Effect of hydrocolloids on properties of dough and quality of gluten-free bread enriched with whey protein concentrate

Rosen Chochkov[1], Denka Zlateva[2], Mariya Dushkova[1], Silviya Topleva[1]

1 – University of Food Technologies, Plovdiv, Bulgaria
2 – University of Economics, Varna, Bulgaria

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Corresponding author:

Rosen Chochkov
E-mail:
rosen4o4kov@abv.bg

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Abstract

Introduction. The effect of hydrocolloids (xanthan gum and guar gum) on dough properties and the quality of gluten-free bread from rice and corn flour enriched with whey protein concentrate was studied.

Materials and methods. For the preparation of the whey protein concentrate it was used a laboratory system with a removable flat membrane module, equipped with a 25 kDa polyacrilonitrile ultrafiltration membrane. Dough consistency was measured by degree of immersion, using automatic penetrometer.

Results and discussion. Based on the preliminary experiments (with 5, 10 and 15 %) it was found that the optimal quantity of whey protein concentrate was 10 %. That is why for the further experimental tests 10 % whey protein concentrate was added to control sample bread. Addition of higher quantities of xanthan gum resulted in weak dough consistency. Concerning the dough consistency it can be concluded that the addition of xanthan gum results in release of the dough, regardless of the quantity used. The best result was obtained when 1.5 % guar gum was added. Maximum increase in bread volume was obtained with 1.5 % guar gum. The specific volume of bread significantly improved with hydrocolloids addition. It was found that the control sample had a lower specific volume. The samples containing hydrocolloids had larger volume than the control. The addition of 1 % xanthan gum resulted in an increase in H/ D index by 50 %, compared to the control sample. When 1.5 % guar gum was added, the highest results were obtained – the increase compared to the control sample was 100 %. Guar gum had greater influence on sensory properties of gluten-free bread from rice and corn flour than xanthan gum. Addition of 1.5 % guar gum led to the best results for almost all sensory properties (without the porosity and aftertaste). The results concerning porosity and aftertaste did not differ those obtained with the addition of 1 % guar gum. Addition of 1.5 % guar gum in formulation of gluten-free bread from rice and corn flour led to the highest volume, uniform crust and crumb color, with no rust and atypical shades. The flavor was pleasant and very well pronounced, evaluated by the panelists with 8 points, while the flavor of samples with xanthan gum had 3 points. The flavor was weaker when 1 % guar gum was used (5 points). The bread samples with guar gum were appreciated as more crisp, with a very pleasant taste and aftertaste.

Conclusions. For the production of gluten-free bread of rice and corn flour enriched with whey protein concentrate, the addition of 1.5 % guar gum is most appropriate.

Introduction

Worldwide, consumer interest for gluten-free products is increasing. According to Hill et al. [1], celiac disease is one of the most common lifelong disorders on a worldwide basis. It is an immune-mediated enteropathy triggered by the ingestion of gluten in genetically susceptible individuals and is characterized by a strong immune response to certain amino acid sequences found in the prolamin fractions of wheat, barley and rye [1, 2]. The removal of traditional food products – bread and bakery products prepared from gluten-containing crops (wheat, rye, barley, oats and triticale) from the menu of celiac disease requires them to be replaced by the other appropriate ones [3].

The demand of gluten-free products, especially bread is increasing as a result of the increase of celiac disease diagnosis at the recent stage [4]. This has encouraged extensive research for the development of gluten-free breads [5]. Production of high quality gluten-free bread is a big challenge due to the absence of gluten, which confers unique viscoelastic properties to dough. That's why bread development without gluten has involved the use of diverse ingredients and additives with the purpose of imitating the viscoelastic properties of the gluten [6, 7, 8]. The addition of hydrocolloids or gums to gluten-free bread formulations is a promising alternative.

Lazaridou et al. [9] investigated the effect of hydrocolloids on dough rheology and quality of gluten-free bread with rice flour, corn starch and sodium caseinate. Hydrocolloids added in a quantity of 1 and 2 % were pectin, carboxymethylcellulose, agarose, xanthan, and oat β-glucan. The rheological dough properties with hydrocolloids carried out by farinograph and rheometer indicated that xanthan has the strongest effect on viscoelastic properties, leading to dough strengthening. Bread volume is increased by the addition of hydrocolloids, with the exception of xanthan gum.

