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ORIGINAL PAPER

Fatty acids composition and rheology properties of wheat and wheat and white or brown rice flour mixture

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Abstract Manufacturing of bread from rice flour only presents technological difficulty because the rice is gluten-free and gluten is the most important structure forming protein. By using wheat and rice flour mixture, this problem can be avoided, and end product is enriched by rice-oil constituents. In this paper fatty acids composition, with an emphasis on total saturated, and total unsaturated fatty acids, rheological and baking properties of wheat–rice flour mixture (70:30 w/w) were investigated. The results show that wheat–rice flour mixture has better fatty acids composition with higher content of stearic, arachidic, lignoceric, oleic, and phthalic acids compared to wheat flour. Also, wheat flour did not include myristic, arachidic, lignoceric and linolenic acids, so rice flour addition made fatty acids profile richer as number of constituents is higher, nine instead six. The content of total unsaturated fatty acids content was higher in wheat–brown rice flour mixture than in wheat flour and in wheat–white rice flour mixture. When rice flour was added to wheat flour the rheological properties were changed: flour mixture had less water absorption, less degree of softening, longer development time, higher gelatinization temperature, but better stability and finally, better quality number and group than wheat flour. So, the wheat and rice flour mixture can be considered as a good quality flour and can be used for making good quality wheat-rice bread and cake.

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Abbreviations

TS	Total saturated fatty acids
TMUS	Total monounsaturated fatty acids
TPUS	Total polyunsaturated fatty acids
TU	Total unsaturated fatty acids
WA	Water absorption
DT	Development time
DSt	Dough stability
DSf	Degree of softening
QN	Quality number
E	Energy
R	Resistance
Ex	Extensibility
T_{max}	Gelatinization temperature
η_{max}	Viscosity
HV	Holding" value, as ratio of height and diameter
PC	Protein content
GC	Gluten content
OC	Oil content
W	Wheat flour
WWR	Wheat–white rice flour mixture
WBR	Wheat–brown rice flour mixture

Introduction

The oil and fatty acids as constituents, because of its association with heart disease, cancer and other chronic diseases [1], is of major research priority. Rice (*Oryza sativa* L.) contains low oil content (OC), below 5% on dry weight basis, but the rice oil has greater reputation than soybean or rape oils and it is deemed as a premium oil like sesame or olive oil. The major constituents of rice oil are oleic acids, linoleic acid (known also as omega 6), triglyceride palmitate (triglyceride fatty ester), with almost no linolenic acid [2]. Rice storage [3, 4], milling [3, 5] and the genotype [6] have a great influence on oil content and fatty acids composition. The rice oil has more unsaponifiables (the substances which are insoluble in water and soluble in ether after alkali extraction) and other trace constituents than other vegetable oil providing various sound features to rice oil [7]. In contrast to rice, rice bran is rich in fatty acids (about 15% on dry weight basis) which has high nutritious quality. The main nutraceutical value constituents are gamma-oryzanol and tocotrienols. Today there are reports that rice bran oil reduces plasma lipid content and both total and low-density lipoprotein cholesterols [8]. In rice bran oil, a 30-carbon isoprenoid, a squalene, which is a key intermediate in the biosynthesis of cholesterol, is found in small amounts (0.1–0.7 %). Squalene has radioprotective and anti-proliferative effect and has the ability to absorb oxygen [9, 10].

There are data that manufacturing of bread from rice flour only presents technological difficulty [11–13] because rice is gluten free [14] and gluten is the most important structure forming protein for bread making [15, 16]. By using wheat and rice flour mixture, technological difficulty can be avoided, the end product has a lower level of gluten and enriched with rice oil constituents. In this paper the fatty acid composition of wheat flour and wheat and rice flour mixture were determined. As rheological properties should have great relevance in predicting the machinability of dough and the quality of end product; and as no data about them is available, the rheological properties of wheat flour and white and white or brown rice flour mixture, were investigated. The present work was undertaken with the following objectives: (1) to prepare wheat–rice flour mixture and investigate the differences of influence of white and brown of rice flour addition on fatty acids composition with an emphasis on total saturated fatty acids content (TS) and total unsaturated fatty acids content (TU), (2) to find the effect of rice flour addition on rheological and (3) on baking properties.

