Gluten-Free Bread Production by the Corn Meal and Soybean Flour Extruded Blend Usage

Duška ĆURIĆ (✉)
Dubravka NOVOTNI
Dubravka TUŠAK
Ingrid BAUMAN
Domagoj GABRIĆ

Summary

The most common disease caused by cereal protein ingestion is celiac disease. This can be treated only by a diet that excludes all foods containing wheat, barley, rye and oat proteins. Corn meal (CM) and defatted soybean flour (DSF) blend processed by High Temperature Short Time (HTST) extrusion cooking for gluten-free bread production was investigated. Corn meal and soybean flour were extruded in three different proportions (w/w): 100 CM / 0 DSF; 87.5 CM / 12.5 DSF; 75 CM / 25 DSF. After milling extruded flour blends were combined in a 1:1 mixture with rice flour for gluten-free bread making. Rheological properties of dough (viscosity and water absorption), baking characteristics, dough and bread yield, were investigated with or without different hydrocolloids addition. Protein content and sensory properties of the gluten-free breads were determined. Bread produced with extruded blend of 75 CM / 25 DSF with addition of guar gum had the biggest volume, the best crumb elasticity, softness and porosity. All bread samples made of extruded flours had high protein content (more than 10% db) and good sensory properties.

Key words

gluten-free bread, rice, corn extrudate, hydrocolloid; dough rheology

University of Zagreb, Faculty of Food Technology and Biotechnology
Pierottijeva 6, 10000 Zagreb, Croatia
✉ e-mail: dcuric@pbf.hr

Received: December 14, 2006 | Accepted: March 19, 2007

Introduction

Coeliac disease is a chronic disorder resulting from an immune reaction to certain cereal proteins. Most toxic for coeliacs are wheat proteins: α-, β- and γ– gliadin, low molecular weight and high molecular weight glutenins, but secalin from rye, hordein from barley and avenin from oat may also be problematic (Skerritt et al. 1990). In untreated coeliac disease the lining of the small intestine is damaged. The villi, which line the inside of the bowel, are flattened and their normal function to break down and absorb nutrients is depleted. This leads to deficiencies in vitamins, minerals and sometimes proteins, carbohydrates and fats. The only effective treatment of coeliac disease is a strict lifelong gluten-free diet. In Croatia, as well in Europe, about 1% of population is affected by coeliac disease. In recent years the demand for gluten-free products has been on the rise; and so interest in gluten-free bread production is growing. Currently starch, dairy proteins and hydrocolloids are added to naturally gluten-free flour (such as rice and/or corn flour) to mimic viscoelastic properties of gluten and to improve structure, sensory attributes and shelf-life (Ylimaki et al. 1991; Sanchez et al. 2002; Gallagher et al. 2003a; Gallagher et al. 2003b; Gallagher et al. 2004; Sivaramakrishnan et al. 2004; Ahlborn et al. 2005; McCarthy et al. 2005; Schober et al. 2005; Lazaridou et al. 2006; Moore et al. 2006). Various hydrocolloids such as hydroxypropylmethyl-cellulose, methyl-cellulose, carboxymethyl-cellulose, locust bean gum, guar gum, xanthan, pectin, and β-glucan for gluten-free bread quality improvement have been studied (Lazaridou et al. 2006). The effect of enzymes such as transglutaminase (Moore et al. 2006) and lipoxygenase (Ribotta et al. 2004) on gluten-free bread quality also has been studied. Soybean proteins and soybean flour have been used for fortification of bakery products to improve their protein quality, mechanical behaviour and storage life of bread (Sanhez et al. 2004; Mohamed et al. 2006).

The aim of this study was to determine the whether starch could be replaced with corn meal or corn meal/soyflour extrudates in gluten-free bread formulation. The effect of xanthan, guar gum, pectin and cellulose addition on gluten-free dough rheology and bread appearance was also investigated.