Xanthan is the only microbial heteropolysaccharide that has hitherto achieved large-scale industrial production (xanthan gum or gum). The extracts of exopolysaccharide from different strains grown in depth in sugars (glucose, fructose, galactose, rhamnose, xylose, maltose, sucrose, lactose), organic acids, amino acids, polyols, industrial raw materials (molasses, hydrolyzed corn starch, acids, hydrolysates) are very different – from 2.8 to 35.0 g/ dm^3 [3, 10, 11, 12]. According to some authors one of the advantages of the xanthan gum is that the quality of this bacterial product can be adjusted using different Xanthomonas strains and fermentation conditions [13]. Therefore, parameters such as temperature, pH, air flow rate, different Xanthomonas species and other sources can be used to improve xanthan gum yield and rheological properties.

Xanthan is an acidic polymer with a molecular weight of 2 – 50.106 D, containing O-glucose, O-mannose, D-glucuronic acid, acetyl groups and pyruvate in a different quantity [14, 15]. The specific structure determines his unique physical and rheological properties [10, 14, 15]: water solubility, very high viscosity at low concentrations, high pseudo plasticity, excellent heat resistance and pH stability, solubility in acids and bases, compatibility with ethanol, methanol, isopropanol and acetone (up to 50–60%), sodium alginate, starch and most salts, stability against microorganisms and enzymes (cellulases, amylases, pectinases). Xanthan has a very wide application in industry, agriculture and medicine [10, 16].

Guar gum is a substance with thickened and stabilized properties, used in various industries, mainly in the food industry. Guar gum is an exo-polysaccharide composed of manganese and mannose. Guar gum has the ability to withstand temperatures of 80 °C for 5 minutes. It is a better emulsifier because of the higher galactose content. It forms a non-ionic hydrocolloid with water. Guar gum is used as a thickening agent in food industry. It is also used as a substitute for replacing wheat flour in bakery products, because it does not contain gluten. It reduces serum cholesterol and lower blood sugar levels. Guar gum is characterized by good biological activity and is capable of acting as an anticoagulant and it also has anticancer and antiviral properties, helping to remove heavy metals from the body [17].

Numerous other fabric forming substances useful in bread-making are known in the literature. No complete data on effect of xanthan and guar gum on the dough properties and gluten-free bread quality were found.

Therefore, the aim of the present study is to investigate the effect of hydrocolloids (xanthan and guar gum) on some dough properties and the quality of gluten-free bread from rice and corn flour enriched with whey protein concentrate.

Materials and methods

Materials

Raw materials: a standard commercial rice flour with physico-chemical properties: moisture – 13.3 %, titrable acidity – 0.4 °H; a standard commercial corn flour with physico-chemical properties: moisture – 12.2 %, titrable acidity – 3.0 °H;

Additional raw materials: water, yeast, salt on requirements for composition and characteristics of the salt for food purposes, sugar, margarine, whey protein concentrate. Guar gum – E412 and xanthan gum – E415 ("KUK", Bulgaria).

Methods

Method for ultrafiltration

For the preparation of the whey protein concentrate, a laboratory system with a removable flat membrane module, equipped with a 25 kDa polyacrilonitrile ultrafiltration membrane, shown in Figure 1 [18], was used.

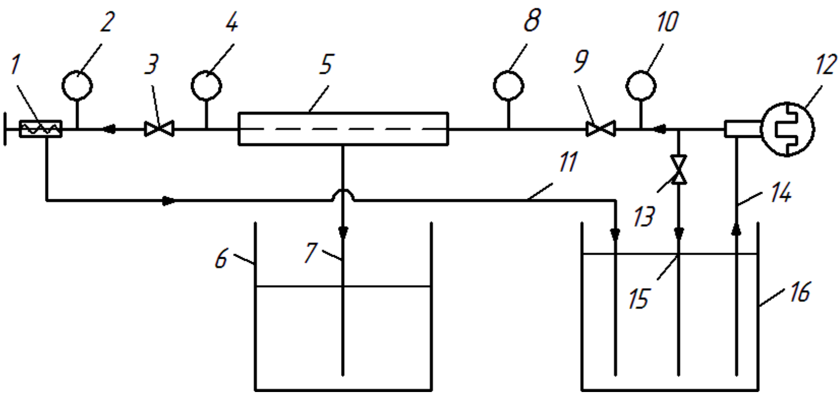

Figure 1. Scheme of a laboratory system with plate and frame membrane module:
1 – valve; 2 – manometer (0–5 MPa); 3 – valve; 4 – manometer (0–0.6 MPa);
5 – replaceable plate and frame membrane module; 6 – tank; 7 – pipeline;
8 – manometer (0–0.8 MPa); 9 – valve; 10 – manometer (0–15 MPa); 11 – pipeline;
12 – pump; 13 – valve; 14 – pipeline; 15 – pipeline; 16 – tank.

