



# Influence of tara gum and xanthan gum on rheological and textural properties of starch-based gluten-free dough and bread

Julio Vidaurre-Ruiz<sup>1</sup> · Shessira Matheus-Diaz<sup>2</sup> · Francisco Salas-Valerio<sup>2</sup> · Gabriela Barraza-Jauregui<sup>3</sup> · Regine Schoenlechner<sup>4</sup> · Ritva Repo-Carrasco-Valencia<sup>2</sup>

Received: 31 October 2018 / Revised: 18 January 2019 / Accepted: 9 February 2019 / Published online: 26 February 2019  
© The Author(s) 2019

## Abstract

The aim of this research was to determine the influence of tara gum and xanthan gum on rheological and textural properties of gluten-free doughs and breads made from corn starch and potato starch. Four formulations were developed: corn starch with xanthan gum (CS-XG), corn starch with tara gum (CS-TG), potato starch with xanthan gum (PS-XG) and potato starch with tara gum (PS-TG) (XG and TG—0.5% of flour). Rheological and textural properties of doughs were evaluated, as well as specific volume, alveolar structure and texture profile of breads. The results showed that the addition of tara gum increased pasting properties of the potato starch formulation, however, in the corn starch formulations, it was not significantly different from xanthan gum addition. All formulations showed more elastic than viscous behavior ( $G' > G''$ ) and these viscoelastic properties had an influence on the kinetics of dough growth during the leavening process. The formulation PS-XG presented high specific volume, low crumb hardness, and good crumb structure, while the PS-TG showed inferior properties. In contrast, in the corn starch formulations, CS-XG and CS-TG presented very similar physical characteristics. The application of tara gum in gluten-free breads is reported for the first time and depending on the starch used it showed desirable properties for obtaining good quality products.

**Keywords** Gluten-free bread · Tara gum · Xanthan gum · Celiac disease · Starches

## Introduction

Celiac disease is defined as an autoimmune enteropathy triggered in genetically predisposed individuals by the ingestion of peptides from gluten and other homologous proteins found in wheat, barley, and rye [1, 2]. The intake of gluten by celiac patients causes lesions in the epithelium of the

small intestine leading to malabsorption of most nutrients [3]. Statistics show that approximately 1% of the world population suffers from this disease [2] and this prevalence of celiac disease is increasing [1]. Although in Peru there are no official reports of the number of celiacs, existence of celiac disease persons is evident and are associated in the “Asociación de Celiacos y Sensibles al Gluten del Perú”. In addition, an increase of gluten-free products for sale in major supermarkets can be observed.

Research on gluten-free bread (GFB) has increased in the last 10 years, with the aim to improve the nutritional and sensory quality aspects of bakery products [2–4]. Due to the absence of gluten, GFB cannot trap leavening gas, resulting in low bread volume, crumbly texture, and high crumb hardness [3]. Consequently, various ingredients and additives are being studied to mimic the viscoelastic properties of gluten to obtain good quality bread products. Starch is the main ingredient in gluten-free breads, and both potato starch and corn starch are commercially available raw materials in Peru. Hydrocolloids are an alternative to increasing the viscosity of doughs and could form sufficiently strong

✉ Regine Schoenlechner  
regine.schoenlechner@boku.ac.at

<sup>1</sup> Programa Doctoral en Ciencia de Alimentos, Universidad Nacional Agraria La Molina, Av. La Molina s/n Lima 12, Lima, Perú

<sup>2</sup> Facultad de Industrias Alimentarias, Universidad Nacional Agraria La Molina, Av. La Molina s/n Lima 12, Lima, Perú

<sup>3</sup> Escuela de Ingeniería Agroindustrial, Facultad de Ciencias Agropecuarias, Universidad Nacional de Trujillo, Trujillo, Perú

<sup>4</sup> Department of Food Science and Technology, University of Natural Resources and Life Sciences, 18 Muthgasse, 1190 Vienna, Austria

emulsions to avoid the collapse of the bread structure. The most used hydrocolloids in the development of gluten-free breads are xanthan gum (XG) and hydroxy-propyl-methyl cellulose (HPMC) [5–7].

XG is an extracellular heteropolysaccharide of high molecular weight (~1000 kDa) secreted by the microorganism *Xanthomonas campestris* [8]. It consists of repeating units of D-glucose, linked to form the  $\beta$ -1,4-D-glucan cellulosic backbone [5]. Recent studies indicate that consumers prefer more natural ingredients and they associate these hydrocolloids as artificial [8]. Hydrocolloids from seeds such as guar gum, locust bean gum and tara gum are potential alternatives for the manufacture of gluten-free breads. These gums are constituted by galactomannans and are energy reserve polysaccharides in endosperm leguminous plant seeds [9]. Tara gum also has a high molecular weight (1000 kDa) [10], consisting in a linear main chain of (1–4)- $\beta$ -D-mannopyranose units attached by (1–6) linkage with  $\alpha$ -D-galactopyranose units; with ratio 3:1 of mannose to galactose [11]. According to some studies [12, 13], the addition of guar gum significantly increases specific volume of bread leading to lower crumb hardness; however, there is less information about locust bean gum and to our best knowledge no information on tara gum in gluten-free bread formulation. Tara gum is a hydrocolloid indigenous to Peru [11] and it is being used as a thickener and stabilizer in different semiliquid products, due to its solubility in cold water and stability at high temperatures. Therefore, it is interesting to investigate the potential of this hydrocolloid for use in local production of gluten-free breads. The objective of this research was to evaluate the influence of tara gum compared to xanthan gum on the rheological and textural properties of gluten-free model doughs and breads, based on corn starch and potato starch.