Materials and methods

Long grain rice (Sunstar overseas LTD, India) was milled and sieved; obtained flour had moisture content 10.8% and protein content 7.3%. Corn starch was obtained from the market (Agrana Starke GmbH, Austria). Extruded corn meal (ECM) and extruded blends of corn meal (CM) and defatted soybean flour (DSF) were purchased from Naše klasje, Croatia. ECM had 11.9% moisture content and 8.1% of proteins; extruded blend of CM and DSF (87.5: 12.5 w/w) (Blend 1) had 8.9% moisture and 11.6% of proteins; and extruded blend of CM and DSF (75: 25 w/w) (Blend 2) had 8.8% moisture and 16.1% of proteins. Other ingredients used in bread formulation were skimmed milk powder (Sirela d.d., Croatia); sodium caseinate (Danisco Ingredients, Denmark); sunflower oil (Zvijezda d.d., Croatia); monoglyceride Dimodan 100/B (Danisco Ingredients, Denmark); sugar (Viro tvornica šećera d.d., Croatia); salt (Solana d.d., Tuzla); fresh yeast *Saccharomyces cerevisiae* (Kvasac d.o.o., Croatia); and hydrocolloids: xanthan, Satiaxane CX-911 (Degussa Texturant Systems, Germany); guar gum, Emulcoll (Degussa Texturant Systems, Germany); pectin, Grinsted LA 410 (Danisco Ingredients, Denmark); and microcrystalline cellulose, Avicel (FMC BioPolymer, Ireland).

Dough rheology

Viscosity of flours, extruded blends and their mixtures with sodium caseinate and hydrocolloids addition was determined in accordance to ICC Standard Method No. 126/1 by MicroViscoAmylograph (Brabender, Germany). The suspension of flour or extrudate (10 g) in water (105 ml) was heated on 93 ^{o}C at the heating rate 7.5 ^{o}C/min and cooled down to 50°C.

The water absorption and the effect of different hydrocolloids on dough rheology was investigated by a farinograph (Brabender, Germany) according to ICC-Standard Method No.115/1. A rice flour sample (100 g) with addition of corn starch, extruded CM, extruded Blend 1 or 2 (100 g), sodium caseinate (4 g) and supplemented with 1, 2 and 3% xanthan, guar gum, pectin or cellulose was used.

Laboratory baking

For laboratory bread making rice flour was mixed with corn starch (Standard sample), extruded corn flour (Sample 1), Blend 1 (Sample 3) or Blend 2 (Sample 2) in proportion 1:1 (w/w). First, milk powder, hydrocolloid, oil, emulsifier, sugar, salt and half of the water were mixed at speed 2 for 30 seconds by a mixer (Supermix 200, Moulinex, France). The obtained cream was mixed with the rice flour, starch or extrudates and the rest of the water with dispersed yeast in farinograph kneader at 120 rpm for 3 min at 30 °C. The dough was divided into pieces (80 g), put in bread pan and proofed in a cabinet at 33 °C and 80% humidity for 75 min. Breads were baked at 210 °C for 20 min after short steaming. Four replicates of bread samples were made.

Bread volume (cm^3) was determined 60 min after baking by millet-seed displacement method. Dough yield (%) (dough mass expressed in g, prepared from 100 g of raw materials) and bread volume yield (%) (bread volume in cm^3 obtained from 100 g of raw materials) were calculated (Ćurić et al. 2002).

Chemical and sensory analysis

Moisture content of the final products was determined following the ICC Standard Method No. 110/1, and protein content was determined by Kjeldahl procedure (ICC Standard Method No. 105/2). The conversion factor of nitrogen to protein was 6.25 for all samples. All the used chemicals were of analytical reagent grade.

Breads were sensory evaluated by panel of five individuals. The parameters were evaluated as recommended by Pyler (1973). The maximum scores for each parameter were: volume 15, crust 15, texture 15, colour 10, crumb grain 10, aroma 15, and taste 20.

Results and discussion

The determined viscosity of raw materials is shown in Figures 1-2. The viscosity of extruded materials was low as expected but increasing in cooling period which indicated good water binding capacity in bread baking. As the amylolitic activity of the flours was low it was important to have higher concentration of fermentable sugars in the formulation.

The farinograph curve obtained for the pure rice flour used in this study has shown the water absorption of 60% and it was not possible to obtain consistency of 500 BU. The farinograph curve of rice flour was improved by corn starch addition (standard sample) as indicated in Figure 3. Furthermore, the hydrocolloids addition improved the water absorption and rheological properties. The best results were obtained by adding hydrocolloids to a level of

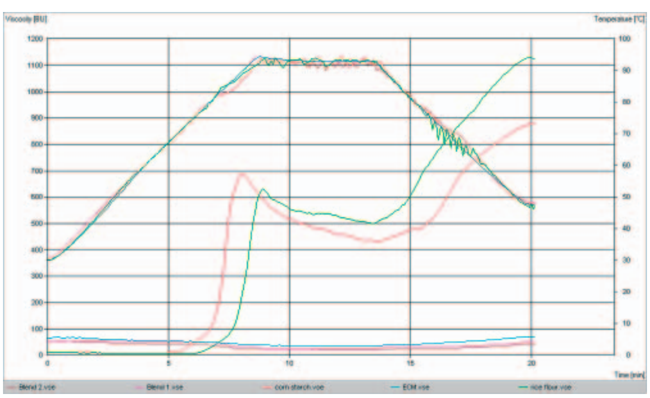

Figure 1. Viscosity of raw materials (MicroViscoAmylograph, Brabender)