Materials and methods

Flours

The wheat flour and rice were bought in the local market. The rice flour was obtained by milling of white and brown rice short grains. A 210 g of wheat flour and 90 g of rice flour were used to make dough mixture, with no additives.

Chemical composition analysis

Flours were analyzed for lipid content (method 945.16, AOAC), protein content (Nx5.95) (method 992.15, AOAC), ash content (method 920.153, AOAC 1995), moisture content (method 985.14, AOAC 1995) and gluten content. Analysis was performed in triplicate.

Rheology measurement

In order to investigate the rice flour addition on rheology properties of wheat flour and wheat–rice flour mixtures, a 70:30 w/w ratio were made. The Brabender farinograph (Brabender Model 8 10 101, Duisburg, Germany) according to ISO 5530-1 test procedure was used for water absorption values (WA value in ml), development time (DT in min), dough stability (DSt in min), degree of softening (DSf in FU) and farinograph quality number (QN) determination. 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 appropriate flour mixture, distilled water and salt, and 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 °C and gelatization maximum (highest viscosity during "heating", η_{max} in AU), the amylograph (Brabender Model PT 100, Duisburg, Germany) and ISO 7973 test procedure were used.

GC analysis

Oil extraction from the wheat flour and wheat–rice flour mixture, was carried out by hexane and by Soxhlet apparatus. Extracts were evaporated under vacuum until the oil residue remains. For GC analysis, fatty acids methyl esters were prepared. The oils were alkaline hydrolyzed and methylated by methanol and BF_3 as catalysts. The final fatty acids methyl esters concentration was about 8 mg/ml in heptane. For obtained methyl esters GC spectra, the HP 5890 SERIES II GAS-CHROMATOGRAPH, HP with FID detector, and integrator 3396 A HP was used. Column was ULTRA 2 (25 m × 0.32 mm × 0.52 µm), with injector temperature of 320°C, and injector volume of 0.4 µl. The carrier gas was He at a constant flow rate of 1 ml/min. The flame ionization detector was at 350°C and split ratio was 1:20. Oven temperature was initially 120°C and was maintained at 120°C, for 1 min, then increased by 15°C/min until 200°C, increased by 3°C/min until 240°C, increased by 8°C/min until 300°C and maintained at 300°C for 15 min. The fatty acids were identified by comparison of retention times of the lipid constituents with those of standards.

Baking test

The dough-base formulation used comprised: 70% wheat flour, 30% rice flour, 30% sugar, 1.8% sodium chloride, 6%

sodium hydrogen carbonate, 0.15% ascorbic acids and 53.5 and 54.5 % of water, for white–white or white–brown rice flour mixture, respectively. Ingredients were mixed in a farinograph, dough was allowed to rest 30 mins at room temperature. Then the dough were sheeted, for cakes round shape were cut out and the height to diameter ratio was determined. The cakes were baked at 180°C for 10 mins, and after baking, the height to diameter ratio was also determined.

Statistical analysis

The statistical analysis, the correlation matrices, as well as cluster analysis and determination of correlation coefficients and Euclidean distances, respectively, were performed by program STATISTICA version 5.0.

Results and discussion

Results of chemical compositions of wheat, wheat–white and wheat–brown rice flour mixture are given in Table 1. There are differences in the protein content, from 8.32 to 9.86%. The addition of brown rice flour to the mixture increases oil content and the wheat–brown rice flour mixture had higher oil content compared to wheat flour, because bran as part of grain with higher oil content is its constituent. As the oil content has greatest influence on the product's energy value, it can be predicted that the bread from this wheat–brown flour mixture will have higher energy value than bread from wheat flour or wheat–white rice flour mixture. In wheat–rice flour mixture, gluten is present in a smaller amount, approximately 17 instead 24%, due to 30% of rice flour portion in flour mixture. So, the addition of rice flour independently, white or brown, decreases the gluten content in flour mixture.

