RHEOLOGY PROPERTIES AND ACYLGLYCEROLS AND FATTY ACIDS COMPOSITION OF THE WHEAT FLOUR SUPPLEMENTED WITH *Boletus edulis* FLOUR

Nada Nikolić[1*], Jelena Stojanović[1], Jasna Mastilović[2], Miodrag Lazić[1], Ivana Karabegović[1], Gordana Stojanović[3]

[1] University of Niš, Faculty of Technology, Department of Food and Biotechnology, Leskovac, Serbia
[2] University of Novi Sad, Institute of Food Technology, Novi Sad, Serbia
[3] University of Niš, Faculty of Science and Mathematics, Department of Chemistry Niš, Serbia

(ORIGINAL SCIENTIFIC PAPER)
UDC 664.6/.7:582.284.52:665.12

In this paper, the rheology properties and composition of fatty acids and acylglycerols of the wheat flour substituted by various portions of the flour from mushrooms *Boletus edulis* were investigated, as well as the effect of lipid components on some rheology properties. Rheology properties and fatty acids and acylglycerols composition depend on the mushroom flour portion in the mixtures. The mushroom flour addition increased the value of the water absorption for 8.1% and maximal pasta viscosity for 48.2%, decreased the dough energy for 80.4% and prolonged the dough stability time for 2.5 min. The content of fatty acids, mono- and di-acylglycerols and the content of total unsaturated fatty acids in mixtures increased with the increase of the mushroom flour portion in flour mixtures, while the content of triacylglycerols and total saturated fatty acids decreased. In order to enrich the wheat flour with mushroom lipid components and obtain the dough with satisfactory rheology properties, the mushroom portion of 10% (w/w) was indicated. The correlation coefficients showed that the lipid components had the influence on the rheology properties of the dough made from wheat-mushroom flour mixtures: the linoleic acid, mono and di-acylglycerols content had a proper correlation with extensibility and gelatinization temperature, while tri-acylglycerols had the opposite correlation.

Keywords: Rheology, Fatty acids, Acylglycerols, Porcino, Wheat

Introduction

Mushrooms are edible fungi and delicious nutritional food in many countries. Hundreds of species of edible mushrooms exist in the wild, but less than 20 are harvested and used as food. The food value of mushrooms is between meat and vegetables [1]. Over recent years the usage and consumption of mushrooms has increased, especially in the vegetarian community [2]. Crisan and Sands (1978) [3] reported that mushrooms in general contain 90% water and 10% dry matter. The content of protein in dry matter varies in a wide range, from 10 to 40% [4]. Besides protein, mushrooms contain 3-21% of carbohydrates, 3-35% of dietary fibre [5], essential amino acids, B-vitamins and vitamin C [6]. The abundant essential amino acid in the mushroom is lysine while the wheat protein is considered to be limiting in essential amino acids like lysine, tryptophan and threonin and hence there is a need for its nutritional quality improvement by using modern biotechnology [7]. The content of lysine in *Boletus edulis* was detected in the range from 52 [8] even to 217 mg/100 g of the dry matter [9].

In mushrooms, the fat content ranges mostly 2-6% in the dry matter and in *Boletus edulis* this content was found to be 2.92 g/100 g of the dry matter [10], with proportions of neutral to polar lipid in the dry matter of 3.3 to 3.1% [11]. The investigation of the fatty acids composition from fifteen wild edible mushrooms of *Boletus* species extracted by Soxhlet apparatuses, with ethanol/water/HCl (90:10:1, v/v/v) over 24 h, showed that the most abundant fatty acids were oleic (15-42%), linoleic (38-58%) and palmitic (7-17%) and the content of stearic acid was 1.9- 4.4% [12]. The investigations on the fatty acids composition of lipid from major types of the wheat flour (*Triticum aestivum*) showed that the concentrations of major fatty acids in free lipid fraction were 1.7–2.1 mg/g of palmitic acid, 1.6–2.1 mg/g of oleic acid and 5.5–6.7 mg/g of linoleic acid, while polyunsaturated fatty acids were predominant to saturated and monounsaturated in all types of flour [13].

Besides nutritional, mushrooms also have the medicinal importance. They have been used as medicine in China since 100 A.D. [14], but the health benefits of basic active principles of mushrooms were promoted in 1960s. Mushrooms have been used in health care for treating simple skin diseases. The anti-tumour properties of aqueous extracts of edible mushrooms are reported by Ikekawa et al. (1969) [15] and the main components which provide these properties were β–D glycans and polysaccharide named lentinan [16]. Bahl (1983) [17] reported that mushrooms cure epilepsy, wounds, skin diseases, heart aliments, rheu-

*** Author address:** Nada Nikolić, Faculty of Technology, University of Niš, Bulevar oslobodjenja 124, 16 000 Leskovac, Serbia
E-mail: nadanikolic64@yahoo.com
The manuscript received: October, 30, 2015.
Paper accepted: November, 19, 2015.

matoid arthritis, cholera besides intermittent fevers, diaphoretic, diarrhoea, dysentery, cold, anaesthesia, liver and gall bladder diseases, and are used as vermicides. Nowadays the data show many other benefities of mushrooms in medicine, and without side effects [18].

