.68^{ab}	1003.65±19.26^{b}	496.58±10.65^{e}	34.59±1.53^{c}
S6	26.45±0.96^{de}	6.64±0.47^{bc}	1287.0±13.45^{ce}	694.49±9.85^{f}	38.77±0.85^{d}
S7	21.25±1.23^{ab}	4.41±0.51^{a}	664.72±15.48^{ad}	335.92±10.14^{d}	31.80±1.85^{ac}
S8	22.92±1.78^{abcd}	5.26±0.81^{ab}	939.22±16.06^{f}	512.53±11.65^{e}	34.44±1.05^{c}
S9	28.24±0.49^{e}	5.33±0.73^{ab}	1254.0±13.05^{e}	731.5912.56^{h}	38.10±0.47^{bd}

Zn-zinc,Cu-copper, Mg-magnesium, Ca-calcium, Fe-iron. Data are expressed as mean ±standard deviation (n=6). ^{a,b,c,e,f}Values with different supercripts within the column are significantly different (Tukey test, p<0.05).

RSM calculation

The RSM calculation for cooked, textural and color attributes and mineral content of analyzed pasta samples showed the statistically significant effects of independent variables, quantity of sesame flour and quantity of liquid eggs, presented in table 5.

The SOP models for all variables were found to be statistically significant (p<0.05). Linear terms for SF and LE were the most important for calculation of the most responces, at the level of significance of p<0.05. Quadratic term for SF (SF^2) was also statistically significant for volume increase (VI) and work of shear (WS), while quadratic term for LE (LE^2) was statistically significant for work of shear.

Interchange terms were the most important for calculation of responces of cooking time (CT) and work of shear (WS). Residual variance was not significant in all investigated responces, and r^2 as indicator for good fit of proposed model for all responses with experimental data was in the range of from 0.85099 to 0.99882.

Table 6. Shows regression coefficients of SOP models for the 14 responses of pasta samples, indicating good fitting capabilities for all SOP models to experimental data.

Table 5. RSM calculation for different characteristics of pasta samples

		Term							
		SF	SF^2	LE	LE^2	SF x LE	Error	Total SS	r^2
df		1	1	1		1	3	8	
		Sum of squares							
Cooking attributes	CT	0.792067*	0.015022	0.843750*	0.003472	0.055225*	0.010553	1.720089	0.99386
	VI	0.558150*	0.048050*	0.224267*	0.012800	0.000225	0.005108	0.848600	0.99398
	CL	11.12482*	0.25681	8.12007*	0.55476	0.00810	0.46754	20.53209	0.97723
Texture attributes	HAR	1381440*	375	442762*	112196	7387	44479	1988640	0.97763
	ADH	90.1713*	0.0057	233.1267*	41.1627	3.8612	12.5021	380.8296	0.96717
	WS	583.515*	15.587*	20.720*	323.512*	146.289*	2.756	1092.379	0.99748
Colour attributes	L*	12.58602*	0.00405	0.04167	0.09680	1.34560	2.46447	16.53860	0.85099
	a*	0.244017*	0.020672	0.070417*	0.020672	0.003025	0.010953	0.369756	0.97038
	b*	17.75040*	1.93389	5.35815*	0.15494	0.03802	0.64029	25.87569	0.97526
Mineral content	Zn	67.60327*	0.52020	4.50667	0.00500	0.17222	2.34564	75.15300	0.96879
	Cu	4.454817*	0.004050	1.500000*	0.045000	0.469225	0.173708	6.646800	0.97387
	Mg	562544.5*	172.1	4297.1	61.5	1.7	2866.3	569943.1	0.99497
	Ca	231394.6*	747.4	7820.7*	167.9	0.1	282.8	240413.5	0.99882
	Fe	99.0641*	0.0050	0.2128	1.7484	0.7656	3.3706	105.1666	0.96795

SF - Quantity of sesame flour, LE - Quantity of liquid eggs, df – degrees of freedom, * - Significant at $p<0.05$ level.