## Materials and methods

### Materials

Corn starch (ARO®), potato starch (ARO®), salt (Lobos®), soy oil (Primor®), white sugar (Cartabio®) and dry yeast (*Saccharomyces cerevisiae*) (Fleischmann®) were purchased from a local supermarket (Lima, Peru). Xanthan gum was supplied by Frutaron®, Peru, and tara gum was provided by Molinos Asociados SAC.

### Dough and bread preparation

Four formulations were developed to evaluate the effect of two types of gums with two different starches. The treatments were: corn starch with tara gum (CS-TG), corn starch with xanthan gum (CS-XG), potato starch with tara gum

(PS-TG) and potato starch with xanthan gum (PS-XG) as shown in Table 1.

The ingredients were calculated based on starch weight (500 g). Dry ingredients such as starch, gum, and salt were mixed for 1 min at low speed in a planetary mixer (KMX93, Kenwood). Yeast was previously dissolved in water and mixed with sugar. Then, water and soy oil were incorporated into the bowl and mixed for another 3 min at high speed. Three hundred grams of the resultant batter were poured into an aluminum cup, fermented for 30 min in a cabinet at 30 °C and 80% humidity (Climacell EVO 111, German) and baked at 170 °C for 55 min (Oster® Gourmet Collection, Peru). After baking, gluten-free bread samples were allowed to cool at room temperature for 2 h.

## Dough rheological measurements

### Viscoelastic properties of the dough

Viscoelastic properties of the dough were measured at 25 °C using a controlled strain rheometer (Haake Mars 60, Thermo Fisher Scientific, Germany) equipped with a system of parallel plates (diameter 35 mm, gap 2 mm). Dough samples were prepared according to the formulations given in Table 1 without adding yeast.

First, a strain sweep test was performed with a stress range of 0.1–100 Pa at a constant frequency of 1 Hz to identify the linear viscoelastic region. On the basis of the results obtained, 0.1% strain was selected and the frequency sweep tests were carried out at the range of 0.1 to 10 Hz [14]. Experimental data were described by the power law model:

$$G'(\omega) = K' \cdot \omega^{n'}$$

$$G''(\omega) = K'' \cdot \omega^{n''}$$

where  $\omega$  is the frequency (Hz),  $K'$ ,  $K''$ ,  $n'$ ,  $n''$  are the experimental constants,  $G'$  is the storage modulus and  $G''$  is the loss modulus. The ratio of viscous to elastic behavior (Tan

**Table 1** Gluten-free bread formulations

Ingredient (% four/ starch base)	CS-XG	CS-TG	PS-XG	PS-TG
Corn starch	100	100	0	0
Potato starch	0	0	100	100
Yeast	3	3	3	3
Sugar	3	3	3	3
Salt	2	2	2	2
Soy oil	6	6	6	6
Xanthan gum	0.5	–	0.5	–
Tara gum	–	0.5	–	0.5
Water	75	75	75	75

$\delta = G''/G'$ ) was also determined according to Tunç and Kahyaoglu [15]. All rheological experiments were performed in triplicate.

### Leavening properties

Leavening properties of the four doughs were examined by Image Analysis following the procedure described by Conte, Del Caro, Balestra, Piga, & Fadda, (2018) with some modifications. Immediately after mixing, a portion of dough was molded into a hollow cylinder ( $\varnothing$  2.7 cm) in the middle of a Petri dish and leavened in a climate chamber at 30 °C and 90% RH for 60 min. Every 10 min, three Petri dishes were scanned at 300 dpi with a scanner (Canon MG3610, Japan). The increase of dough diameter ( $D_t$ ) was analyzed using ImageJ 1.51j8 software (National Institutes of Health, USA) and modeled using Gompertz equation:

$$D_t = D_0 + C \cdot \exp(-\exp(-V_{\max} \cdot (t - X))),$$

where  $D_0$  is the initial diameter,  $C$  represents the asymptotic amount of increase that occurs as  $t$  increases indefinitely,  $V_{\max}$  is the maximum diameter growth rate and  $X$  is the time at which the absolute growth rate is a maximum.

### Pasting properties of formulations

Pasting properties of the four formulations (without yeast) were analyzed using a hybrid rheometer (HR-3, TA Instruments, USA). The test was performed in excess water. Approximately 2.8 to 3 g of samples were weighed and dissolved in 25 to 25.2 mL of water, according to the correction of sample weights and water volume of AACC method (76–21) [16]. The sample was initially stirred at 160 rpm for 2 min at 50 °C, then heated to 95 °C at the rate of 6°C/min and maintained at 95 °C for 5 min. Then, the sample was cooled to 50 °C at the rate of 5.3°C/min and finally maintained at 50 °C for 2 min. The peak viscosity (PV), trough viscosity (TV), breakdown (BD), final viscosity (FV), setback (SB), and peak time (PT) were identified from the pasting curve. All samples were measured in triplicate.