The rheology properties are sensitively dependent on the dough composition i.e. the water and salt content and the mixing time [19], and have great relevance in predicting the product quality such as mixing behaviour, sheeting and baking performance [20,21]. In the available literature, there are data about the dough rheology and bread properties when wheat flour was supplemented with some mushroom flour, but no data about the effect of *Boletus edulis* on these properties. Thus, the investigation of the effect of maitake (*Grifiola frondosa*), mushroom powder on bread properties showed that the mushroom powder drastically decreased the dough strength [22] and had the effect on deteriorating the bread properties such as the bread height and a specific volume. Hong et al. (2005) [23] reported that the final viscosities decreased by increasing the amount of the oyster mushroom (*Pleurotus ostreatus*) powder to the wheat flour. The gradual increase of the water absorption (WA), the dough development time (DT) and the mixing tolerance index of the dough and a decrease of the dough stability (DSt) by increasing the amount of this mushroom powder were also observed. The value of WA was also increased when the powder of Nigerian oyster mushroom (Pleurotus plumonarius) was used to replace 5-25% wheat flour, but the loaf volume, specific volume, crumb grain and loaf quality decreased [24]. The data of increasing WA, dough weaking, mixing tolerance index and ratio between dough resistance to extensibility (R/Ex), and decreasing of DT, DST, extensibility (Ex) and resistance to extension (R) with increasing the level of oyster mushroom flour were reported by Hesham et al. (2007) [25]. Although the lipid content in the flour is low, previous investigations showed the high absolute value of correlation coefficients between lipid components such as mono-acylglycerols, di-acylglycerols, palmitic and oleic acid content and rheology properties, especially Ex and DSt, when buckwheat [26] or soy flour [27] was used to replace the wheat flour.

In order to investigate the possibility of Boletus edulis mushroom for obtaining the dough for potential new food products, considering its nutritional properties and health benefits, the present work was undertaken with the aim to investigate the effect of the mushroom flour addition on rheology properties. The mixtures with the portions of mushroom flour of 5, 10, 15 and 20% w/w were prepared. The effect of the mushroom flour addition on the fatty acids and acylglycerols composition, with an emphasis on total saturated fatty acids (TS), total monounsaturated fatty acids (TMUS), total polyunsaturated fatty acids (TPUS) and total unsaturated fatty acids content (TU) was investigated too, and the effect of some lipid components on the rheology properties based on the correlation coefficients was evaluated.

Experimental

Flour and flour mixtures

The wheat flour (WF) type 500 produced by “Fidelinka”, Subotica, Serbia, was bought from the local market. The mushroom (*Boletus edulis*) flour (MF) was obtained from wild, fresh mushrooms from eko-region Piskupovo, Leskovac, Serbia, after cutting to slices (0.4 mm of thickness) drying at 35 ºC for 5 h, milling (IKA Model M120) and sieving through a 0.30 mm riddle. 285, 270, 255 and 240 g of the wheat flour and 15, 30, 45 and 60 g of the mushroom flour, respectively, were used to make 300 g of the dough mixture with 5% (WM 5), 10% (WM 10), 15% (WM 15) and 20 % (w/w) (WM 20) mushroom flour portions, without adding additives.

Flour analysis

The protein content (PC) was determined by the Kjeldahl method (N x 5.7). The ash content (AC) was determined by staking at 800 ºC for 5 h. The lipids content (LC) was determined by the trichloroethylene duplicate extraction for the same sample by using reflux (1: 20 w/v, at boiling temperature, 60 minutes). The extracts were combined and 5 ml were dried at 110 ºC to the constant weight, and the dry residue content was read out on the analyzer display (Scaltec SMO 01, Scaltec instruments, Germany). For lipids isolation and acylglycerols and fatty acids characterization, the rest of combined extracts was evaporated under vacuum and the lipid residue was obtained. For the gluten content (GC) determination, the dough was prepared by adding a sodium chloride solution and wet gluten was isolated by dough washing and then weighed [28].

Rheology measurement

For the water absorption values (WA value in ml), the development time (DT in minutes), dough stability (DSt in minutes), a degree of softening (DSf in FU) and the farinograph quality number (QN) determination, the Brabender farinograph (Brabender Model 8 10 101, Duisburg, Germany) and ISO 5530-1 test procedure were used. For extensograph measurement, the Brabender extensograph (Brabender, Model 8600-01, Duisburg, Germany) and test procedure ISO 5530-2 were used. The samples were prepared from the flour, distilled water and salt. The data for energy (E in cm^2), resistance (R in EU), extensibility (Ex in mm) and ration number (R/Ex) were recorded on the extensograph curve. To obtain amylograph data, gelatinization temperature (T_{max} in oC and gelatization maximum (η_{max} in AU), the amylograph (Brabender Model PT 100, Duisburg, Germany) and ISO 7973 test procedure was used.

