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A mixture design study to determine interaction effects of wheat, buckwheat, and rice flours in an aqueous model system

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ABSTRACT

Mixture design approach was used to study effects of interactions between wheat, buckwheat and rice flours on pasting and textural properties of an aqueous model system. Each flour type had a marked effect on these properties, but their interaction effects were more remarkable on pasting properties, furthermore reversing the way of linear effects on textural properties. The results of this study revealed that buckwheat and rice flours should be used as a combination in the baking formulations when lower breakdown viscosity values are requested. It was also found that the use of rice flour with buckwheat flour as a combination increased viscosity of the flour mixture, but decreased retrogradation and syneresis rate. On the other hand, use of wheat flour in combination with buckwheat flour resulted in lower hardness, gumminess, chewiness and resilience in the flour mixture. These results revealing the interaction effects should suggest very advantageous findings for baking industry because they would have an opportunity to have a free hand in controlling these texture profile analysis (TPA) parameters in accordance with their purposes by considering these interaction results.

1. Introduction

A great amount of efforts have been recently exerted to develop gluten-free products by removal of gluten from cereal-based products, such as bread, biscuit, pasta and cake, which brings some remarkable technological challenges. These challenges are gaining desired viscoelasticity, gas holding ability and crumb structure of dough and batter in the absence of gluten which achieves all of these functions alone. Other challenges are the risks to obtain low quality, poor mouthfeel and low flavor products (Gallagher, Gormley, & Arendt, 2004). To overcome the mentioned problems, some alternative ingredients such as starches (Lopez, Pereira, & Junqueira, 2004), dairy products, gums and hydrocolloids (Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, 2007), proteins from different flour sources (Marco & Rosell, 2008) and prebiotics (Korus, Grzelak, Achremowicz, & Sabat, 2006) have been recently used to mimic its technological functions. Use of rice and buckwheat flours has recently received a great attention, in this respect (Sakač, Torbica, Sedej, & Hadnađev, 2011; Torbica, Hadnađev, & Hadnađev, 2012). However, use of such flours is limited since manufacturers still prefer to use refined, unenriched other flour sources (Gallagher, 2008).

Although some steps have recently been taken to enhance some technological properties through the introduction of pseudocereals and other nutritive flours in bread and pasta formulations, a limited number of studies have been reported on the replacement of wheat flour in cake-making (Gallagher, 2008). Furthermore, no attempt has still appeared to be done on the use of alternative flour sources like buckwheat flour in the production of cake products (Gallagher, 2008). However, in order to control effects of these mentioned alternative ingredients, it is essential to have information on their interactions in any product environment.

So far, a number of studies have been undertaken to investigate the effect of different flours on several properties of dough and final products. In such studies, effect of each flour was evaluated, independently. However, in order to reach exact results, their interaction effects should also be analyzed using a statistical tool allowing investigation of functions of the ingredients and approval of

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importance of the ingredient interactions (Arteaga, Li-Chan, Nakai, Cofrades, & Jiménez-Colmenero, 1993). Mixture design methodology is very useful in this purpose which is applied to predict response for any combination of the ingredients, to determine effects of the ingredients on the responses of each component individually and in combination with the other components and to find optimum values in order achieve targeted response values (Cornell, 2002). Therefore, the aim of the present study was to evaluate the effect of flour type (wheat, buckwheat and rice) on pasting properties of flour mixture samples and textural properties of aqueous model system gel mixture samples using the simplex lattice mixture design.

2. Material and methods

2.1. Materials and determination of proximate composition

In this study, wheat flour (*Triticum compactum*, soft wheat) was procured from Bafra Eris Flour and Feed Co., Samsun, Turkey. Buckwheat (*Fagopyrum esculentum*, originated from Ukraine) and rice flour (*Oryza sativa*, Turkey) were provided from Yar Legume, Antalya, Turkey and Aro-tech, Aro Food and Agriculture Products Trade. Inc, Izmir, Turkey, respectively. Dry matter content of the flour samples was determined by drying of samples at 105 °C for 4 h in a drying oven (FN 120,Nuve, Ankara, Turkey). Ash content was determined by incineration of the samples at 550 °C for 6 h. Protein content was determined based on the Dumas method (AOAC, 2000) using an automatic nitrogen analyzer (FP 528, Leco, USA). Final protein contents were determined by multiply of the obtained nitrogen values with 5.70.