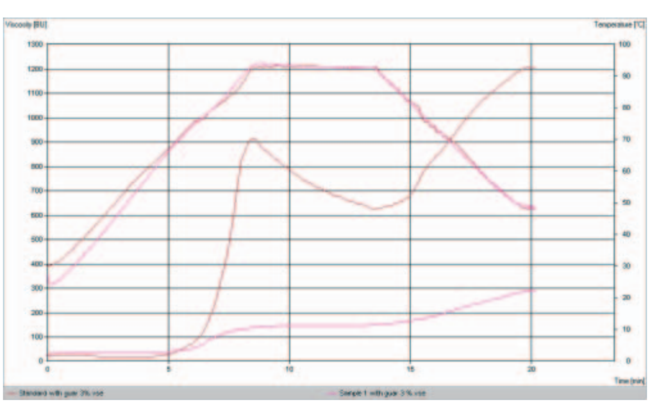

Figure 2. Viscosity of standard and sample 1 with guar gum addition (3%)

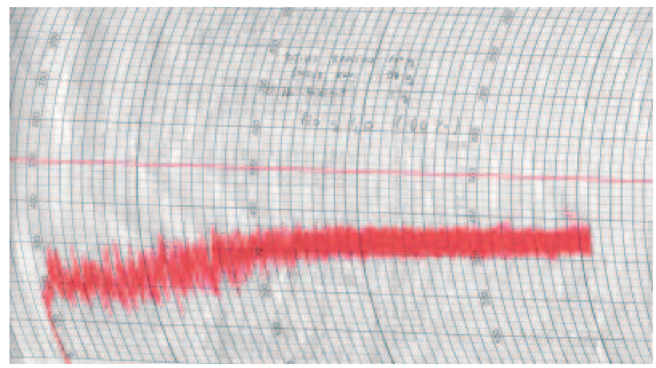

Figure 3. Farinograph curve of standard sample (rice flour, 100 g; corn starch, 98 g; sodium caseinate, 2 g; water, 120 g)

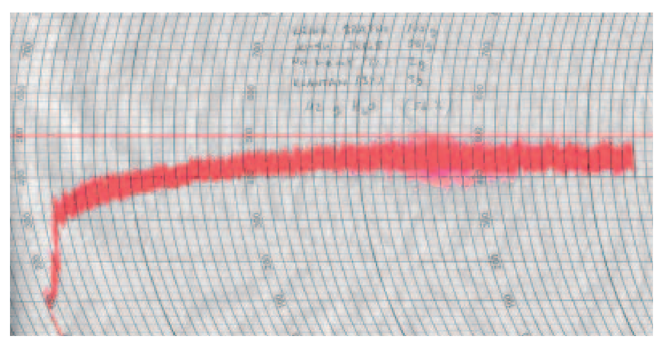

Figure 4. Farinograph curve of standard sample with xanthan addition (3%); water absorption 56%

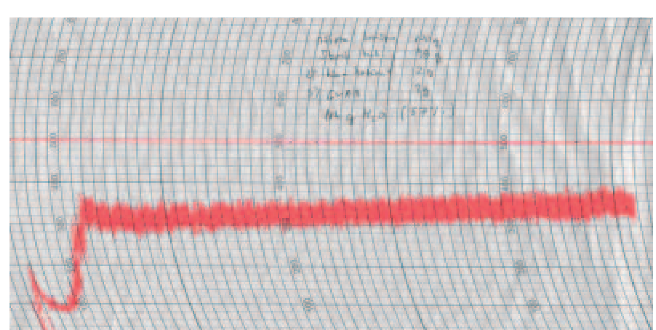

Figure 5. Farinograph curve of standard sample with guar gum addition (3%) water absorption 57%