HPLC analysis

For HPLC analysis, lipid residues were dissolved into the mixture of 2-propanol:n-hexane, 5:4 v/v to obtain the solution with the concentration of 5 mg/ml and filtered through 0.45 μm Millipore filters. The HPLC method of Holčapek et al. (1999) [29] and the Agilent 1100 High Performance Liquid Chromatograph, a Zorbax Eclipse XDB-

C18 column: 4.4 m x 150 mm x 5 µm (Agilent Technologies, Wilmington, USA) and an UV/ViS detector were used. The binary solvent mixture was methanol (solvent A) and 2-propanol:n-hexane, 5:4 by the volume (solvent B) and flow rate of 1 ml/min with a linear gradient (from 100% A to 40% A+ 60% B in 15 min). The column temperature was held constant at 40 ºC and the components were detected at 205 nm. The fatty acids, mono-acylglycerols (MAG), di-acylglycerols (DAG) and tri-acylglycerols (TAG) were identified by comparing the retention times of the lipids components with those of standards. In order to obtain the content of acylglycerols present in the samples, the calibration curves for analyzed acylglycerols were prepared.

GC analysis

For the GC analysis, the lipid residues were alkaline hydrolyzed and methylated by methanol and BF_3 as catalysts. The final fatty acids methyl esters concentration was 8-10 mg/ml in the diethyl ether. The methyl esters were analyzed by the GC analysis using Hewlett-Packard 6890 N gas chromatograph equipped with a fused silica capillary column DB-5MS (5% phenylmethylsiloxane, 30m x 0.25 mm, a film thickness of 0.25 µm, Agilent Technologies, USA) and coupled with a 5975B mass selective detector from the same company. The injector operated at 250 °C. The isotermal oven temperature was 150 ºC (4 min), from 150 to 340 °C at the heating rate of 5 °C/min and then isothermally maintained for 10 min. The carrier gas was helium with a flow of 1.0 ml/min. Fatty acids were identified by a the comparison of retention times of lipid components with those of the standards. The percentage composition of the fatty acid was computed from GC peak areas without the use of correction factors.

Statistical analysis

The STATISTICA, version 5.0 software was used to perform the statistical analysis. The means and standard deviations were obtained by using Descriptive Statistics, marking the Median & Quartiles and Confirm Limits for Means. Correlations coefficients were obtained by using the options of Analysis, Quick Basic Stats and Correlation matrices.

In order to classify the flour mixtures consisting of wheat with different mushroom flour portions into groups, the cluster analysis and options of Joining (Tree Clustering), the complete linkage method and horizontal incicle plot were used.

Results and discussion

Flour properties

The wheat flour was B1 quality number (QN), and had the protein content of 9.6±0.4 g/100 g, the ash content of 0.41±0.04 g/100 g, the lipid content of 0.94±0.1 g/100 g, the wet gluten content of 20.3±0.4 g/100 g and the dietary fibber content of 2.8±0.2 g/100 g. The protein content in the mushroom flour was 28.4±0.6 g/100 g, the ash content was 6.8±0.15 g/100 g, the lipid content was 2.3±0.1 g/100 g, the dietary fibber content of 11.8±0.3 g/100 g, and it was gluten free. The values taken were the averages of triplicate measurements of the same sample followed by standard deviation.

Rheology measurements

The farinograph, extensograph and amylograph data of flours and five flour mixtures with different portions of the mushroom flour are given in Table 1.

Table 1. Rheology properties of wheat flour (WF) and wheat–mushroom flour mixtures with different portion of mushroom flour

	WF	5%	10%	15%	20%
		Farinograph data			
WA (ml)	54.1±0.6	55.0±0.6	55.5±0.6	57.9±0.6	58.5±0.7
DT (min)	1.5±0.1	1.9±0.1	2.0±0.1	2.5±0.2	4.5±0.3
DSt (min)	0.5±0.1	2.5±0.2	2.5±0.2	2.5±0.1	3.0±0.1
DSf (FU)	65±2	215±6	205±5	185±6	165±3
QN	58.7±2.7	32.1±1.5	35.3±1.8	34.1±1.5	44.3±1.9
Group	B_1	C_1	C_1	C_1	C_1
		Extensograph data			
E (cm^2)	76.4±3.5	15.0±1.2	16.8±0.9	33.0±1.1	25.1±1.1
R (EU)	345±15	85±8	95±12	180±14	185±14
Ex (EU)	135±7	136±8	162±7	175±7	121±5
R/Ex	2.56	0.48	0.70	1.17	1.49
		Amylograph data			
T_{max} (ºC)	77.5±0.3	80.0±0.4	81.0±0.3	81.5±0.3	82.0±0.3
η_{max} (AU)	675±3	675±3	720±3	830±3	1000±4