Fatty acids composition of wheat flour, wheat–white and wheat–brown rice flour mixture in 70:30 w/w ratio are given in Table 2. Wheat flour contained a total of 78.62% unsaturated fatty acids consisting mainly of linoleic (57.67%) and oleic acids (20.28%). Total polyunsaturated fatty acids were at a higher rate (58.34%) than monounsaturated fatty acids (20.28%). This flour contained 21.19% of total saturated fatty acids where the main saturated fatty acids were palmitic acids with the content of 19.56%. The stearic acid content was 1.37%, while behenic and phthalic acid content were less than 1%. So, the content of total unsaturated fatty acids was nearly four times higher than the total saturated fatty acids content (78.62–21.19%).

Table 1 Flour and flour mixture chemical composition analysis

Flour/Content (%)	PC	Ash	OC	GC
Wheat flour	9.86 ± 0.34	0.48 ± 0.04	1.9 ± 0.05	23.9 ± 0.4
Wheat–white rice flour mixture	8.32 ± 0.35	0.44 ± 0.04	1.8 ± 0.05	17.3 ± 0.5
Wheat–brown rice flour mixture	8.50 ± 0.36	0.82 ± 0.06	2.1 ± 0.05	16.9 ± 0.5

Data are presented as means of three determinations ±SD

PC Protein content, *OC* oil content, *GC* gluten content

Wheat–white rice flour mixture has similar fatty acids composition as wheat–brown rice flour mixture, with linoleic and oleic acids as the main constituents with content of approximately 50 and 25%, respectively. Linolenic acid was detected only in brown rice flour, in small amount of 1.24%, so in wheat–brown rice flour mixture its content was 0.37%. Phthalic acid and the monoolein, squalene and sitosterol, as other oil constituents, were found in both rice flour mixture.

The content of total saturated fatty acids of 20.23% was less in wheat–brown rice flour mixture, compared to the wheat–white rice flour mixture, where the content was 21.59%, and the content of total unsaturated fatty acids was higher in the wheat–white rice flour mixture (76.13%) in comparison to the wheat–brown rice flour mixture (74.50%). These results of unsaturated and saturated fatty acids content in flour mixtures bring the higher TU/TS ratio in wheat–brown rice flour mixture 3.68 compared to TU/TS ratio in wheat–rice flour mixture of 3.53. Therefore, the fatty acids composition in wheat–brown rice flour mixture is such that the unsaturated fatty acids content is higher than in mixture with the white rice flour. The content of TU (calculated based on oil content in flours and percentage of TU) independent of TU/TS ratio, is the highest in wheat–brown rice flour mixture where is 1.56 g instead of 1.48 g and 1.37 g in wheat and wheat–white rice flour mixture, respectively.

According to the results form Table 2, mixture with rice flour has better fatty acid composition with higher contents of stearic, arachidic, lignoceric, oleic, and phthalic acid, compare to wheat flour. Although myristic acid was not detected in wheat–brown rice flour mixture, it was probably present (as it was detected in pure brown flour in small content of 0.17%) but was not at detectable levels. It is evident that wheat flour does not include myristic, arachidic, lignoceric and linolenic acid, so rice flour addition made fatty acids profile more richer (number of constituents is higher, 9 instead 6).

According to the results for corn bread [17], similar fatty acids composition can be expected in fermented dough and in bread as dough fermentation did not changed the fatty acids composition and was slightly affected by the baking process.