### Bread properties

#### Bake loss

The amount of water released and the material lost during baking was calculated by differences between the initial dough weight and the weight of the bread after cooling for 2 h, according to Horstmann et al. [17].

$$\% \text{ Bake loss} = \frac{\text{Weight of dough} - \text{weight of bread after cooling}}{\text{Weight of bread after cooled}} \times 100.$$

### Specific volume

Bread volume (mL) was measured by laser topography (BVM-6610, Perten Instruments, Sweden) and specific bread volume (mL/g) was calculated by dividing the volume with the bread weight.

### Crumb structure

Four slices of each bread were scanned (Canon MG3610, Japan) at 600 dpi resolution, then processed using ImageJ 1.51j8 software (National Institutes of Health, USA). The images were converted to 8 bits, then the width measurement of the piece of bread was dimensioned, the binarization process was carried out and the elliptically shaped particles were analyzed. The number of cells/cm<sup>2</sup>, the % of area occupied by the cells and the average of cell area (mm<sup>2</sup>) were calculated according to Sciarini et al. [4].

### Textural properties of bread

The texture profile analysis (TPA) was carried out on breads 2 h after baking using an Instron Universal Testing Machine (Model 3365, Instron Co., USA). Cylinder-shaped pieces (2.5 cm of diameter and 2.5 cm of height) were obtained from the central parts of six breads. The test was performed at a speed of 60 mm/min to compress the bread crumb to 50% of its original height. The hardness, cohesiveness, springiness, gumminess, and chewiness of the crumb were calculated from the TPA curve.

### Statistical analysis

Data were analyzed using Statgraphics Centurion XVII (StatPoint Technologies Inc., Warrenton, Va., USA). A one-way analysis of variance (ANOVA) with separation of means by the Tukey test ( $p < 0.05$ ) and nonlinear regression analysis was applied to determine the rheological and kinetic parameters of the leavening process. All the analyses were carried out at least in triplicate and mean values  $\pm$  standard deviation are presented.

## Results and discussion

### Dough evaluation

#### Viscoelastic properties

The viscoelastic properties of the four formulations are shown in Table 2. In all treatments,  $G'$  (elastic modulus) was greater than  $G''$  (viscous modulus), which suggests a solid elastic-like behavior. A similar behavior was reported in others works [6, 18]. The formulation CS-XG was the most elastic one of all the treatments, while the formulation PS-XG was the most viscous one. Doughs with tara gum (CS-TG and PS-TG) showed lower values of  $G'$  and  $G''$ . The  $\tan(\delta)$ , which indicates the ratio of viscous to elastic behavior, was less than 1 for all treatments. The formulations with xanthan gum obtained lower values of  $\tan(\delta)$ , while the formulation PS-TG obtained a value of  $\tan(\delta)$  close to 1, which indicates a balanced relationship between its viscous and elastic behavior. This behavior is characteristic of the so-called weak gels and is in agreement with previous observations regarding the viscoelastic properties of gluten-free doughs [6, 19].

According to Ziobro et al. [20], it is difficult to predict the exact influence of the rheological properties of the dough on the bread crumb structure and texture. Low viscosity of the dough positively influences quality of the final product, because it improves gas cell expansion during proofing, and in this way, positively affects volume and allows obtaining well-aerated crumb [21]. Nevertheless, too low viscosity could lead to structure weakening, and thus decrease gas retention and negatively influence bread quality [22].

The results obtained in this investigation showed that formulations with low  $\tan(\delta)$  (CS-XG, CS-TG, and PS-XG) were more consistent, and therefore is expected that these doughs could hold the gas produced during the fermentation process.