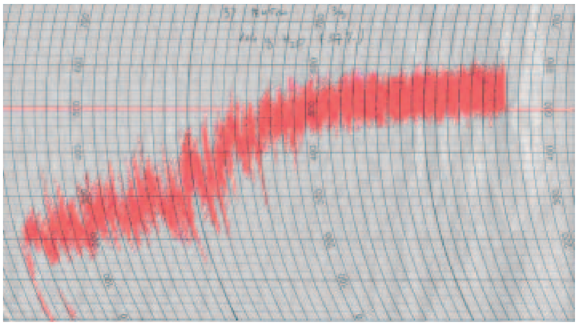

Figure 6. Farinograph curve of standard sample with pectin addition (3%); water absorption 57%

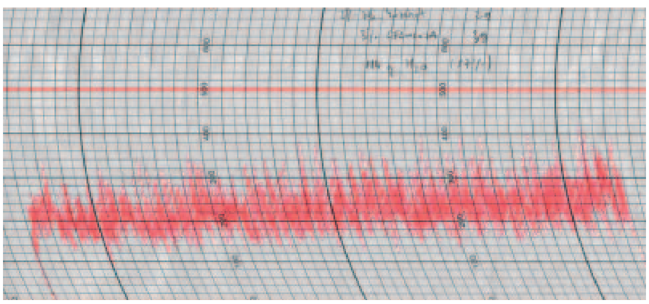

Figure 7. Farinograph curve of standard sample with cellulose addition (3%); water absorption 57%

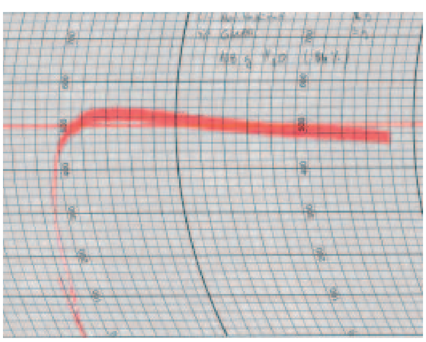

Figure 8. Farinograph curve of sample 1 with guar gum addition (3%); water absorption 84%

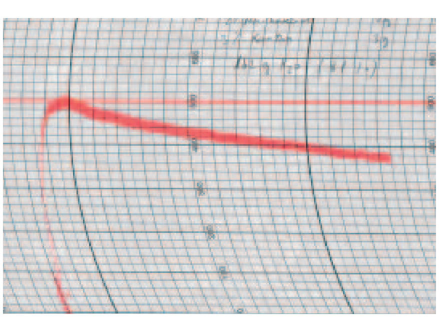

Figure 9. Farinograph curve of sample 1 with xanthan addition (3%); water absorption 81%

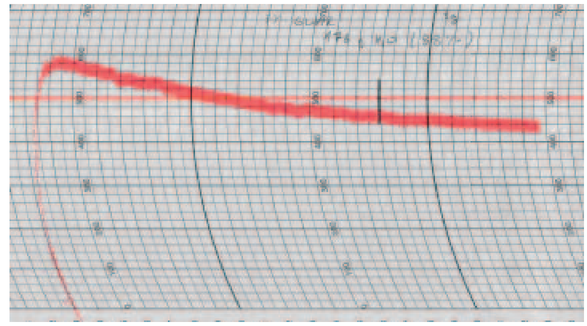

Figure 10. Farinograph curve of sample 2 with guar gum addition (3%); water absorption 88%

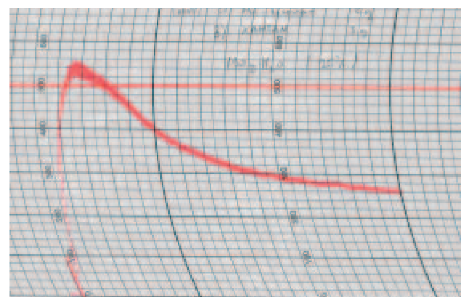

Figure 11. Farinograph curve of sample 2 with xanthan addition (3%); water absorption 95%

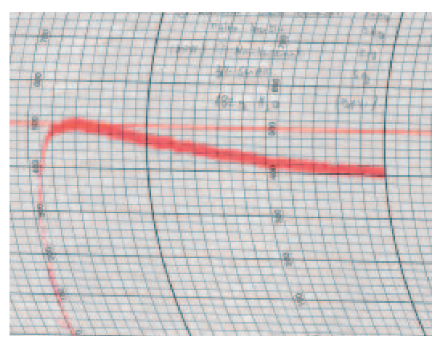

Figure 12. Farinograph curve of sample 3 with guar gum addition (3%); water absorption 91%