This system was equipped with: a 2500 cm² plate and frame membrane module, a high-pressure triple pump (up to 15 MPa) with a feed flow rate of 330 dm³/ h, a pipeline system with two manometers (0-15 MPa) for the inlet and outlet pressure, a special pressure regulating valve.

The ultrafiltration process was carried out with defatted whey from white brined cheese under the following operating conditions: working pressure – 0.4 MPa, working temperature – 20 °C, volume reduction factor – 6, feed flow rate of 330 dm³/h. The whey protein concentrate obtained was used to enrich gluten-free bread.

Dough and bread formulation

The bread formulation composition [19] is presented in table 1.

Table 1

Bread formulation composition

Ingredients	Samples				
	Control sample (CS)	Sample with 1 % xanthan gum	Sample with 1.5 % xanthan gum	Sample with 1 % guar gum	Sample with 1.5 % guar gum
Rice flour, g	350	350	350	350	350
Corn flour, g	150	150	150	150	150
Yeast, g	30	30	30	30	30
Salt, g	7.5	7.5	7.5	7.5	7.5
Water, cm³	350	350	350	350	350
Margarine, g	20	20	20	20	20
Sugar, g	20	20	20	20	20
Whey concentrate, g	50	50	50	50	50
Xanthan gum, g	–	5.0	7.5	–	–
Guar gum, g	–	–	–	5.0	7.5

Dough preparation is made with two phases with an initial temperature of 29 – 30 °C in kneading machine (Labomix 1000, Hungary), obtained from rice flour, water, yeast and sugar, rising time – 90 minutes. Preliminary infusion of corn flour was applied, then it was cooled and the main dough was prepared. It included 10 % whey protein concentrate, corn flour, margarine, other yeast, salt and hydrocolloids. Mix the dough to obtain a homogeneous mass. The dough rests for 40 minutes, divided and forms on a floor and form bread and final fermentation – 60 minutes at 35 °C (Tecnopast CRN 45–12, Novacel ROVIMPEX Novaledo, Italy). After the final fermentation, the pieces of dough were put into an electric oven (Salva E-25, Spain) pre-heated to 200 – 220 °C. The baking time was 24 min for form bread and 16 min for floor bread. After baking, the bread was allowed to cool down for 3 h at room temperature [19].

Methods for assessment of dough properties and bread quality

Dough consistency by degree of immersion (K_{60}), P.U. It determines the degree of immersion of a calibrated body placed in a bushing of an automatic penetrometer AP-4/2

(Germany). 40 g of dough was prepared and then divided into pieces of 13 g. Each piece of dough was placed in a bush and placed in a laboratory thermostat at 35 °C for 60 min. Then, on a penetrometer, the immersion of the body, which lasts 5 seconds, was determined automatically [19].

Loaf volume and H/D index (ratio of height to diameter) of bread. The loaf volume of bread samples was measured 180 min after the loaves were removed from the oven by the seed displacement method using bread volumeter (Sadkiewicz Instruments, Bydgoszcz, Poland) [19].

The height and diameter of the bread samples were measured in 10 replicates (at different positions of the bread samples) each by using digital caliper S301 (Hedue GmbH, Mönchengladbach, Germany), and the average values were determined. On the basis of the results the H/ D index (the ratio of height to diameter) of bread was calculated [19].

Sensory evaluation. Sensory evaluation of bread was performed according to ISO 13299:2016 "Sensory analysis. Methodology. General guidance for establishing a sensory profile" [20]. The terms and definitions given in ISO 5492:2008 [21] were applied. Sensory properties of bread were evaluated by a trained sensory panel consisted of 10 panelists (22 – 43 years old), who evaluated the bread's quality. Sensory analysis of bread was performed 3 h after the loaves were removed from the oven. Panelists were asked to evaluate the following indicators: volume, crust color, crumb color, odor, mastication, porosity, taste and aftertaste. The following conditions were provided: controlled preparation and presentation of the samples, comfortable conditions for consuming the products and for questioning the panelists, and absence of communication (verbal and non-verbal) between them, guaranteeing independent responses. The samples were sliced (slices about 1.5 cm thick) and served in white plates with codes. Plain water was used for mouth rinsing before and after each sample testing. The experimental data were statistically processed using the SPSS statistical package version 17.