#### Kinetics of the leavening process

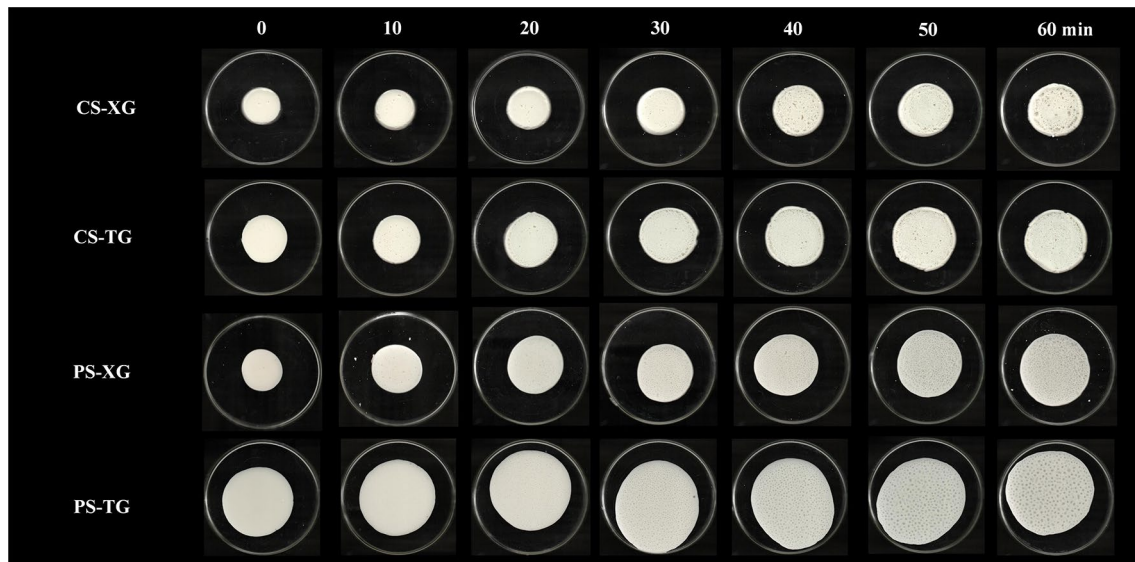
Table 2 shows the kinetic parameters of dough growth evolution during the leavening process. The initial diameter ( $D_0$ ) of the formulation PS-TG was higher than the other treatments, this is related to its viscoelastic properties, because this dough presented a less viscous and elastic behavior than the other formulations, therefore this dough spread more easily once placed in the Petri dish (Fig. 1). In the same way, since this dough was more fluid, it also experienced a higher growth rate ( $V_{\max}$ ) compared to the other formulations. The ratio of viscous to elastic behavior of doughs ( $\tan(\delta)$ ) was negatively correlated with the necessary time to reach the maximum growth rate of dough ( $X$ ) during fermentation ( $r = -0.97$ ;  $p < 0.05$ ), which indicates that more elastic dough will need a longer fermentation time. Gluten free-doughs are usually fermented between 30 and 45 min [2, 8, 17] and is very seldom few times, considered as a research variable. According to Cappa et al. [23] if the fermentation time is not controlled, the structure of the gluten-free dough could weaken causing a collapse of the dough during the baking process.

A good agreement between experimental data and the Gompertz equation was observed in all treatments (correlation coefficient  $R^2$  between 0.89 and 0.99). With respect to the kinetic parameters obtained, the value of  $C$ , which represents the difference between the maximum and minimum diameter achieved, was greater in the PS-GX formulation than in the other formulations, which indicates that

**Table 2** Viscoelastic properties of dough and kinetic parameters during fermentation

Gluten-free dough		CS-XG	CS-TG	PS-XG	PS-TG
Rheological properties	$G'$ (Pa) – 1 Hz	17450.00 ± 551.54 <sup>d</sup>	463.20 ± 44.60 <sup>b</sup>	1733.50 ± 116.50 <sup>c</sup>	309.20 ± 14.29 <sup>a</sup>
	$k'$ (Pa.s <sup>n'</sup> )	12712.00 ± 1402 <sup>d</sup>	350.69 ± 21.62 <sup>b</sup>	603.95 ± 27.78 <sup>c</sup>	260.31 ± 11.16 <sup>a</sup>
	$n'$	0.82 ± 0.10 <sup>d</sup>	0.43 ± 0.01 <sup>a</sup>	0.48 ± 0.03 <sup>a</sup>	0.66 ± 0.04 <sup>c</sup>
	$G''$ (Pa) – 1 Hz	616.35 ± 57.55 <sup>c</sup>	107.86 ± 16.54 <sup>a</sup>	878.45 ± 42.75 <sup>d</sup>	249.07 ± 17.45 <sup>b</sup>
	$k''$ (Pa.s <sup>n''</sup> )	519.60 ± 22.95 <sup>c</sup>	98.89 ± 9.33 <sup>a</sup>	234.86 ± 96.05 <sup>b</sup>	221.78 ± 5.44 <sup>b</sup>
	$n''$	0.41 ± 0.08 <sup>b</sup>	0.30 ± 0.03 <sup>a</sup>	0.52 ± 0.11 <sup>c</sup>	0.47 ± 0.02 <sup>b</sup>
	$\tan(\delta)$ – 1 Hz	0.21 ± 0.08 <sup>a</sup>	0.23 ± 0.01 <sup>a</sup>	0.51 ± 0.01 <sup>b</sup>	0.81 ± 0.03 <sup>c</sup>
Kinetic parameters	$C$	1.33 ± 0.10 <sup>a</sup>	1.41 ± 0.23 <sup>a</sup>	2.34 ± 0.36 <sup>b</sup>	1.45 ± 0.15 <sup>a</sup>
	$D_0$ (cm)	3.45 ± 0.06 <sup>a</sup>	4.12 ± 0.15 <sup>b</sup>	3.89 ± 0.24 <sup>a</sup>	6.18 ± 0.24 <sup>c</sup>
	$V$ (min <sup>-1</sup> )	0.08 ± 0.01 <sup>a</sup>	0.08 ± 0.02 <sup>a</sup>	0.06 ± 0.01 <sup>a</sup>	0.12 ± 0.04 <sup>b</sup>
	$X$ (min)	21.54 ± 1.12 <sup>b</sup>	19.95 ± 4.84 <sup>b</sup>	16.94 ± 5.60 <sup>b</sup>	6.23 ± 1.67 <sup>a</sup>
	$R^2$	0.99	0.99	0.98	0.89

