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

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Abstract: Pasta is suitable for correcting nutrition plans because it is quick and easy to prepare, an easily digestible food and 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 measuring rheological parameters. The effect of the quantity of the sesame flour (0, 10 and 20 g per 100 g of flour) and liquid eggs (0, 12.4 and 24.8 g per 100 g of flour) on the technological and nutritive quality of spelt pasta was investigated. Standard score analysis was applied for the evaluation of the contribution of sesame flour and liquid eggs to the quality spelt pasta. Significant differences between spelt flour and spelt flour with 10 and 20 g sesame flour per 100 g flour was confirmed by application of the Post-hoc Tukey's HSD test at the 95 % confidence limit. Sesame flour adversely influenced farinograph and mixolab characteristics, while data pointed to higher maximum scores (0.63) for cooking, textural, colour and mineral characteristics of the pasta with sesame flour and eggs at 20 and 24.8 g per 100 g of flour, respectively. This pasta could be good source for satisfying the daily needs of minerals recommended by the 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, the Middle East and Asia for its edible oil and seeds that are used in traditional foods.[1] This oleaginous plant is attributed with a high nutritional value due to its contents of high

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amounts of proteins rich in sulphur-amino acids, essential fatty acids, B-complex vitamins, and minerals, such as Mn, Cu, Ca, Mg, Fe and P.[2,3] The health benefits of 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 were confirmed by Gerstenmeyer *et al.*[4] and Nikmaram *et al.*[5,6] Sesame seed plays an important role in human nutrition due to application in culinary, mostly bakery, products. The medicinal, pharmaceutical, industrial and agricultural uses of sesame seed are also significant.[3]

Pasta is the most popular foodstuff and its consumption rising. The quality of pasta depends on the properties of flour raw materials, mainly their protein content, while the starch characteristics are less important.[7,8] Even durum semolina, which is the best raw material for pasta production throughout 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 amounts of complex carbohydrates and low sodium, total fat, fibre, minerals and essential fatty acids. Its nutritional value could be improved by the additional of functional components.[11,12] Over the past few decades, to cater for health-conscious consumers who prefer having a product rich in protein, healthy lipids and other health benefits, 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 its nutritive and biological value, which is reflected in the increase of the contents of lysine, omega-3 fatty acids and lecithin.[14–16]

In this study, the rheological properties of pasta dough enriched with sesame flour were investigated. Additionally, with the aim of obtaining a new functional product with good quality and improved mineral composition, the effects of sesame flour (10 and 20 g per 100 g of flour) and liquid eggs (12.4 and 24. g per 100 g of 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 the 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 ground at the Institute for Food Technology in Novi Sad (Serbia) on a hammer mill type "Sever-Subotica" (2300 rpm, sieve hole diameter 1.5 mm, particle size < 12 mm). The mineral content of the sesame flour was: zinc: 51.30 mg $(100\ g)^{-1}$, calcium: 22.38 mg $(100\ g)^{-1}$, manganese: 26.05 mg $(100\ g)^{-1}$, iron: 86.72 mg $(100\ g)^{-1}$, calcium: 20305 mg $(100\ g)^{-1}$, determined by AOAC.[17] The eggs were supplied by a local food market.

Dough rheology tests

The dough behaviour during development and mixing was tested with Farinograph using a 300 g bowl (Brabender, Germany). A 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 moisture content of the flour mixtures, 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 decrease at a rate of 4 °C min^{-1} 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 values 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] The moisture of wholemeal flour, with or without sesame flour and liquid eggs, was adjusted in a paddle mixer by adding 31.5 g water per 100 g of flour. The wholemeal spelt flour was replaced by 10 or 20 g per 100 g of sesame flour, and 12.4 g or 24.8 g of liquid eggs per 100 g of sample, based on the total mass of flour and sesame flour, were added. The pasta formulations are given in Table I. Two pasta batches of 1.5 kg were prepared for each formulation, giving a total of 3 kg, which were needed for the production of enough sample to be tested. Wholemeal pasta was tested as a control sample.