Rheology properties of wheat flour and wheat–rice flour mixture, are given in Table 3. Farinograph, extensograph and

Table 2 Fatty acids and lipid component composition of wheat flour and wheat and white or brown rice flour mixture (70:30 w/w)

Component (%)	Wheat flour	Wheat–white rice flour mixture	Wheat–brown rice flour mixture
Myristic acid (14:0)	–	0.16 ± 0.05	–
Palmitic acid (16:0)	19.56 ± 0.43	19.32 ± 0.47	18.3 ± 0.45
Stearic acid (18:0)	1.37 ± 0.14	1.61 ± 0.16	1.39 ± 0.16
Arachidic (20:0)	–	0.14 ± 0.05	0.19 ± 0.06
Behenic acid (22:0)	0.26 ± 0.06	0.17 ± 0.06	0.18 ± 0.05
Lignoceric acid (24:0)	–	0.19 ± 0.05	0.17 ± 0.05
Oleic acid (18:1)	20.28 ± 0.21	25.57 ± 0.22	24.26 ± 0.25
Linoleic acid (18:2)	57.67 ± 0.72	50.56 ± 0.69	49.87 ± 0.63
Linolenic acid (18:3)	–	–	0.37 ± 0.05
Phthalic acid	0.67 ± 0.08	0.69 ± 0.08	0.81 ± 0.09
2-Monoolein	–	0.28 ± 0.04	3.34 ± 0.05
Squalene	–	0.26 ± 0.05	0.49 ± 0.05
Sitosterol	–	0.64 ± 0.14	0.25 ± 0.11
TS (%)	21.19 ± 0.45	21.59 ± 0.47	20.23 ± 0.45
TMUS (%)	20.28 ± 0.21	25.57 ± 0.22	24.26 ± 0.25
TPUS (%)	58.34 ± 0.72	50.56 ± 0.69	50.24 ± 0.63
TU (%)	78.62 ± 0.93	76.13 ± 0.91	74.50 ± 0.89
TU/TS	3.71	3.53	3.68

Data are presented as means of three determinations ±SD

TS Total saturated fatty acids, *TMUS* total monounsaturated fatty acids, *TPUS* total polyunsaturated fatty acids, *TU* total unsaturated fatty acids, *TU/TS* ratio of total unsaturated to total saturated fatty acids

Table 3 Rheology data of wheat flour and wheat and white or brown rice flour mixture (70:30 w/w)

	Wheat flour	Wheat–white rice flour mixture	Wheat–brown rice flour mixture
Farinograph data			
WA (ml)	58.2 ± 0.6	53.5 ± 0.5	54.0 ± 0.6
DT (min)	2.0 ± 0.2	7.0 ± 0.2	8.0 ± 0.3
DSt (min)	1.5 ± 0.1	9.5 ± 0.2	3.0 ± 0.1
DSf (FU)	40 ± 2	20 ± 2	30 ± 2
QN	68.0	87.5	78.4
Group	B1	A1	A2
Extensograph data			
E (cm^2)	101.2 ± 5.8	52.2 ± 4.5	52.0 ± 4.5
R (EU)	370 ± 10	280 ± 10	340 ± 10
Ex (EU)	144 ± 10	120 ± 10	99 ± 10
R/Ex	2.57	2.33	3.43
Amylograph data			
T_{max} (^{0}C)	88.4 ± 1.1	98.1 ± 1.2	90.2 ± 1.3
η_{max} (AU)	480 ± 20	790 ± 25	870 ± 20

Data are presented as means of three replication ±SD

amylograph data depend on the rice flour addition. Addition of white or brown rice flour to wheat flour results in lesser water absorption (WA) and longer development time (DT) compared to wheat flour. These results, i.e., for rice dough, are compatible with results from Hema et al. (2004) [12]. Wheat–rice flour mixture had lesser degree of softening (DSf) but better stability (DSt) than wheat flour only. As degree of softening of wheat–white and wheat–brown rice flour mixture were 20 and 30 FU, respectively, and still less than 75 FU, can be considered as a good quality flour. Also, results showed addition of both rice flour to wheat flour make flour quality number and quality group better.