*values are the means and standard deviation (n=3) obtained by descriptive statistics and marking the Median & Quartiles and Confirm Limits for Means
WA - water absorption; DT - development time; Dst - dough stability; DSf - degree of softening; QN - quality number; E – energy; R – resistance; Ex –extensibility; R/Ex - ratio R to Ex number
T_{max} - gelatinization temperature; η_{max} - gelatization maximum

The addition of *Boletus edulis* flour in portions of 5, 10, 15 and 20% to the wheat flour changed the farinograph data. Water absorption increased with the increase of the mushroom flour portion in the mixtures from 55.0 to 58.50%. As the main component responsible for the water absorption in the wheat dough is gluten, and as the mushroom flour is gluten free but with a higher protein content than the wheat flour (9.6 to 28.4 g/100 g), higher absorption properties are probably due to protein components and a higher content of dietary fibres in the mushroom flour, as the results show that the content of dietary fibre in the mushroom flour was over four times higher than in the wheat flour (11.8±0.3 and 2.8±0.2 g/100 g, respectively). There is a report that Boletus edulis mushroom contains up to 28.8% of dietary fibre [30] and generally the fibre provides better properties of the water absorption. This is mainly due to the greater number of hydroxyl groups which exist in the fibre structure which allow a greater interaction of water through the hydrogen bonding [31]. The effect of increasing the water absorption value is reported when the wheat flour has been supplemented with Nigerian [24] and Egyptian oyster mushroom flour [25], too.

The differences for the dough development time among the flour mixtures with mushroom flour portions from 5 to 20% (w/w) ranged from 1.8 to 4.5 minutes. The dough stability for the mixture with the mushroom flour portion of 5 and 10% was higher (2.5 and 3.0 min, respectively) than for the dough from the wheat flour was

only 0.5 min. The degree of softening decreased from 215 to 165 BU when the mushroom flour portion in the flour mixture increased and all values were higher than 65 BU, which was found for the dough made of the wheat flour only. The reason for the decrease in the degree of softening might be the destruction and shortening of the fibres in the gluten network [32].

The addition of the mushroom flour changed the quality number and group of wheat-mushroom mixtures. The quality number of the studied mixtures was lower (32.1 to 44.3) than the number of the wheat flour (58.7) (Table 1) and the group was C1 instead of B1 [33].

The data for the flour mixtures with different portions of the mushroom flour obtained on extensograph showed that all dough had lower values for energy (ranging from 58.1 to 70.8 EU) and resistance (ranging from 85 to 178 EU) in comparison to the dough made of the wheat flour only, where these values were 76.4 and 345 EU, respectively. The extensibility of the dough with the mushroom flour ranged from 121 to 175 EU and decreased with increasing the mushroom flour portions. The ration number, R/Ex, varied in the range from 0.49 to 1.47. These values were lower than the ratio number in the wheat flour (2.56) and this indicates the lower fermentation tolerance of the dough with the mushroom flour [33]. By comparing our results to those found in literature, obtained by using oyster mushroom flour, the addition of the mushroom flour had the same influence on the dough development time and dough resistance, while the influence on other rheology data was opposite [23-25]. The results are also different from each other, depending on the type of the mushroom and its origin. These differences could be explained by a different chemical composition of the mushroom flour, especially the protein composition. High protein content probably affects most farinographic characteristics.

Concerning amylograph data, the dough with the mushroom flour had higher T_{max} and maximal pasta viscosity than the dough with the wheat flour only. The value of T_{max} increased from 80 to 82 ºC and maximal pasta viscosity from 690 to 995 AU when the mushroom flour portion increased. This indicates that the addition of the mushroom flour to the wheat flour changes the process of wheat starch gelatinisation and it occurs at higer temperatures when higher values of pasta viscosity are reached. This might be due to the higher content of some of mushroom components in comparison to the wheat flour, such as protein and lipid which have been reported to increase the viscosity in food [34].

Acyglycerols and fatty acids composition

The lipid profile (fatty acids, mono-, di- and tri-acylglycerols content) of the wheat flour, mushroom flour and wheat-mushroom flour mixtures obtained by HPLC analysis is presented in Table 2, and the fatty acids composition obtained by a GC analysis is presented in Table 3.