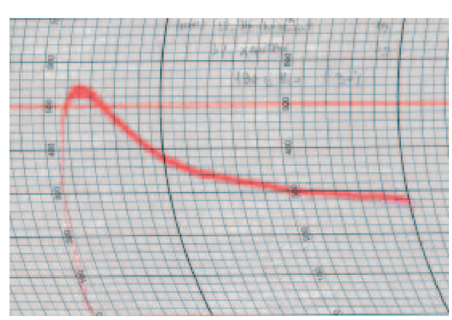

Figure 13. Farinograph curve of sample 3 with xanthan addition (3%); water absorption 90%

Table 1. Dough and bread yield with xanthan addition (3%)

Parameter	Standard	Sample 1	Sample 2
Dough yield, %	190.2	195.3	198.3
Bread yield, %	149.8	166.7	169.3
Volume yield, cm^3/100 g	232.0	250.2	265.5

Table 2. Dough and bread yield with guar gum addition (3%)

Parameter	Standard	Sample 1	Sample 2	Sample 3
Dough yield, %	181.9	200.8	205.6	205.6
Bread yield, %	154.1	169.4	171.7	172.2
Volume yield, cm^3/100 g	241.7	294.9	353.8	344.5

Table 3. Sensory evaluation of breads with guar gum addition (3%)

Parameter	Standard	Sample 1	Sample 2	Sample 3
Volume	8	11	15	13
Crust	15	14	13	10
Colour	10	10	10	10
Crumb grain	10	10	10	10
Texture	12	14	15	13
Aroma	13	15	12	14
Taste	15	20	20	16
SUM (max = 100)	83	94	95	86

3% w/w rice flour. The highest water absorption of standard sample was obtained by xanthan addition (3% w/w rice flour) followed by pectin, guar gum and cellulose as it is shown in Figures 4-7. When the dough was made with corn extrudate, Blend 1 or Blend 2 instead of corn starch, the water absorption increased significantly (Figures 8-13). Blend of rice flour and corn extrudate had the best rheology with guar gum addition (3%, w/w rice flour) as indicated in Figure 8. Dough with xanthan was too firm and during mixing it was releasing the water (Figure 9). Dough with added pectin or cellulose was too sticky. The highest elasticity and the shortest development time were obtained with xanthan addition in all samples but the dough was too firm. The best improving effect of hydrocolloid incorporation was actually obtained by guar gum application as proven in bread baking.

When extruded flours were used the bread volume significantly increased. Maximum bread volume was achieved with the addition of guar gum as a hydrocolloid. Xanthan gum addition resulted in overly firm dough and low volume breads. This is in accordance with study by Lazaridou (2006). Also the porosity of those breads was non-uniform. Volume yield of breads produced with xanthan ranged from 232 to 265 cm^3/100 g (Table 1) and with guar gum from 241 to 344 cm^3/100 g of flour (Table 2).

Table 4. Sensory evaluation of breads with xanthan addition (3%)

Parameter	Standard	Sample 1	Sample 2
Volume	7	9	10
Crust	15	13	10
Crumb colour	10	10	10
Crumb grain	10	10	10
Texture	7	12	13
Aroma	13	12	10
Taste	13	16	14
SUM (max = 100)	75	82	77

Table 5. Protein content of breads produced with guar gum addition (3%)

Sample	Standard	Sample 1	Sample 2	Sample 3
Proteins (Nx6.25) g/g db	7,84	11,05	13,68	11,68

The sensory analysis of fresh breads performed by panellists for seven parameters showed the overall acceptability for all bread samples. Scores ranged from 75 to 95 out of 100 (Table 3-4). Bread sample 2 with added guar gum exhibited the best appearance in terms of structure, volume and taste, followed by sample 1 and 3, with the same hydrocolloid.

In the Table 5 the protein content of bread samples produced with guar gum addition is shown. The protein content was much higher when the extruded CM, Blend 1 and Blend 2 were used instead of corn starch. Those breads had protein content higher than 10% db.

Conclusions

All produced gluten-free breads had good sensory characteristics. Addition of hydrocolloids such as guar gum, xanthan and cellulose can improve mechanical structure of gluten-free breads. In this study, guar gum addition at 3% w/w rice flour gave the best improvement of dough rheological properties. Extruded corn meal and extruded blend of corn meal and defatted soybean flour produced significantly higher bread specific volume and bread yield. These breads had also the best sensorial attributes. Extruded corn meal or extruded blend of corn meal and soybean flour usage instead of corn starch resulted in increased bread protein content. All gluten-free breads produced with extruded materials had very high protein content, more than 10% db. Bread sample 2 made of Blend 2 and rice flour (1:1) had the highest protein content (13.68% db). Extruded corn meal and extruded blend of corn meal and defatted soybean flour can be successfully used in a high quality gluten-free bread production. Since the production process is direct and simple it could help to introduce low-cost industrialized gluten-free fresh bakery products. The optimal formulation for gluten-free bread in production conditions as described was the one made of corn meal and defatted soybean flour extruded blend and guar gum (3% w/w rice flour) demonstrated by high volume and bread yield, protein content and sensory mark.