Amylose contents of the flour samples were determined based on isolation of starch from the flour samples according to the methodology described by Wang and Wang (2004). For this purpose, 100 g from each flour sample was individually weighed and soaked in 200 ml of NaOH (0.1% w/v) for 18 h. After that, the slurries were blended using a high shear Waring blender at a high speed for 120 s and passed through a 63 mm screen. The samples were then centrifuged at 1400 g for 10 min. The supernatants were discarded and the sedimented starch samples were reslurried for two times and washed with 0.1% of NaOH and the starches were collected after final centrifugation. Finally, the starch samples were washed with distilled water and neutralized with 1.0 M hydrochloric acid to pH 6.5, followed by centrifugation. The neutralized starch samples were washed with distilled water for three times, dried at 50 °C for 24 h, grounded and passed though a sieve with 150 mm pore diameter and used for the amylose level analysis. The amylose levels of the isolated starch samples were determined according to the methodology described by Mohammadkhani, Stoddard, and Marshall (1998). For this purpose, 5 mg of each isolated starch sample was weighed into a glass tube and 1 ml of ethanol and 2.7 ml of NaOH (1 N) were added to the glass tube. Then, the samples were kept at 175 °C for 15 min to provide a complete gelatinization. The tube was then cooled, mixed on a vortex and filled with 25 ml of distilled water. Two and half ml of sample was taken from the stock solution and neutralized with 2 ml of citric acid solution (0.15% w/v) and then 1 ml of fresh iodine solution (0.2 g I_2+2 g KI +250 ml distilled water) and 14.5 ml of distilled water were added and the final samples were kept at 4 °C for 20 min. At the end, the absorbances of the samples were recorded at 620 nm using a spectrophotometer (Agilent 8443 spectrophotometer, USA). The amylose levels of the samples were determined using a calibration curve using amylose standard (Sigma Aldrich Chemical Co, Steinheim, Germany). The analyses were performed triplicate with two repetitions.

2.2. Rapid visco analyzer (RVA) measurements

Pasting properties of flour mixture (FM) samples were determined using a Rapid Visco Analyzer (Perten RVA 4500, Australia). 3 g of each FM (Table 1) sample at 14 g/100 g moisture basis was directly weighed into aluminum RVA canisters. Then, 25 mL of distilled water was added to achieve a total weight of 28 g. The formed slurry samples (aqueous flour mixture dispersion) were heated to 50 °C and stirred at 160 rpm for 10 s. Then, the samples were held at 50 °C for 1 min, and then heated up to 95 °C for 3.42 min and held at that temperature for 5 min, and cooled down to 50 °C for 6.18 min. Values measured from the pasting profile of each FM sample were peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature. Thermocline windows software was used to process the recorded data (Perten RVA 4500, Australia). All measurements were repeated three times with three replications.

2.3. Texture profile analysis (TPA)

TPA parameters of FM gels obtained from RVA experiments were determined. For this purpose, the gel samples prepared from flour mixtures in the canisters were covered with parafilm and stored at 4 °C for 24 h prior to texture profile analyses. The texture profile analysis (TPA) of gel mixtures (GM) was carried out using a texture analyzer (TAXT2i, Stable Micro Systems Ltd., Surrey, England) equipped with a load cell of 5 kg and managed by Texture Exponent Programs. A double compression cycle test was performed for the gel samples in the RVA canisters up to 25% strain compression of the original portion height using an aluminum cylinder probe (SMS P/5, 5 mm diameter) at a trigger force of 5 g at the speed of 1 mm/s. The measurements were performed in triplicate with three replications. The following parameters were quantified: Hardness (g), Gumminess (g), Chewiness (g × mm) and Resilience.

2.4. Experimental design

In the present study, the simplex lattice mixture design (SLMD) according to the procedures described by Karaman, Yilmaz, and Kayacier (2011) was used to evaluate the effect of wheat flour (X_1), buckwheat flour (X_2) and rice flour (X_3) on the pasting properties and TPA parameters of the FM and GM samples, respectively. Component proportions were expressed as fractions of the mixture with a sum ($X_1 + X_2 + X_3$) of one. The factors, levels and

Table 1
Components of flour mixture (FM) samples[a] prepared according to simplex lattice mixture design.

Mixtures	Coded values			Uncoded values (ingredient proportions)		
	X_1	X_2	X_3	Wheat flour (%)	Buckwheat flour (%)	Rice flour (%)
1	1.000	0.000	0.000	100	0	0
2	0.333	0.333	0.333	33.3	33.3	33.3
3	0.000	0.000	1.000	0	0	100
4	0.000	0.000	1.000	0	0	100
5	1.000	0.000	0.000	100	0	0
6	0.667	0.167	0.167	66.7	16.7	16.7
7	0.167	0.667	0.167	16.7	66.7	16.7
8	0.500	0.500	0.000	50	50	0
9	0.167	0.167	0.667	16.7	16.7	66.7
10	0.000	1.000	0.000	0	100	0
11	0.000	0.500	0.500	0	50	50
12	0.500	0.000	0.500	50	0	50
13	0.000	1.000	0.000	0	100	0
14	0.500	0.500	0.000	50	50	0

[a] Each FM sample was prepared based on 12 g of flour plus 100 g of water.