Results and discussion

Based on the preliminary experiments (with 5, 10 and 15 %) it was found that the optimal quantity of whey protein concentrate was 10 %. That is why for the further experimental tests 10 % whey protein concentrate was added to control sample bread.

When wheat flour is used, the gluten structure makes it possible to attach all the components to the dough, retaining a portion of CO_2 that ensures stability of the system. With gluten-free products, instability of the system and impossibility of gas retention is observed. Gluten-free types of flour cannot participate in a baking process alone, due to the fact that a loose, unrelated and insufficiently developed structure of crumb is produced. For this purpose, hydrocolloids (xanthan and guar gum) should be used. According to Ferrero et al. [17] hydrocolloids can positively or negatively modify dough rheology, which depends on their structure, concentration and the interactions with other components.

Effect of hydrocolloids (xanthan gum and guar gum) on dough consistency

The effect of hydrocolloid addition on dough consistence is summarized in Figure 2. When the difference between the experimentally determined results before and after resting increased, the consistency of the dough was weaker.

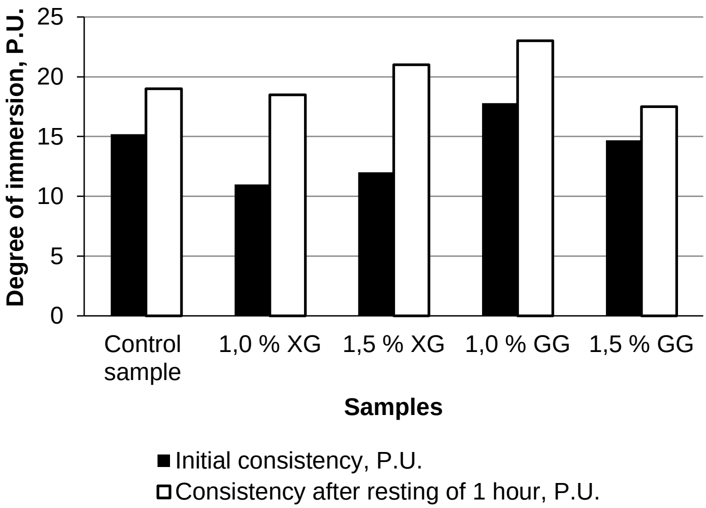

Figure 2. Effect of hydrocolloids on the degree of immersion in rice and corn flour dough enriched with whey protein concentrate

The initial dough consistency of the control sample is 15 P.U. and after resting (1 hour) it changed insignificantly, reaching 19 P.U. Li & Nie [22] point out that those hydrocolloids were used in gluten-free breads to improve dough handling properties and to enhance the quality of bread. They were capable of controlling the rheology and texture of aqueous systems throughout the stabilization of emulsions, foams and suspensions. The initial immersion of dough with the addition of 1.0 and 1.5% xanthan gum (xanthan gum) did not differ significantly compared to the control sample – results 11 P.U. and 12 P.U. After resting (1 hour), the immersion rate of the samples with xanthan gum changed, more significantly by addition of 1.5% (9 P.U.). It was found that the addition of higher quantities of xanthan gum resulted in weak dough consistency. This is probably due to poorly formed bonds on the part of the added hydrocolloid, which results in insufficient bonding of the dough structure.

The initial consistency of dough was significantly higher than the control sample by addition of guar gum (1.0 %). Upon addition of 1.5 % guar gum, the slightest change in the immersion rate (2.8 P.U.) was achieved. This reveals better structural properties and dough consistency. Capriles & Areas [23] point out, that some hydrocolloids (including guar gum) improved dough development and gas retention through an increase in viscosity, producing gluten-free breads with higher baking and quality properties. Demirkesen et al. [6] also reported that the inclusion of guar gum into rice bread formulation led to increased visco-elastic moduli of dough.

It can be concluded that the incorporation of xanthan gum results in release of the dough, regardless of the quantity used. The best dough consistency was obtained with the addition of 1.5% guar gum.

Effect of hydrocolloids (xanthan gum and guar gum) on bread volume and H/D index

The effect of hydrocolloids on bread volume is shown in Figure 3.