Table 6. Regression coefficients of SOP of 14 responces of pasta samples

	Term					
	β_0	β_1	β_{11}	β_2	β_{22}	$\beta_1 \times \beta_2$
	Cooking attributes					
CT	4.020278*	0.065417*	-0.000867	0.046438*	-0.000271	-0.000948*
VI	3.260833*	-0.062250*	0.001550*	-0.003293	-0.000520	0.000060
CL	6.659444*	0.060000	0.003583	-0.012500	-0.003425	0.000363
	Texture attributes					
HAR	2598.025*	55.021	-0.137	-12.829	1.540	-0.347
ADH	12.49306*	0.49658	-0.00053	-1.15517*	0.02950	-0.00792
WS	153.9019*	-1.0326*	-0.0279*	-2.6889*	0.0827*	0.0488*
	Colour attribues					
L*	78.50000*	-0.21183	0.00045	-0.01801	-0.00143	0.00468
a*	2.358056*	-0.037750*	0.001017	-0.022917	0.000661	-0.000222
b*	11.68306*	0.35892*	-0.00983	0.11324	-0.00181	0.00079
	Mineral content					
Zn	19.42417*	0.21292	0.00510	0.04509	0.00033	0.00167
Cu	4.780833*	0.129417*	-0.000450	0.011492	-0.000976	-0.002762
Mg	696.2375*	32.5391*	-0.0928	-3.0007	0.0361	-0.0052
Ca	264.3831*	15.7871*	0.1933	4.4018*	-0.0596	-0.0012
Fe	30.63917*	0.46008	-0.00050	-0.13071	0.00608	-0.00353

* - Significant at $p<0.05$ level

Score calculation

By using score analysis, 14 different responses of pasta quality parameters were quantified in dimensionless values that were further calculated in one score value which was comparable between the different pasta formulations. In that way score values of 9 pasta samples allowed the possibility of comparing total quality of the analyzed samples and optimization of their formulation.

Figure 1 shows score values of pasta samples with different quantity of sesame flour and liquid eggs and it can be seen that, by increasing the quantity of sesame flour and liquid eggs, total quality of the pasta samples was increased. Pasta sample S9 achieved maximum score value of 0.63 of maximum 1, pointing at pasta with the best formulation due to the highest achieved total technological quality.

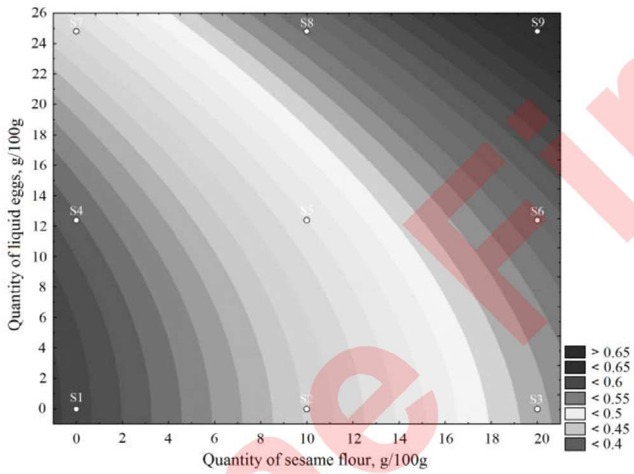

Figure 1. Score values of pasta formulation with sesame flour and liquid eggs

CONCLUSION

Based on investigated data, it can be concluded that farinograph and mixolab data can successfully measure the influence of sesame flour (10 and 20 g/100 g of flour) on pasta dough rheology.