From extensograph data, the energy of wheat–rice flour mixture is two times lower than the energy of wheat flour, so rice flours are "weaker" than wheat flour only and have less extensibility. Ratio number (R/Ex) shows that the volume of bread with brown rice flour will be less than bread with white rice flour.

Farinograph and extensograph data seem to be contradictory: farinograph data showed that rice–wheat flour mixture had better flour quality number and group than wheat flour and extensograph data show the same flour mixture was "weaker". The flour is strong as well as gluten content and wheat–rice flour mixture had lower gluten content. But, the quality number and quality group include not only gluten content but also other constituents and depend on dough behavior during kneading. Besides, during extensograph measurement, dough stayed 3 × 45 mins when probably the dough becomes weak.

Pasting properties are regarded as the most important indices in evaluation of starch properties [18]. Both flour mixtures have higher gelatinization temperature compared to wheat flour, so addition of both rice flour altered starch pasting properties. When brown rice flour was added gelatization maximum of flour mixture was significantly higher than gelatization maximum of wheat flour. The white rice flour addition had the same but lesser influence.

Table 4 Cake "holding value" (HV) of wheat flour and and wheat and white or brown rice flour mixture (70:30 w/w)

	Wheat flour	Flour mixture with white rice	Flour mixture with brown rice
HV^1	0.52 ± 0.02	0.58 ± 0.03	0.57 ± 0.03
HV^2	0.33 ± 0.02	0.46 ± 0.03	0.43 ± 0.03
HV^1/HV^2	1.57 ± 0.02	1.24 ± 0.03	1.32 ± 0.03

Data are presented as means of three determinations ± SD

HV^1 ratio of cake height and diameter before baking, *HV^2* ratio of cake height and diameter after baking

Indrani and Rao (2007) [19] investigations show when oil was added up to 20%, strength of dough decreases, the farinograph stability increase is probably due to delay in gluten development. Also, oil tends to weaken dough, reducing the strength and increasing the dough plasticity. Our results show these tendencies even when difference in oil content in wheat flour and wheat–brown rice flour mixture is small (0.2%).

There are reports, that stearic and linoleic acid affects rice starch properties [16]. Stearic acid significantly changed starch pasting properties to lower value, while linoleic acid showed the same but lesser impact. In wheat–rice flour mixture, the content of stearic acid is higher than wheat flour and lower value of *T*max and η_{max} were expected. Comparing wheat flour and wheat–rice flour mixture, the significant difference is in linoleic acid content (up to 8%) and higher amylograph data were obtained. The reason may be the different states of fatty acids in flour: in first case the stearic and linoleic acid was added as solution to pure rice starch while in our case these acids are constituents of flour oil and besides pure rice starch there are wheat starch and other components such as protein, ash, etc.

In order to investigate the baking properties of wheat and wheat–rice flour mixture, the cake "holding" value (HV), which represents the ratio of height (*h*) and diameter, (*d*), before (HV^1) and after baking (HV^2) were determined and given in Table 4. Based on the results, the cake from wheat–rice flour mixture had good before and after baking "holding" value (slightly less than cake from wheat flour), and assured good quality wheat–rice bread and cake.

Between some parameters of wheat flour, wheat–white and wheat–brown rice flour mixture, the correlation coefficients and the respective significance levels were done and data presented in Table 5. The sample size were nine ($N = 9$, three flours and three determinations) and the correlations which are above value of 0.8, were considered. Some correlations are ordinary: high gluten content (GC) goes along with high protein content (PC), WA, Dsf and Ex as well as high Dst goes with small *R*. As in paper, the flour fatty acids composition had special attention, the appropriate correlations are that high oil content (OC) is associated with small TS (TU/TS > 0, because TS content is smaller than TU content) while high TU content is associated with high protein content (so with high gluten content) and high TU causes small $\eta_{max.}$ Baking properties, i.e., holding value does not depend on oil, TS and TU contents. Better holding value is when protein content, Dsf and *R* is high and when Dst and η_{max} are small.