\*Values followed by different letters in the same row are significantly different ( $p < 0.05$ )



**Fig. 1** Gluten-free doughs during leavening process. *CS-XG* corn starch with xanthan gum, *CS-TG* corn starch with tara gum, *PS-XG* potato starch with xanthan gum, *PS-TG* potato starch with tara gum

this dough achieved the greatest development during the leavening process. According to Romano et al. [24], the mathematical modeling of the leavening process provides an idea of the speed and intensity of dough growth. As well as, it can provide a general idea about the appropriate time of fermentation of a dough, since this time depends largely on the composition and the consistency of doughs. The results obtained in this investigation showed that the fermentation time is influenced by the initial rheological properties of the dough.

### Pasting properties

The results obtained for the pasting properties of the four formulations are summarized in Table 3. Potato starch formulations (*PS-XG* and *PS-TG*) exhibited higher values of PV, TV, BD, and FV compared to the corn starch formulations, which are in agreement with previous findings [17, 25]. Formulations with corn starch (*CS-XG* and *CS-TG*) obtained higher SB values compared to potato starch formulations, which suggest that the formulations with corn starch

will have a higher rate of retrogradation and syneresis in the final product [26]. No significant differences were observed for the pasting properties between *CS-XG* and *CS-TG*, but between *PS-XG* and *PS-TG*. Partially, these results could be explained by the different amount of amylose in the starches [17], but the different effect of XG and TG on corn starch and potato starch could not be fully clarified.

The formulation *PS-TG* had highest PV and BD, followed by the formulation *PS-XG*. These results indicate a strong interaction between the galactomannan from tara gum and the starch from potato. According to the literature, the increase in peak viscosity can be interpreted assuming that the system is biphasic, with the gum located in the continuous phase and its concentration is greatly increased due to swelling of the starch granules during gelatinization [27–29]. Chaisawang and Supphantharika [28] evaluated the behavior of native and anionic tapioca starch granules during gelatinization by SEM and noted that guar gum did not entrap envelop the starch granules, but formed a sheet structure in the continuous phase; therefore, the starch granules can swell freely before physical breakdown, which results in

**Table 3** Pasting properties of formulations

Formulation	Peak viscosity (Pa s)	Trough viscosity (Pa s)	Breakdown (Pa s)	Final viscosity (Pa s)	Setback (Pa s)	Peak time (min)
<i>CS-XG</i>	1.913 ± 0.00 <sup>a</sup>	0.819 ± 0.00 <sup>a</sup>	1.094 ± 0.01 <sup>a</sup>	1.915 ± 0.01 <sup>a</sup>	1.095 ± 0.01 <sup>a</sup>	8.40 ± 0.0 <sup>a</sup>
<i>CS-TG</i>	1.910 ± 0.02 <sup>a</sup>	0.793 ± 0.00 <sup>a</sup>	1.116 ± 0.02 <sup>a</sup>	1.854 ± 0.01 <sup>a</sup>	1.060 ± 0.01 <sup>a</sup>	8.30 ± 0.0 <sup>a</sup>
<i>PS-XG</i>	3.338 ± 0.01 <sup>b</sup>	1.249 ± 0.01 <sup>c</sup>	2.090 ± 0.00 <sup>b</sup>	2.033 ± 0.00 <sup>a</sup>	0.784 ± 0.00 <sup>b</sup>	6.05 ± 0.2 <sup>b</sup>
<i>PS-TG</i>	3.732 ± 0.09 <sup>c</sup>	1.179 ± 0.02 <sup>b</sup>	2.558 ± 0.07 <sup>c</sup>	2.015 ± 0.11 <sup>a</sup>	0.841 ± 0.09 <sup>b</sup>	6.30 ± 0.0 <sup>b</sup>

\*Values followed by different letters in the same column are significantly different ( $p < 0.05$ )



an increase in peak viscosity. Similar results were reported by Rodriguez-Sandoval et al. [30] who evaluated the effect of guar gum and a mixture of guar gum/HPMC on the pasting profile of a tapioca starch–precooked corn flour mixture.

In the case of xanthan gum, it is well documented that the incorporation of this gum decreases the viscosity pasting properties of the starches, because the starch granules are completely entrapped by a tight gum layer which causes restricted swelling at high temperatures, limiting the increase in viscosity and subsequently retarding gelatinization of starch granules [8, 28, 31]. With respect to FV, all the formulations showed similar values so it is expected that the springiness of the final products will be very similar [32].

As already mentioned before, gluten-free doughs should be sufficiently viscous so that they can retain the gas produced during the leavening process, but it is also desired that the viscosity of the dough is stable during the baking process. Although the formulation PS-TG can achieve a high viscosity during the heating process, it experiences a high breakdown, which suggests a low stability during the baking process.