The eggs positively affected pasta cooking attributes (decreasing cooking loss), pasta texture (increase hardness) and colour (increasing yellowness). The sesame flour adversely affected on technology quality but positively affected on mineral content of pasta. The RSM well described mathematical models for all 14 responses of pasta quality, which were statistically significant (p<0.05). Score analysis successfully point at optimal formulation of pasta as a functional food. Pasta sample with sesame flour and eggs in the quantity of 20 g and 24.8 g per 100 g of flour, respectively achieved maximum score value of 0.63, with the best content of essential mineral elements (maximum of Zn, Cu, Mg, Ca, and Fe 28.24; 5.33; 1254.0; 731.59; and 38.10 mg/100 g; respectively), thus satisfying daily requirements of mineral elements recommended by FAO/WHO. Pasta with sesame flour could be a valuable source of essential elements in daily diet.

Acknowledgements. These results are part of the project supported by the Ministry of Education and Science of the Republic of Serbia, III 46005.

ИЗВОД

УТИЦАЈ СУСАМОВОГ СЕМЕНА И ЈАЈА НА ТЕХНОЛОШКИ И НУТРИТИВНИ КВАЛИТЕТ ТЕСТЕНИНЕ ОД СПЕЛТЕ

ВЛАДИМИР ФИЛИПОВИЋ[1], ЈЕЛЕНА ФИЛИПОВИЋ[2], ЈАНА СИМОНОВСКА[3] и ВЕСНА РАФАЈЛОВСКА[3]

[1]*Технолошки факултет, Универзитет у Новом Саду, Бул. цара Лазара 1, 21000 Нови Сад, Србија;* [2]*Научни Институт за прехрамбене технологије, Универзитет у Новом Саду, Бул. цара Лазара 1, 21000 Нови Сад, Србија;* [3]*Технолошко металуршки факултет, Универзитет "Св. Кирил и Методиј", Руђер Бошковић 16, 1000 Скопље, Република Македонија*

Тестенина је погодна намирница али је за исхрану потебно нутритивно кориговати. Тестенина се брзо и лако припрема, лако је сварљива и представља једну од најчешће заступљених намирница у исхрани у многим земљама света. У овом раду је испитан утицај сусамовог брашна на реолошке особине теста за производњу тестенине и утицај количине сусамовог брашана (0, 10 и 20 %) и јајног меланжа (0 g/kg , 124 g/kg и 248 g/kg) на технолошки и нутритивни квалитет тестенине од спелте. Стандардна оцена је примењена за процену доприноса сусамовог брашна и јаја на квалитет тестенине. Post-hoc Tukey's HSD тест је показао статистички значајне разлике имеђу спелтиног брашна и спелтиног брашна са 10 % и 20 % сусамовог брашна. Сусамово брашно негативно утиче на фаринографске и миксогравске показатеље, али позитивно утиче на квалитет куване тестенине, текстуру, боју и минерални састав. Највећу стандардну оцену (0,63) има тестенина са 20% сусамовог брашна и 24,8 g јајног меланжа. Ова тестенина може да буде добар извор за задовољавање дневних потреба у минералним материјама прописаних од стране FAO/WHO.

(Примљено 4. априла, прихваћено 8. маја 2017)

REFERENCES

1. O. E. Kajihausa, R. A. Fasasi, Y. M. Atolagbe, *Official Journal of Nigerian Institute of Food Science and Technology* **32** (2014) 8.
2. H. Zebib, G. Bultosa, S.Abera, *Ethiopia Agricultural Sciences* **6** (2015) 238.
3. S. Gharvy, H. Harhar, Z. Bouzoubaa, A. Asdadi, A. El Yadin, Z. Charrouf, *Journal of the Saudi Society of Agricultural Sciences* (2015) http://dx.doi.org/10.1016/j.jssas.2015.03.004
4. E. Gerstenmeyer, S. Reimer, E. Berghofer, H. Schwatrz, G. Sontag, *Food Chem.* **138** (2013) 1847.
5. N. Nikmaram, F. Garavand, A. Elhamirad, S. Beiraghi-Toosi, G. Goli-Movahhed, *Qual. Assur. Saf. Crop* **7** (2015) 713.
6. N. Nikmaram, H..M. Kamani, *Electronic Journal of Polish Agricultural Universities*, **19** (2016) 1.
7. D. Dziki, J. Laskowski, *Pol. J. Food Nutr. Sci.* **15** (2005) 153.
8. J. Filipović, Z. Miladinović, L. Pezo, N. Filipović, V. Filipović, A. Jevtić-Vukmirović, *Hem. Ind.* **69** (2015) 59.
9. J. Filipović, L. Pezo, N. Filipović, V. Filipović, M. Bodroža-Solarov, M. Plančak, *Int. J. Food. Sci. Tech.* **48** (2013) 195.