Table 2. The fatty acid (FA), mono-acylglycerols (MAG), di-acylglycerols (DAG) and tri-acylglycerols (TAG) content in wheat flour (WF), mushroom flour (MF) and in wheat-mushroom flour mixtures with different mushroom flour portions

Component	WF	MF	Mushroom flour portion			
			5%	10%	15%	20%
FA*	28.64	73.20	30.87	33.09	35.32	37.55
FA**	269	1544	334	399	464	530
MAG*	3.01	5.25	3.12	3.23	3.35	3.46
MAG**	28	111	32	36	40	45
DAG*	7.72	5.21	7.59	7.47	7.34	7.22
DAG**	73	110	75	77	78	80
TAG *	60.54	16.35	58.33	56.12	53.91	51.70
TAG**	567	345	556	545	534	523

* value expressed as g per 100 g of lipid
** value expressed as mg per 100 g of flour or the flour mixture

Table 3. The fatty acids content of lipid from the wheat flour (WF), mushroom flour (MF) and wheat-mushroom flour mixtures with different mushroom flour portions

Component (g/100g of lipid)	WF	MF	Mushroom flour portion			
			5%	10%	15%	20%
Palmitic acid (16:0) *	15.36	4.39	14.81	14.26	13.71	13.17
Palmitic acid (16:0) **	144	93	142	139	136	134
Stearic acid (18:0) *	1.03	-	0.98	0.93	0.87	0.82
Stearic acid (18:0) **	9.7	-	9.2	8.7	8.2	7.8
Behenic acid (22:0) *	0.18	-	0.17	0.16	0.15	0.14
Behenic acid (22:0) **	1.7	-	1.6	1.5	1.4	1.3
Oleic acid (18:1) *	13.34	1.41	12.74	12.15	11.55	10.95
Oleic acid (18:1) **	125	29	121	116	111	106
Linoleic acid (18:2) *	66.57	45.08	65.49	64.42	63.34	62.27
Linoleic acid (18:2) **	623	951	642	658	674	691
Phthalic acid*	0.46	0.43	0.46	0.46	0.45	0.45
Phthalic acid**	4.3	9	4.5	4.8	5.0	5.2
TS**	164	93	161	157	153	149
TMUS**	126	29	121	158	111	106
TPUS**	626	951	642	658	675	691
TU**	751	980	763	774	787	797
TU/TS**	4.58	10.54	4.74	4.93	5.14	5.34

* value expressed as g per 100 g of lipid
** value expressed as mg per 100 g of flour or the flour mixture
TS - total saturated fatty acids content; TMUS - total monounsaturated fatty acids content; TPUS - total polyunsaturated fatty acids content; TU - total unsaturated fatty acids content; TU/TS - ratio total unsaturated fatty acids content to total saturated fatty acids content

The lipids from the wheat flour had the highest content of TAG (over 60% and it was 569 mg/100 g of the flour) and the lowest content of MAG (approximate 3% , i.e. 28 mg/100 g of the flour). The lipids from the mushroom flour had the highest content of fatty acids (over 73% i.e. 1544 mg/100 g of the flour) and the lowest content of MAG and DAG (approximate 5% i.e. 110 mg/100 g of the flour). The content of FA, MAG and DAG in the mixtures had the same changing tendency as the mushroom flour portion: it increased when the mushroom flour portion in flour mixtures increased, while the content of TAG displayed the opposite changing tendency. The increased content of FA could be important, as they have been reported to exhibit antibacterial activities [35].

The GC analysis showed that the lipid of the wheat flour contained 16.57% of total unsaturated fatty acids (TU) mainly consisting of linoleic (66.57%) and oleic acid (13.34%) (Table 3). The total polyunsaturated fatty acids (TPUS) content was higher (66.57%) than that of mon-

ounsaturated fatty acids (TMUS) (13.34%). The wheat flour contained 16.57% of total saturated fatty acids (TS) where the main fatty acid was palmitic acid (15.36%). The stearic acid content was only 1.03% of total fatty acids. Finally, the content of total unsaturated fatty acids was almost five times greater than content of total saturated fatty acid (the TU/TS ratio was 4.82).

The lipid from the mushroom flour contained 45.36% of TU, composed of linoleic acid (27.30%) and oleic acid (18.06%). The palmitic acid was determined to be the only saturated fatty acid with the content of 4.53%. Based on the GC analysis, in addition to the fatty acids, the components such as ergosterol (provitamin D) with the content of 5.43% and stigma sterol with the content of 1.74% were also detected. Comparing the mushroom fatty acid composition to those found in the wheat flour, the greatest differences were determined in the ratio of TU to TS content (10.01 to 4.82). This ratio in all flour mixtures was higher than in the wheat flour, which caused the content of total unsaturated fatty acids to increase and the content of total saturated fatty acid decrease when the mushroom flour replaced the wheat flour in the flour mixture. This is important as there are dietary recommendations to decrease saturated and increase unsaturated fatty acids due to their health benefits for the human heart [36].

Statistical analysis

The correlation coefficients between lipid parameters (palmitic, oleic and linoleic acid content, MAG, DAG and TAG content) and rheology properties (WA, DSt, Ex, T_{max}, and η_{max}) of the wheat flour and the wheat-mushroom flour mixtures are shown in Table 4.