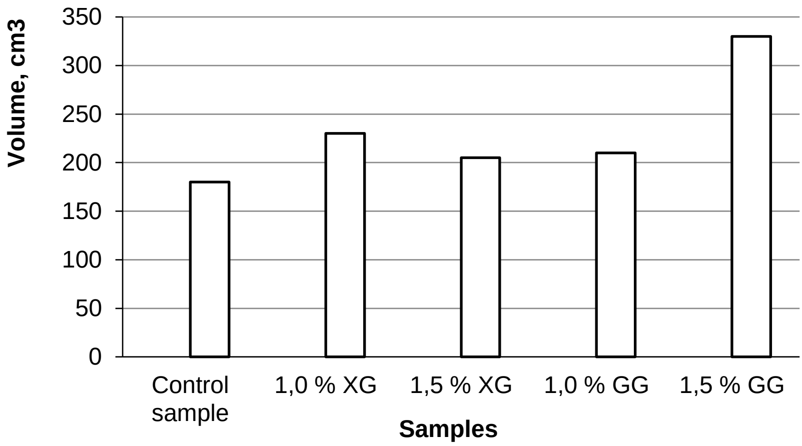

Figure 3. Effect of hydrocolloids on the volume of gluten-free bread made of rice and corn flour enriched with whey protein concentrate

The specific volume of bread significantly improved with hydrocolloids addition. It was found (fig. 3) that the control sample had a lower specific volume. The samples containing hydrocolloids had larger volume than the control. The control sample volume was 180 cm^3. Addition of 1% xanthan gum resulted in an increased volume by 29.7% compared to the control sample. Increasing of the quantity hydrocolloid, bread volume decreased. Experimental results for samples containing 1.5% xanthan gum and 1.0% guar gum were almost identical. Most significant increase in bread volume was obtained with 1.5% guar gum – by 75% compared to the control sample. These results are supported by those obtained by other authors. Ferrero et al. [17] also reported an improving of bread volume and crumb porosity due to the use of hydrocolloids in bread formulation. Hejrani et al. [24] investigated the specific volume of bread samples prepared with the addition of 0.4% and 0.8% of guar gum and xanthan gum respectively. It was found, that the samples containing hydrocolloids had greater volume. Gambus et al. reported that all loaves with xanthan gum displayed better volume in comparison to standard sample [25].

The results obtained for H/D index of gluten-free bread enriched with whey protein concentrate and hydrocolloids are presented in Figure 4.

From the results obtained for H/D index of gluten-free bread enriched with whey protein concentrate with hydrocolloids, the data presented above were confirmed. The addition of hydrocolloids changes the viscoelastic properties of dough and gives additional strength to the gas cells which leads to increased gas retention. The addition of 1% xanthan gum resulted in an increase in H/D index by 50%, compared to the control sample. When 1.5% guar gum was added, the highest result was obtained – the increase compared to the control sample was 100%.

Effect of hydrocolloids (xanthan gum and guar gum) on sensory properties of gluten-free bread

Sensory evaluation of gluten-free bread samples made of rice and corn flour enriched with whey protein concentrate containing different quantities of guar gum and xanthan gum was performed by 10 trained panelists (Figure 5).

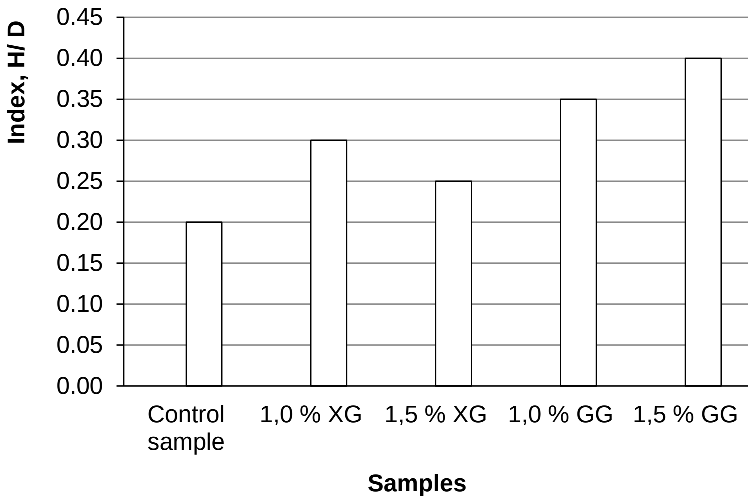

Figure 4. Effect of hydrocolloids on H/D index of gluten-free bread made of rice and corn flour enriched with whey protein concentrate