TABLE I. Pasta formulations with sesame flour and liquid eggs: experimental design and the actual level of the independent variables: sesame flour (x_1, X_1); liquid eggs (x_2, X_2)

Exp. No.	Independent variable			
	Coded level		Actual level	
	x_1	x_2	X_1 / g 100 g^{-1}	X_2 / g 100 g^{-1}
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

Pasta cooking quality

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

Pasta texture

The textural properties of the cooked pasta were measured with a 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. Two spaghetti strands were held close together and positioned centrally under the sample during testing.

Pasta colour

The pasta colour was measured using a tri-stimulus colorimeter type CR-400 (Konica, Minolta, Tokyo, Japan) equipped with a D65 illuminant. The results are 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 light conditions, at 28 °C, using the colour attributes of a white control plate,[11] L^*: 98.76; a^*: –0.04 and b^*: 2.01.

Mineral content of pasta

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

Statistical analysis

Second order polynomial models (SOP) were developed using the response surface methodology (RSM) to evaluate the influence of sesame flour (X_1) and liquid eggs (X_2) quantities on the values of cooking parameters (cooking time – *CT*, volume increase – *VI*, cooking loss – *CL*), textural (hardness – *HAR*, adhesiveness – *ADH* and work of shear – *WS*) and colour (brightness/lightness – L^*, greenness/redness – a^* and blueness/yellowness – b^*), attributes, and mineral composition (Zn, Cu, Mg, Ca and Fe). The obtained results were collected using 3×3 experimental design plan, with 9 runs (1 block), as presented in Table I.

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

$$Y_k = \beta_{k0} + \sum_{i=1}^{2}\beta_{ki}X_i + \sum_{i=1}^{2}\beta_{kii}X_i^2 + \beta_{k12}X_1X_2\,,\ k \in (1,14) \tag{1}$$

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

The obtained results were expressed as the mean ± standard deviation (*SD*). Analysis of variance (ANOVA) was utilized to show relations between the applied assays, while the following post-hoc Tukey's HSD test at the 5 % significance level ($p < 0.05$) was used 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 the responses of the pasta quality parameters and migrates them from their original unit system into a new dimensionless system, thereby allowing further mathematical calculation of different types of responses.[23] The maximum value of the normalised score presents the optimum value of all the combined analysed responses and indicates the optimum quantity of added sesame flour and liquid eggs in the pasta formulation:

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

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

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

where y_n is: *CL* and *ADH*.

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

$$\max[S_i] \rightarrow \text{optimum} \tag{5}$$

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 II. The values for water absorption, 15 min drop, quality number and quality class decreased with addition of 10 and 20 g of sesame flour per 100 g of flour. The decrease is the result of reduced protein content because part of flour was replaced with sesame flour as a non-protein raw material.[24] The quality number of the whole meal spelt flour (48.8) correlated with a strong gluten flour. Increasing the quantity of sesame flour in

TABLE II. Rheology data of whole meal spelt flour with added sesame flour; data are expressed as mean ± standard deviation ($n = 6$); values with different superscripted letters within a row are significantly different (Tukey test, $p < 0.05$)

Parameter	Quantity of sesame flour, g per 100 g of flour		
	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 on warming, Nm min^{-1}	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 gelation, Nm min^{-1}	1.88±0.80[a]	1.26±0.54[a]	1.04±0.36[a]
Speed of enzymatic degradation, Nm min^{-1}	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]

meal spelt flour from 10 to 20 g per 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 formation was confirmed 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 the weakening of the protein network during warming ($p < 0.05$) of the samples with sesame flour compared to spelt flour were registered using mixolab. The influences of the sesame flour on the time of dough development, dough elasticity, dough stability, and speed of starch gelation were insignificant. Statistically significant ($p < 0.05$) decreases in the values of maximum torque, speed of enzymatic degradation, warm pasta stability and retrogradation of starch were observed in samples with sesame flour (10 and 20 g per 100 g of flour). Incorporation of sesame in the flour formulation resulted in a reduction of the speed of starch gelation, which led to a decrease in the stability of the starch network. It could be expected that the pasta dough would need some corrections related to the strengthening of the gluten network.