Table 4. Correlation matrix for wheat and four wheat-mushroom flour mixtures (correlations are significant at p< 0.05, N=10)

	PA	OA	LA	MAG	DAG	TAG	WA	DSt	Ex
OA	0.49								
LA	-0.78	-0.35							
MAG	-0.78	-0.33	0.99						
DAG	-0.71	-0.33	0.95	0.97					
TAG	-0.92	0.48	-0.91	-0.92	-0.90				
WA	-0.60	-0.37	**0.87**	**0.89**	**0.92**	-0.76			
DSt	-0.74	-0.25	**0.86**	**0.81**	0.76	-0.79	0.59		
Ex	-0.69	-0.42	**0.93**	**0.96**	**0.92**	**-0.85**	0.90	0.68	
T_{max}	-0.79	-0.37	**0.95**	**0.93**	**0.88**	**-0.87**	0.75	0.98	0.86

PA - palmitic palmitic acid content; OA – oleic acid content; LA - linoleic acid content; MAG – mono-acylglycerols content; DAG –di-acylglycerols content; TAG – tri-acylglycerols content;
WA - water absorption; DSt - dough stability; Ex - extensibility; T_{max} - gelatinization temperature

The sample size was ten (N=10 (5x2): wheat flour and four wheat-mushroom flour mixtures and the maximal and minimal value of three determinations). Only the correlations which were above the absolute value of 0.85 were taken into consideration. The correlations showed that *Boletus edulis* lipid components have an influence on the rheology properties of the dough made from wheat-mushroom flour mixtures. The linoleic acid and MAG content had a positive correlation with all given rheology parameters. The high DAG content was associated with a high value of WA, Ex, and T_{max}, and TAG decreased values of Ex and T_{max}. The oleic acid content was not correlated with any of the given rheology parameters. Using a cluster analysis, based on multiple variables, the wheat and mushroom flour and their mixtures were classified into groups. The number of variables was six wheat and mushroom flour and five wheat-mushroom flour mixtures: WM 5, WM 10, WM 15 and WM 20. The number of cases i.e. parameters were nine (five rheology: WA, DSt, R, Ex and η_{max} and four lipid parameters: FA, TAG, TS and TU content). The obtained linkage distances for the wheat flour, mushroom flour and their mixtures are presented by means of a dendrogram in Fig. 1.

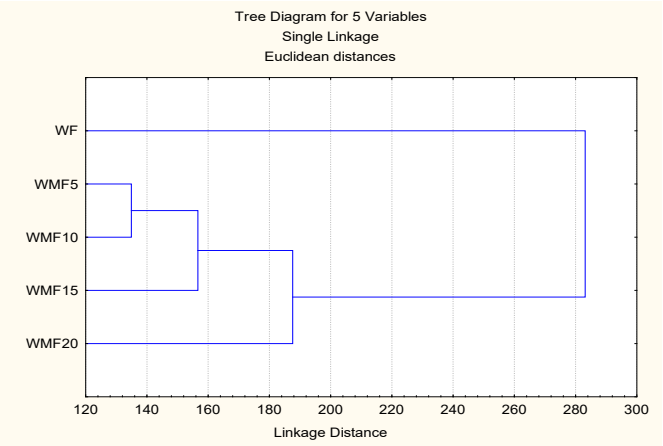

Figure 1. Dendrogram obtained by using Euclidean distance and a complete linkage method, based on rheological and lipid parameters for the wheat flour (WF) and flour mixtures (WMF) with various portions of the mushroom flour (5, 10, 15 and 20% w/w)

The mixtures with the mushroom flour portion of 5 and 10% (w/w) are joined with WF at the same distance level of 135 and make up the group of the flour mixtures with the most similar properties to those of the wheat flour. The mixture with the mushroom flour portion of 15% (w/w) is joined with WF flour at the distance level of 157 and the mixture with the mushroom flour portion of 20% (w/w) is at the highest distance level of 188. In order to enrich the wheat flour with mushroom components and obtain the dough with similar rheology properties as those of the dough made of the wheat flour only, the mushroom portion of 10% (w/w) is indicated.

Conclusion

Dough rheology properties and acylglycerols and the fatty acids composition of the wheat flour are changed by replacing with the mushroom flour and depended on the mushroom flour portion in the mixtures. In order to enrich the wheat flour with mushroom components and obtain the dough with similar rheology properties as those of the dough made of the wheat flour only, the mushroom

portion of 10% (w/w) is indicated. The correlation coefficients showed that *Boletus edulis* lipid components had an influence on the rheology properties of the dough made from wheat-mushroom flour mixtures: linoleic acid and the mono-acylglycerols content had a positive correlation with the water absorption, dough stability, extensibility and gelatinization temperature, high di-acylglycerols content was associated with a high value of the water absorption, extensibility and gelatinization temperature, while tri-acylglycerols decreased the values of extensibility and gelatinization temperature.

Acknowledgement

This work was supported under the project No 172047 by the Ministry of Education, Sciences and Technological Development of the Republic of Serbia.