## Bread evaluation

### Bake loss, specific volume, and crumb structure of gluten-free bread

Table 4 shows the bread properties obtained for the four studied formulations. Regarding to bake loss, it was evident that the formulations with tara gum (CS-TG and PS-TG) lost more water than the formulations with xanthan gum, this result is related to the way in which the gum interacts with the starch. As mentioned earlier, galactomannans are dispersed in the continuous phase allowing complete gelatinization and subsequent retrogradation of the starch, therefore the water absorbed by the starches is ready to evaporate. In contrast, xanthan gum entraps the starch granules thus delaying evaporation of water during baking. This is

largely advantageous because it can slow down bread staling by delaying formation of amylopectin recrystallisation during storage [31]. Additionally, these results may be due to the negative charge of the xanthan gum molecule. It is known that the groups of acetic and pyruvic acids available in the chemical structure of the xanthan gum molecule allow higher water absorption through hydrogen bonds [33], compared to the neutral charge presented by galactomannans [8].

The formulation PS-XG achieved the highest specific volume followed by CS-TG, CS-XG, and PS-TG. Specific volume was highly correlated with the number of cells/cm<sup>2</sup> and the % area occupied by the alveoli, demonstrating that the bread with higher specific volume had better alveolar structure.

In gluten-free breads made from PS-TG, the crumb collapsed (see Fig. 2), therefore, it was not possible to measure the crumb structure. According to Sciarini et al. [4], this effect is characteristic to systems with a rapid water loss. The collapse of the crumb can also be caused by the coalescence of the alveoli during the early stage of baking as a result of a too rapid expansion of the CO<sub>2</sub> bubbles [34]. This baking result was not unexpected because the dough presented low viscoelasticity and a rapid growth rate during the leavening process. The collapse of the crumb might be avoided by decreasing the water content of the formulation or by inclusion of protein sources that have a high water absorption, another possibility could eventually be reducing the fermentation times of the dough. The average cell area was very similar in all formulations. According to Sciarini et al. [4], if the cell area ranges between 2.00 and 10.00 mm<sup>2</sup>, they are considered large alveoli or cells, which lead to the formation of a spongier crumb.

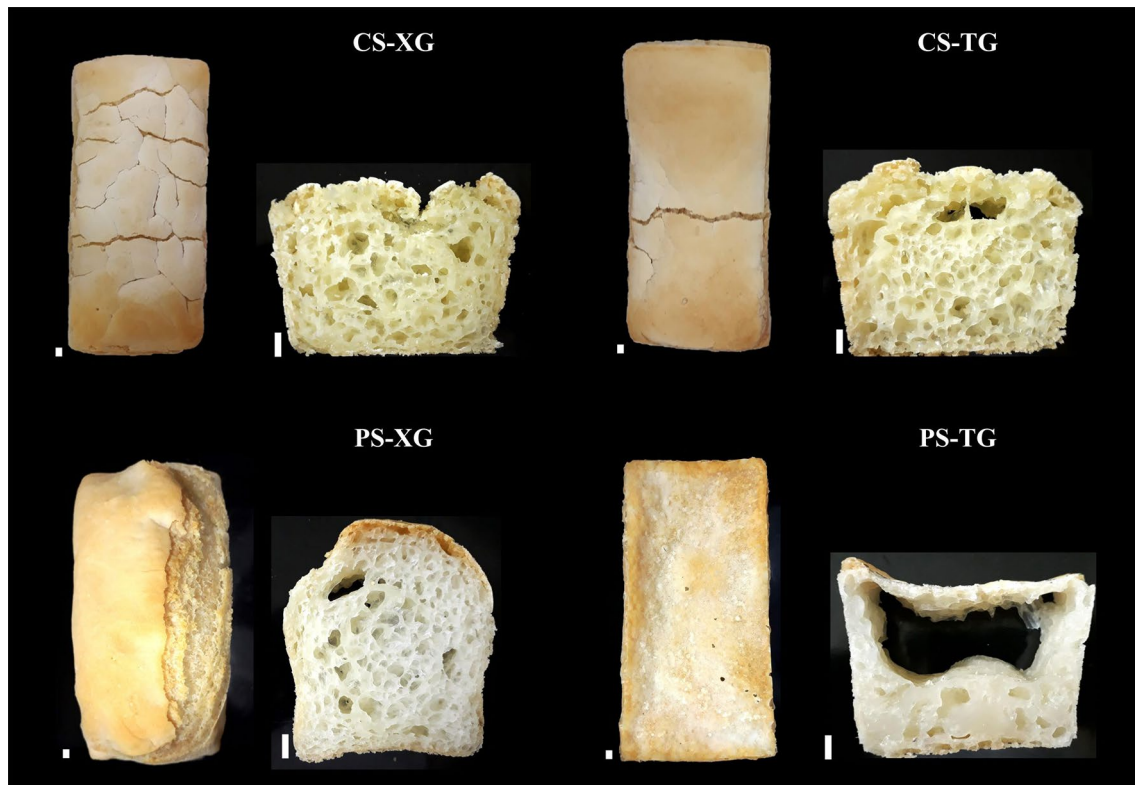
### Textural properties of gluten-free bread

The results of TPA are shown in Table 4. The lowest hardness was found in formulation PS-XG, the highest in formulation PS-TG, basically due to the collapse of the crumb