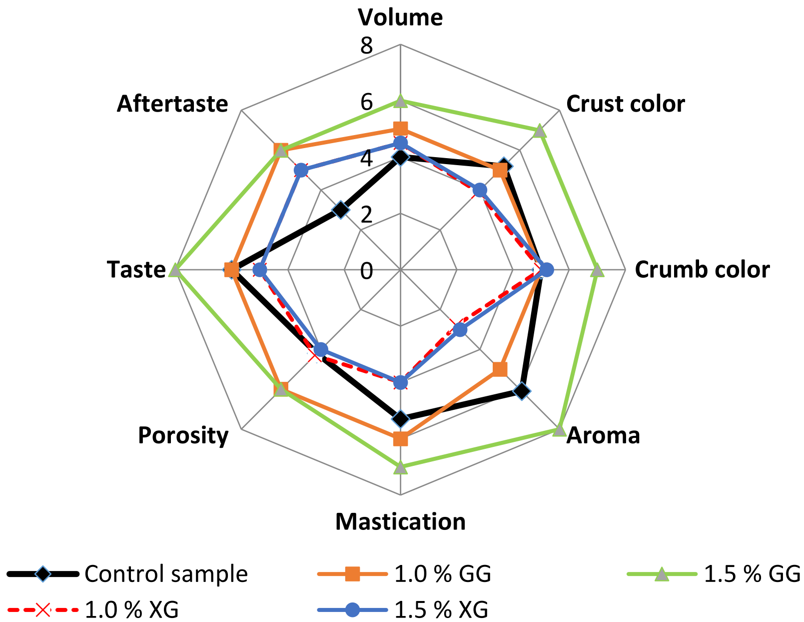

Figure 5. Effect of hydrocolloids on the sensory profile of gluten-free bread made of rice and corn flour enriched with whey protein concentrate

There was a positive effect of hydrocolloids on all sensory indicators. Guar gum had greater influence on sensory properties of gluten-free bread from rice and corn flour than xanthan gum. The addition of xanthan gum and guar gum increased bread volume, compared to the control sample. The most significant effect was obtained with the addition of 1.5% guar gum. Addition of 1.5% xanthan gum led to the most unsatisfactory results. For most of the indicators, points judged by the panelists were lower than those for the control sample and the samples with guar gum. Addition of 1.5% guar gum in formulation of gluten-free bread from rice and corn flour led to the highest volume, uniform crust and crumb color, with no rust and atypical shades. According to Sabanis et Tzia sensory evaluation by a trained panel revealed a preference for bread containing 1.5% hydroxypropylmethylcellulose because of its loaf volume, appearance and firmness characteristics [26]. The flavor was pleasant and very well pronounced, evaluated by the panelists with 8 points, while the flavor of samples with xanthan gum had 3 points. The flavor was weaker when 1% guar gum was used (5 points). The bread samples with guar gum were appreciated as more crisp, with a very pleasant taste and aftertaste. It was concluded, that the use of guar gum increased sensory score of the samples, as the improvement in properties being more pronounced when 1.5% hydrocolloid was used. Gambus et al. also reported that the use of guar gum and pectin mixture in 1:1 ratio reduce gumminess and chewiness of guar bread and too high crispiness and low resilience of pectin bread [27]. Only two indicators make an exception – the results concerning porosity and aftertaste did not differ those obtained with the addition of 1% guar gum.

Gambus et al. reported that irrespective of the share of xanthan gum, its addition to the dough led to better cohesiveness of bread on the day of baking. For these authors' higher quantities of xanthan gum in mixture of hydrocolloids decreased bread hardness on the day of baking and after 72 hours of storage [25].

Conclusion

Results obtained from this study reveal that the use of hydrocolloids in gluten-free bread formulation is appropriate. The addition of xanthan gum resulted in the dough being released, regardless of the quantity used. When 1.5% guar gum was added, an optimal dough consistency is achieved. When using 1.5% guar gum, the highest results for bread volume and H/D index were obtained. With regard to the sensory evaluation, samples prepared with GG in quantities of 1.0 and 1.5% were considered by the panelists as more crisp and obtained higher grades for taste and aftertaste. Most unsatisfactory were the results for sensory quality of bread prepared with 1.5% xanthan gum – uneven crust color, less pronounced aroma and taste, poor mastication, under-developed porosity. As a result of the research carried out, it was found that for the production of gluten-free bread of rice and corn flour enriched with whey protein concentrate, the addition of 1.5% guar gum is most appropriate.

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