10. W. Biel, S. Stankowski, A. Jaroszewska, S. Pużyński, P. Bośko, *J. Integr. Agric*. **15** (2016) 1763.
11. J. Filipović, L. Pezo, V. Filipović, J. Brkljača, J. Krulj, *Lebensm-Wiss. Technol.* **63** (2015) 43.
12. T. Liu, N. Hamid, K. Kantono, L. Pereira, M.M. Farouk, O.S. Knowles, *Food Chem.* **213** (2016) 108.
13. J. Filipović, L. Pezo, N. Filipović, V. Filipović, *APTEFF.* **45** (2014) 23.
14. V. Jurić, I. Jajić, V..Bursić, J..Jurić, *Letopis naučnih radova* **1** (2005) 138.
15. J. Filipović, Z. Miladinović, L. Pezo, N. Filipović, V. Filipović, A. Jevtić-Vukmirović, *Hem. Ind.* **69** (2015) 59.
16. J. Exler, K. M. Phillips, K. Y. Patterson , J. M. Holden, *J. Food Compos. Anal.* **29** (2013) 110.
17. AOAC. *Official methods of analysis* (17th ed.). Arlington, VA: Association of Official Analytical Chemists, 1990.
18. AACC (American Association of Cereal Chemists). *Approved Methods of AACC-Method*, tenth ed. USA, St. Paul, MN. 2000.
19. Regulations on the Physical and Chemical Methods of Analysis for Quality Control of Grain, Milling and Bakery Products, Pasta and Deep Frozen Dough, Official Gazette 78/1988.
20. J. Filipović, S. Ahmetxhekaj, V. Filipović, M. Košutić, *Chem. Ind. Chem. Eng. Q.* (2016); in press: DOI:10.2298/CICEQ160208049F
21. G. Kaluđerski, N. Filipović *Methods for the investigation of cereals, flour and final product quality*. Faculty of Technology, Novi Sad, 1998, p.295.
22. STATISTICA (Data Analysis Software System), v. 10, StatSoft, Inc, Tulsa, OK, USA www.statsoft.com, 2010.
23. T. Jayalakshmi, A. Santhakumaran, *International Journal of Computer Theory and Engineering* **3** (2011) 89.
24. G. Huang, Q. Guo, C. Wang, H. H. Ding, W. S. Cui, *Lebensm-Wiss Technol*. **71** (2016) 274.
25. C. S. Raina, S. Singh, A. S. Bawa, D. C. Saxena, *J. Texture Stud.* **36** (2005) 402.
26. G. M. Borrelli, A. Troccoli, N. Di Fonzo, C. Fares, *Cereal Chem*. **76** (1999) 335.
27. B. M. Donatella, A. B. Ficco, M. Anna, A. Mastrangelo, T. A. Daniela, M. Grazia, A. Borrelli, A. Pasquale De Vita, A. C. Fares, A. R. Beleggia, A. C. Platani, R. Papa, *Crop Pasture Sci.* **65** (2014) 1.
28. WHO Technical Report Series, *Protein and Amino Acid Requirements in Human Nutrition,* Chapter: Protein–energy interactions, Joint FAO/WHO/UNU, Geneva, Switzerland, 2002; 79.