By cluster analysis flours are joined based on six parameters (PC, OC, ash content, GC, TS an TU content) from flour chemical composition (Fig. 1a) at a distance level of 2.2 while they are joined based on six parameters (WA, Dst, Dsf, *R* Ex and η_{max}) from rheological properties (Fig. 1b) at a distance level of approximately 100. In the present case, white and brown rice flours are joined with wheat flour at a distance level of 7.3 and 330, based on chemical composition and rheological properties, respectively. Cluster analysis shows the same similarity of wheat–white and wheat–brown mixture to wheat flour.

Conclusion

Wheat–rice flour mixture has better fatty acids composition with higher content of stearic, arachidic, lignoceric, oleic,

Table 5 Correlation matrix for the flour parameters obtained for data of three flours (wheat flour, wheat-white and wheat-brown rice flour mixture) and three determinations ($N = 9$)

	PC	OC	GC	WA	DST	DSF	*R*	Ex	η_{max}	TS	TU
OC	−0.17										
GC	0.97	0.27									
WA	0.97	−0.02	0.96								
DSt	−0.64	−0.57	−0.59	−0.76							
DSf	0.88	0.29	0.83	0.94	−0.92						
R	0.78	0.44	0.72	0.88	−0.96	0.98					
Ex	0.88	−0.53	0.91	0.82	−0.26	0.60	0.47				
η_{max}	−0.91	0.41	−0.97	−0.89	0.48	−0.73	−0.60	−0.91			
TS	0.14	−0.85	−0.18	−0.03	0.66	−0.32	−0.45	0.52	−0.24		
TU	0.86	−0.59	0.89	0.78	−0.20	0.54	0.39	0.98	−0.90	0.59	
HV^1/HV^2	0.95	0.08	0.93	0.99	−0.83	0.97	0.91	0.74	−0.86	−0.14	0.71

Correlations are significant at $p \leq 0.05$

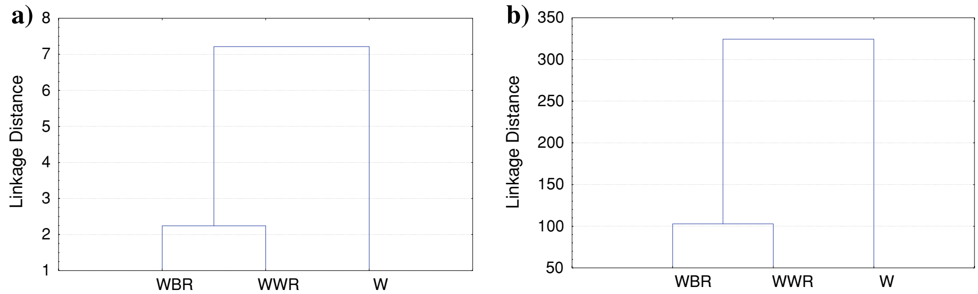

Fig. 1 Dendrogram obtained for six parameters of chemical composition (**a**) and six parameters of rheological properties (**b**), of wheat flour (*W*), wheat–white rice flour (*WWR*) and wheat–brown rice flour mixture (*WBR*)

and phthalic acids, compared to wheat flour. Also, wheat flour did not include myristic, arachidic, lignoceric and linolenic acids, so rice flour addition made fatty acids profile more rich in number of constituents, nine instead six. Rice flour addition changes rheological properties: wheat–rice flour mixture had less water absorption property, less degree of softening, longer development time and better stability than wheat flour. This flour mixture also had higher gelatinization temperature compared to wheat flour, but finally, the addition of rice to wheat flour makes the flour quality number and group better than wheat flour only. Also, the wheat–rice flour mixture had good before and after baking "holding" value, and assure good quality wheat–rice bread and cake. So, the wheat–rice flour mixture can be considered as a good quality flour and can be used for making good quality wheat–rice bread and cake.

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