**Table 4** Quality characteristics of gluten-free bread formulations based on starch

Quality parameters	CS-XG	CS-TG	PS-XG	PS-TG
Baking loss (%)	16.64 ± 2.5 <sup>a</sup>	18.77 ± 1.5 <sup>b</sup>	15.85 ± 0.7 <sup>a</sup>	17.67 ± 0.7 <sup>ab</sup>
Specific volume (mL/g)	2.24 ± 0.04 <sup>b</sup>	2.41 ± 0.01 <sup>c</sup>	2.77 ± 0.05 <sup>d</sup>	1.93 ± 0.03 <sup>a</sup>
N° cells/cm <sup>2</sup>	52.48 ± 5.3 <sup>a</sup>	46.40 ± 10.9 <sup>a</sup>	83.50 ± 8.5 <sup>b</sup>	–
% Area of cells	31.04 ± 2.8 <sup>ab</sup>	28.11 ± 3.9 <sup>a</sup>	33.20 ± 3.0 <sup>b</sup>	–
Average cell area (mm <sup>2</sup> )	2.83 ± 0.3 <sup>a</sup>	2.69 ± 0.5 <sup>a</sup>	2.87 ± 0.3 <sup>a</sup>	–
Crumb hardness (N)	2.37 ± 0.25 <sup>b</sup>	2.42 ± 0.04 <sup>b</sup>	1.90 ± 0.00 <sup>a</sup>	12.64 ± 0.17 <sup>c</sup>
Cohesiveness	0.01 ± 0.00 <sup>a</sup>	0.01 ± 0.00 <sup>a</sup>	0.04 ± 0.00 <sup>b</sup>	0.01 ± 0.09 <sup>a</sup>
Springiness	0.01 ± 0.00 <sup>a</sup>	0.01 ± 0.00 <sup>a</sup>	0.01 ± 0.00 <sup>a</sup>	0.01 ± 0.00 <sup>a</sup>
Gumminess (N)	1.40 ± 0.12 <sup>a</sup>	1.44 ± 0.01 <sup>a</sup>	7.50 ± 0.30 <sup>c</sup>	6.41 ± 0.24 <sup>b</sup>
Chewiness (N)	1.37 ± 0.12 <sup>a</sup>	1.33 ± 0.03 <sup>a</sup>	7.38 ± 0.32 <sup>c</sup>	6.45 ± 0.29 <sup>b</sup>

\*Values followed by different letters in the same row are significantly different ( $p < 0.05$ )



**Fig. 2** Representative images of gluten-free breads. *CS-XG* corn starch with xanthan gum, *CS-TG* corn starch with tara gum, *PS-XG* potato starch with xanthan gum, *PS-TG* potato starch with tara gum. The white bar represents 1 cm

and consequent agglomeration. Negative correlations were observed between crumb hardness and specific volume ( $r = -0.81$ ,  $p < 0.05$ ),  $N^\circ$  cells/cm<sup>2</sup> ( $r = -0.85$ ,  $p < 0.05$ ) and % area of cells ( $r = -0.98$ ;  $p < 0.05$ ). Similar results have been reported by Horstmann et al. [8] who found that gluten-free breads made from potato starch and xanthan gum were softer than breads made from potato starch and locust bean gum.

In the case of cohesiveness, the formulation PS-XG was more cohesive than the formulations with corn starch. According to Demirkesen et al. [35] and Liu et al. [31], it is desirable that gluten-free breads have moderate cohesiveness values because breads with too low cohesion are susceptible to fracture and crumble. Elasticity of the formulations with xanthan gum (CS-XG and PS-XG) was very similar, however, a lower elasticity value was obtained in formulation with tara gum (CS-TG). The formulation PS-XG obtained the highest gumminess and chewiness values, while no significant difference, of these parameters, was observed in the formulations with corn starch (CS-XG and CS-TG).

## Conclusions

In this study, it was possible to evaluate the effect of tara gum and xanthan gum on the rheological properties of the doughs and physical quality parameters of gluten-free breads made from corn starch and potato starch. It was found that tara gum significantly affected the pasting properties of the formulations with potato starch. The viscoelastic properties were different for all the formulations. The kinetics of dough growth during the leavening process was modeled correctly using the Gompertz equation, and it was demonstrated that fermentation time was influenced by the viscoelastic properties of the doughs. With respect to the physical quality parameters, when using potato starch, a gluten-free bread with high specific volume, good crumb structure, and desirable textural properties was obtained after addition of xanthan gum, but not when adding tara gum. In the corn starch breads, addition of xanthan gum

as well as tara gum produced breads with very similar physical characteristics. Therefore, the influence of the type of hydrocolloid used for the preparation of gluten-free breads depends to a large extent on the starch used. In corn starch, tara gum is a potential additive to improve the rheological and textural characteristics of gluten-free bread formulations.