Quality of spelt pasta with sesame flour and eggs

In the 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 important pasta characteristic is the cooking quality, expressed as cooking time, volume increase and cooking loss. The obtained results presented in Table III showed that the cooking time was affected by the amount and type of the supplements. The cooking time ranged from 4.04 to 5.51 min. In the pasta formulations with sesame flour (S2, S3, S5, S6, S8 and S9), the cooking time was significantly increased ($p < 0.05$) in comparison to that of the pasta without sesame flour (S1, S4 and S7), probably due to the incorporation of sesame lipids.[9] Statistically significant differences in the cooking time ($p < 0.05$) were determined for the pasta samples with eggs (S4–S9), which indicated that protein and fatty substances from the eggs reinforced and strengthened the glutinous structure of the product[8] and reduced the adverse influence of sesame supplementation, as was indicated by farinograph and mixolab data. The volume increase as a pasta quality parameter represents the ability of starch to swell. In general, the high contents of sesame flour and eggs in the dough statistically decreased the pasta volume during cooking ($p < 0.05$), since part of the flour was replaced by a non-starch constituent. These data were in agreement with the mixolab data, Table II. Increasing the quantity of the sesame flour in pasta dough significantly increased the cooking loss ($p < 0.05$), which was consistent with the cooking time. The positive influence of liquid eggs in decreasing pasta cooking losses was statistically significant, which indicated that liquid eggs helped in strengthening the structure of the pasta dough.

TABLE III. Quality of pasta** with sesame flour and liquid eggs; *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). Values with different superscripted letters within a column are significantly different (Tukey test, $p < 0.05$)

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

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 the matrix structural network of starch and gluten and other included ingredients in the formulations, such as meat, omiga-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 the 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, which was also confirmed by Filipović *et al.*[8,13]. 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 III). The egg lipids, phospholipids and triglycerides had positive influence on the adhesiveness of cooked pasta, according to Raina *et al.*[25] and Filipović *et al.*[8] The sesame flour adversely affected adhesiveness, resulting in higher values. In the samples with sesame flour (S2, S3, S5, S6, S8 and S9), decreasing work of shear (*WS*) was determined, due to an adverse influence on gluten structure in the pasta dough. Moreover, the work of shear was decreased in the samples with eggs in the pasta formulation (Table III).

Statistically significant differences ($p < 0.05$) between the pasta samples with and without sesame flour and eggs were found for the colour attributes (Table III). 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 influences of sesame flour and eggs on the red colour (a^*) were insignificant. A higher a^* value (2.34) was observed for the sample S1, while a^* decreased in the pasta with sesame flour and eggs. The yellowness (b^*) of the pasta samples significantly increased ($p < 0.05$) with increasing quantity of sesame flour and quantity of eggs in pasta formulation. The egg pasta colour attributes were consistent with previous research of Filipović *et al.*[8,13] Traditionally, durum semolina containing pasta are light yellow coloured, derived from carotenoids, namely from β-carotene.[26] In addition to their role as an important aesthetic parameter, carotenoids have important nutritional and health roles. These pigments provide protection from ocular diseases[8,27] and, due to their antioxidant capacity, positively contribute to the reduction of the risk of chronic degenerative diseases.

The effect of sesame flour and eggs on the mineral content of the pasta is given in Table IV. The zinc content of the 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 with increasing quantity of sesame flour. The sesame flour (20 g per 100 g of flour) significantly influenced an increasing in the copper (Cu) content (S3, S6 and S9) while eggs added in the pasta samples caused an insignificant decrease in the Cu quantities. Compared to the pasta without sesame flour (S1, S4 and S7), the addition of sesame flour contributed to statistically significant higher values of magnesium (S2, S3, S5, S6, S8 and S9). In the case of the effect of eggs, statistically significant decreases ($p < 0.05$) in the quantities of Mg were determined in the pasta (S4, S5, S6, S7, S8 and S9) compared to pasta samples without eggs (S1, S2 and S3). Statistically significant differences in calcium (Ca) content were determined for all pasta formulations, except for the formulations 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. The ANOVA test showed statistically significant differences ($p < 0.05$ level) in the iron content between the values of pasta samples without sesame flour (S1, S4 and S7) and the pasta with 10 and 20 g of sesame flour per 100 g of flour (S2, S5 and S8 and S3, S6 and S9, respectively). These results were in accordance with data reported by Filipović *et al.*,[20] who concluded that the mineral composition was highly influenced by the quantity of added sesame flour. In 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 (28.24; 5.33; 1254.0; 731.59; 38.10 mg kg^{-1},[28] respectively) necessary for the optimal mineral status and normal functioning of the body.