References

[1] Z. Bano, Nutritive value of Indian mushroom and medicinal practices, Economic Botany, 31 (1976) 367-371.
[2] G. Shakuntala, P.B. Samudra, V. Deepak, C. Sudeshna, Fungal biotechnology in food and feed processing, Food Research International, 42 (2009) 577-587.
[3] E. Crisan, A. Sands, A nutritive value of edible mushrooms, in The biology and cultivation of edible mushrooms, S.T., Chang, W.A. Hayes Ed., Academic press, New York and London 1978, p. 172.
[4] M.I. Friedman, Protein nutritional quality of foods and feeds, Marcel Dekker Inc., New York, 1975, p. 68.
[5] U.V. Mallavadhani, A.S. Sudharkar, K.S. Satyanarayana, A. Mahapatra, W. Li, R.B. Van Breemen, Chemical and analytical screening of some edible mushrooms, Food Chemistry, 95 (2006) 58-64.
[6] W. Breene, Nutritional and medicinal value of speciality mushrooms, Journal of Food Protection, 53 (1990) 883-894.
[7] D. Yadav, N.K. Singh, Wheat Triticin: A potential target for nutritional quality improvement. Asian Journal of Biotechology, 3 (2011) 1-21.
[8] B. Ribeiro, P. Andrade, B. Silva, P. Baptista, M. Seabra, P. Valentão, Comparative study on free amino acid composition of wild edible mushroom species, Journal of Agricultural and Food Chemistry, 56 (2008) 1073-1079.
[9] Y. Tsai, L. Tsai, L. Mau, Non-volatile taste components of Agaricus blazei, Agrocybe cylindracea and Boletus edulis, Food Chemistry,107 (2008) 977-983.
[10] S. Beluhan, A. Ranogajec, Chemical composition and non-volatile components of Croatian wild edible mushroom, Food Chemistry, 124 (2011) 1076-1082.
[11] Kalač, P. In Mushrooms: Types properties and nutrition. Chemical composition and nutrition value of european spices of wild growing mushroom, S. Andresand, N. Baumann Ed., Nova Science Publishers, New York 2012, p. 129.
[12] L. Hanuš, I. Shkrob, V. Dembitsky, Lipids and fatty acids of wild edible mushrooms of the genus Boletus, Journal of Food Lipids, 15 (2008) 370-383.
[13] N. Kashlan, S. Hassan, P. Srivastava, A. Mohanna, Fatty acids composition and distribution in the free lipid fraction of major types of wheat flour and bread consumed in Kuwait, Food Chemistry, 43 (1992) 199-201.
[14] N. Gunde-Cimmerman, Medicinal value of the genus Pleurotus (Fr.) P. Karst. (Agaricales S. I., Basidiomycetes), International Journal of Medicinal Mushrooms, 1 (1999) 69-80.
[15] T. Ikekawa, N. Uehara, Y. Maeda, M. Nakanishi, F. Fukuoka, Antitumour activity of aqueous extracts of edible mushrooms, Cancer Research, 29 (1969) 734-735.
[16] G. Chihara, Y. Maeda, J. Namuro, T. Sasaki, F. Fukuoka, Inhibition of mouse sarcoma 180 polysaccharides from Lentinus Edodes (Berk.) sing, Nature, 222 (1969) 687-688.
[17] N. Bahl, Medicinal value of edible fungi, Indian Mushrooms Science II, 2 (1983) 203-209.
[18] W. Bilal, H. Bodha, H. Wani, Nutritional and medicinal importance of mushrooms, Journal of Medicinal Plants Reserch, 4 (2010) 2598-2604.
[19] M. Keentok, M.P. Newberry, P. Gras, F. Bekes, R.I. Tanner, The rheology of bread dough made from four commercial flours, Rheology Acta, 41 (2002) 173-179.
[20] B. Dobraszczyk, P. Morgenstern, Rheology and bread making process, Journal of Cereal Science, 38 (2003) 229-245.
[21] G. Calderón-Domínguez, M. Neyra-Guevara, R. Farrera-Rebollo, R. Arana-Errasquín, R.Mora-Escobedo, Structural and farinographic changes during mixing of a yeast sweet dough, Nahrung/Food, 47 (2003) 312-329.
[22] M. Seguchi, N. Morimoto, M. Abe, Y. Yoshino, Effect of maitake (Grafiola frondosa) mushroom properties on bread powdered on bread properties, Journal of Food Science, 66 (2011) 261-264.
[23] H. Hong, S. Kim, S. Song Effect of oyster mushroom (Pleurotus osreatus) powder on bread quality, Journal of Food Science and Nutrition, 10 (2005) 214-218.
[24] C. Okafor, I. Okafor, U.Ozumba, N. Elemo, Quality Characteristics of bread made from wheat and Nigerian oyster mushroom (Pleurotus plumonarius) powder, Pakistan Journal of Nutrition, 11 (2012) 5-10.
[25] E. Hesham, S. Hussein, E. Mostafa, Rheology properties and quality evaluation of Egyptian balady bread and biscuit supplemented with flours of ungerminated and germinated legume seeds or mushroom, Polish Journal of Food and Nutrition Science, 57 (2007) 487-496.
[26] N. Nikolić, M. Sakač, J. Mastilović, Effect of buckwheat flour addition to wheat flour on acylglycerols and fatty acids composition and rheology properties, LWT-Food Science and Technology, 44 (2011) 650-655.
[27] N. Nikolić, M. Lazić, The main components content, rheology properties, and lipid profile of wheat-soybean flour, in Recent Trends for Enhancing the Diversity and Quality of Soybean Products, D. Krezhova Ed., InTech, Rijeka 2011, p. 81.
[28] J. Trajković, J. Baras, S.Mirić, S. Šiler, Analiza životnih namirnica, Faculty of Technology and Metallurgy,Beograd, 1983, p. 54.
[29] M. Holčapek, P. Jandera, J.Fisher, B. Prokeš, Analytical monitoring of biodiesel by high-performance liquid chromatography with various detection methods, Journal of Chromatography A, 858 (1999) 13-31.
[30] M. Nikolova, E. Pavlova, G. Bekyarov, A. Slavov, Kratchanova, M. Chemical characteristics of edible mushroom grown in Bulgaria, Scientific Works of the Universtity of Food Technology, 56 (2009) 449-455.
[31] C.Rosell, J.Rojas, B. Beedito, Influence of hydrocolloids