References

Ahlborn G. J., Pike O. A., Hendrix S. B., Hess W. M., Huber C. S. (2005). Sensory, mechanical, and microscopic evaluation of staling in low-protein and gluten-free breads. Cereal Chem 82: 328-335.

Ćurić D., Đugum J., Bauman I. (2002) The influence of fungal amylase supplementation on amylolytic activity and baking quality of flour. J Food Sci Tech, 37: 673-680.

Gallagher E., Gormley T. R., Arendt E. K. (2004). Recent advances in the formulation of gluten-free cereal-based products. Trends Food Sci Tech 15: 143-152.

Gallagher E., Kunkel A., Gormley T. R., Arendt E. K. (2003a). The effect of dairy and rice powder addition on loaf and crumb characteristics, and on shelf life (intermediate and long-term) of gluten-free breads stored in a modified atmosphere. Eur Food Res Technol 218: 44-48.

Gallagher E., Gormley T. R., Arendt E. K. (2003b). Crust and crumb characteristics of gluten free breads. J Food Eng 56: 153-161.

International Association for Cereal Chemistry. ICC-Standard No 115/1 Method for using the Brabender Farinograph. Approved 1972, revised 1992.

International Association for Cereal Chemistry. ICC-Standard No 126/1 Method for using the Brabender Amylograph. Approved 1972, revised 1992.

International Association for Cereal Chemistry. ICC-Standard No 105/2 Determination of Crude Protein in Cereals and Cereals Products for Food and Feed. Approved 1972, revised 1992.

International Association for Cereal Chemistry. ICC-Standard No 110/1 Determination of the Moisture Content of Cereals and Cereal Products. Approved 1972, revised 1992.

Lazaridou A., Duta D, Papageorgiou M., Belc N., Biliaderis C. G. (2007). Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. J Food Eng. 79, 3: 1033-1047.

McCarthy D. F., Gallagher E., Gormley T. R., Schober T. J., Arendt E. K. (2005). Application of response surface methodology in the development of gluten-free bread. Cereal Chem 82: 609-615.

Mohamed, A.A., Rayas-Duarte, P., Shogren, R.L. and Sessa, D.J. (2006) Low carbohydrates bread: Formulation, processing and sensory quality. Food Chem, 99, 686-692.

Moore M. M., Heinbockel M., Dockery P., Ulmer H. M., Arendt E. K. (2006). Network formation in gluten-free bread with application of transglutaminase. Cereal Chem 83: 28-36.

Pyler E. J. (1973). Baking science and technology. Siebel Publishing Company, Chicago.

Ribotta P. D., Ausar S. F., Morcillo M. H., Perez G. T., Beltramo D. M., Leon A. E. (2004). Production of gluten-free bread using soybean flour. J Sci Food Agric 84: 1960-1974.

Sanchez H. D., Osella C. A., de la Torre M. A. (2004). Use of response surface methodology to optimize gluten-free bread fortified with soy flour and dry milk. Food Sci Technol Int 10: 5-9.

Sanchez H. D., Osella C. A., de la Torre M. A. (2002). Optimization of gluten-free bread prepared from cornstarch, rice flour, and cassava starch. J Food Sci 67: 416-419.

Schober T. J., Messerschmidt M., Bean S. R., Park S. H., Arendt E. (2005). Gluten-free bread from sorghum: quality differences among hibrids. Cereal Chem 82: 394-404.

Sivaramakrishnan H. P., Senge B., Chattopadhyay P. K. (2004). Rheological properties of rice dough for making rice bread. J Food Eng 62: 37-45.

Skerritt J., Devery J., Hill A. (1990). Gluten Intolerance: Chemistry, celiac toxicity, and detection of prolamins in food, *Cereal Foods World,* 35: 638-639.

Ylimaki G., Hawrysh Z. J., Hardin R. T., Thompson A. B. R. (1991). Response surface methodology in the development of rice flour yeast breads: sensory evaluation. J Food Sci 56: 751-755.

---

acs72_37