TABLE IV. Mineral contents (mg kg^{-1}) of pasta containing sesame flour and liquid eggs; data are expressed as mean ±standard deviation (n = 6). Values of different superscripted letters within each column are significantly different (Tukey test, $p < 0.05$)

Exp.	Zn	Cu	Mg	Ca	Fe
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}

RSM *calculation*

The *RSM* calculation for the cooked, textural and colour attributes and mineral content of the analyzed pasta samples showed statistically significant effects of the independent variables, the quantity of sesame flour and the quantity of liquid eggs, are presented in Table V.

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 the calculation of most of the responses, at a level of significance of $p < 0.05$. The quadratic term for *SF* (SF^2) was also statistically significant for the volume increase (*VI*) and work of shear (*WS*), while the quadratic term for *LE* (LE^2) was statistically significant for the work of shear.

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

The regression coefficients of the SOP models for the 14 responses of the pasta samples, Table VI, indicated good fitting capabilities for all SOP models to the experimental data.

Score calculation

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

TABLE V. RSM calculation for different characteristics of the pasta samples (sum of squares); *SF* – quantity of sesame flour, *LE* – quantity of liquid eggs, *df* – degrees of freedom, * – significant at the $p < 0.05$ level

Properties		Term							r^2
		SF	SF^2	*LE*	LE^2	*SF*×*LE*	Error	Total *SS*	
		df							
		1	1	1	–	1	3	8	
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

TABLE VI. Regression coefficients of *SOP* of the 14 responses of the pasta samples; * – significant at the $p < 0.05$ level

Parameter	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 attributes						
*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

TABLE VI. Continued

Parameter	Term					
	β_0	β_1	β_{11}	β_2	β_{22}	$\beta_1\times\beta_2$
	Mineral content					
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

The score values of the pasta samples with different quantities of sesame flour and liquid eggs are shown in Fig. 1, from which it could be seen that on increasing the quantity of sesame flour and liquid eggs, total quality of the pasta samples was increased. Pasta sample S9 achieved the maximum score value of 0.63 of a possible 1, indicating that this is the best formulation because it lead to the pasta with the highest achieved total technological quality.

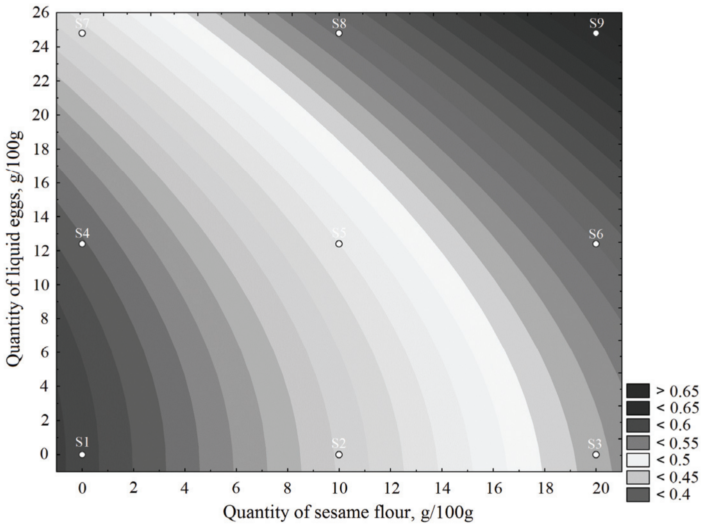

Fig. 1. Score values of pasta formulation with sesame flour and liquid eggs.

CONCLUSIONS

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

The eggs positively affected pasta cooking attributes (decreasing cooking loss), pasta texture (increase hardness) and colour (increasing yellowness). The sesame flour adversely affected the technological quality but positively affected the 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 indicated the optimal formulation of pasta as a functional food. The pasta sample with sesame flour and eggs in quantities of 20 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 of 28.24, 5.33, 1254.0, 731.59 and 38.10 mg per 100 g flour, respectively), thus satisfying the daily requirements of the mineral elements recommended by FAO/WHO. Pasta with sesame flour could be a valuable source of essential elements in the daily diet.

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И З В О Д

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

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Тестенина је погодна намирница али ју је за исхрану потребно 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, 124 и 248 g kg^{-1}) 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.

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