on dough rheology and bread quality, Food Hydrocolloids, 15 (2001) 75-81.
[32] L. Dodok, V. Szemes, Laboratórne kontrolné metódy pre pekárenskú a cukrársku prax, CpaC, Pezinok, 1998, p. 52.
[33] Djaković, Lj. Pšenično brašno, Faculty of Technology, Novi Sad,1980, p. 67.
[34] I. Oduro, O. Ellis, T. Narh, Expanding breadfruit utilization and its potential for pasta production, Discovery and Innovation, 19 (2007) 243-247.
[35] P. Desbois, J. Smith, Antibacterial free fatty acids: activities, mechanisms of action and biotechnological potential, Applied Microbiology and Biotechnology, 85 (2010) 1629-1642.
[36] J. Baum, M. Kris-Etherton, C. Willett, H. Lichtenstein, L. Rudel, C. Maki, J. Whelan, E. Ramsden, Fatty acids in cardiovascular health and disease: a comprehensive update, Journal of Clinical Lipidology, 6 (2012) 216-234.

Izvod

REOLOŠKA SVOJSTVA I SASTAV ACILGICEROLA I MASNIH KISELINA MEŠAVINE PŠENIČNOG I BRAŠNA PEČURKE *Boletus edulis*

Nada Nikolić[1], Jelena Stojanović[1], Jasna Mastilović[2], Miodrag Lazić[1], Ivana Karabegović[1], Gordana Stojanović[3]

[1] Univerzitet u Nišu, Tehnološki fakulltet, Leskovac, Srbija
[2] Univerzitet u Novom Sadu, Institut za prehrambene tehnologije, Novi Sad, Srbija
[3] Univerzitet u Nišu, Prirodno-matematički fakultet, Odsek za hemiju, Niš, Srbija

(ORIGINALNI NAUČNI RAD)
UDK 664.6/.7:582.284.52:665.12

U radu su ispitana reološka svojstva i sastav acilglicerola i masnih kiselina mešavine pšeničnog i različitog udela brašna vrganja (*Boletus edulis*). Dodatak brašna vrganja povećava sposobnost vezivanja vode za 8,1% i vrednost maksilanog viskoziteta suspenzije za 48,2%, smanjije energiju testa za 80,4% i produžuje vreme stabilnosti testa za 2,5 min. Sadržaj masnih kiselina, mono- i di-acilglicerola kao i sadržaj ukupnih nezasićenih masnih kiselina u mešavini brašna raste sa povećanjem udela brašna vrganja, a sadržaj tri-acilglicerola i ukupnih zasićenih masnih kiselina se smanjuje. Zamenom dela pšeničnog brašna brašnom vrganja sadržaj ukupnih nezasićenih masnih kiselina se povečava, a sadržaj ukupnih zasićenih masnih kiselina se smanjuje. Da bi se pšenično brašno obogatilo lipidnim koponentama vrganja, a dobijeno testo imalo zadovoljavajuća reološka svojstva, preporučen je udeo brašna vrganja od 10%. Korelacioni koeficijenti pokazuju da lipidne komponente vrganja imaju uticaja na reološka svojstva dobijenog testa. Tako su linolna kiselina, mono- i di-acilgliceroli su u pozitivnoj, a tri-acilgliceroli u negativnoj koelaciji sa rastegljivošću testa i temperaturom želatinizacije.

Ključne reči: Reologija, masne kiseline, acilgliceroli, vrganj, pšenica