**Acknowledgements** Open access funding provided by University of Natural Resources and Life Sciences Vienna (BOKU). The authors would like to thank the PROTEIN2FOOD Project (European Union's Horizon 2020, No. 635727) for the financial support of this research. The first author wishes to thank Cieniciactiva of CONCYTEC for financing the PhD studies, as well Professors Raul Siche and Carmen Velezmore for the support of rheological analyzes.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Compliance with ethics requirements** This article does not contain any studies with human or animal subjects.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

## References

- DeGeorge KC, Frye JW, Stein KM et al (2017) Celiac disease and gluten sensitivity. *Prim Care Clin Off Pract* 44:693–707. <https://doi.org/10.1016/j.pop.2017.07.011>
- Alvarez-Jubete L, Auty M, Arendt EK, Gallagher E (2010) Baking properties and microstructure of pseudocereals flours in gluten-free bread formulations. *Eur Food Res Technol* 230:437–445. <https://doi.org/10.1007/s00217-009-1184-z>
- Mir SA, Shah MA, Naik HR, Zargar IA (2016) Influence of hydrocolloids on dough handling and technological properties of gluten-free breads. *Trends Food Sci Technol* 51:49–57. <https://doi.org/10.1016/j.tifs.2016.03.005>
- Sciarini LS, Ribotta PD, León AE, Pérez GT (2012) Incorporation of several additives into gluten free breads: Effect on dough properties and bread quality. *J Food Eng* 111:590–597. <https://doi.org/10.1016/j.jfoodeng.2012.03.011>
- Hager AS, Arendt EK (2013) Influence of hydroxypropylmethylcellulose (HPMC), xanthan gum and their combination on loaf specific volume, crumb hardness and crumb grain characteristics of gluten-free breads based on rice, maize, teff and buckwheat. *Food Hydrocoll* 32:195–203. <https://doi.org/10.1016/j.foodhyd.2012.12.021>
- Mancebo CM, San Miguel M, Martínez MM, Gómez M (2015) Optimisation of rheological properties of gluten-free doughs with HPMC, psyllium and different levels of water. *J Cereal Sci* 61:8–15. <https://doi.org/10.1016/j.jcs.2014.10.005>
- Mohammadi M, Sadeghnia N, Azizi MH et al (2014) Development of gluten-free flat bread using hydrocolloids: Xanthan and CMC. *J Ind Eng Chem* 20:1812–1818. <https://doi.org/10.1016/j.jiec.2013.08.035>
- Horstmann SW, Axel C, Arendt EK (2018) Water absorption as a prediction tool for the application of hydrocolloids in potato starch-based bread. *Food Hydrocoll* 81:129–138. <https://doi.org/10.1016/j.foodhyd.2018.02.045>
- Mirhosseini H, Amid BT (2012) A review study on chemical composition and molecular structure of newly plant gum exudates and seed gums. *Food Res Int* 46:387–398. <https://doi.org/10.1016/j.foodres.2011.11.017>
- Ma Q, Du L, Yang Y, Wang L (2017) Rheology of film-forming solutions and physical properties of tara gum film reinforced with polyvinyl alcohol (PVA). *Food Hydrocoll* 63:677–684. <https://doi.org/10.1016/j.foodhyd.2016.10.009>
- Wu Y, Ding W, Jia L, He Q (2015) The rheological properties of tara gum (*Caesalpinia spinosa*). *Food Chem* 168:366–371. <https://doi.org/10.1016/j.foodchem.2014.07.083>
- Mezaize S, Chevallier S, Le Bail A, De Lamballerie M (2009) Optimization of gluten-free formulations for French-style breads. *J Food Sci* 74:140–146. <https://doi.org/10.1111/j.1750-3841.2009.01096.x>
- Mohammadi M, Azizi MH, Neyestani TR et al (2015) Development of gluten-free bread using guar gum and transglutaminase. *J Ind Eng Chem* 21:1398–1402. <https://doi.org/10.1016/j.jiec.2014.06.013>
- Ziobro R, Witczak T, Juszcak L, Korus J (2013) Supplementation of gluten-free bread with non-gluten proteins. Effect on dough rheological properties and bread characteristic. *Food Hydrocoll* 32:213–220. <https://doi.org/10.1016/j.foodhyd.2013.01.006>
- Tunç MT, Kahyaoglu T (2016) Improving rheological and baking properties of gluten-free breads using defatted hazelnut flour with various gums. *Int J Food Eng* 12:343–353. <https://doi.org/10.1515/ijfe-2015-0207>
- AACC (2010) AACCI method 76-21.01, 11th edn. AACCI, S. Paul, Minnesota
- Horstmann S, Belz M, Heitmann M et al (2016) Fundamental study on the impact of gluten-free starches on the quality of gluten-free model breads. *Foods* 5:30. <https://doi.org/10.3390/foods5020030>
- Demirkesen I, Mert B, Sumnu G, Sahin S (2010) Rheological properties of gluten-free bread formulations. *J Food Eng* 96:295–303. <https://doi.org/10.1016/j.jfoodeng.2009.08.004>
- Lazaridou A, Duta D, Papageorgiou M et al (2007) Effects of hydrocolloids on dough rheology and bread quality parameters in gluten-free formulations. *J Food Eng* 79:1033–1047. <https://doi.org/10.1016/j.jfoodeng.2006.03.032>
- Ziobro R, Juszcak L, Witczak M, Korus J (2016) Non-gluten proteins as structure forming agents in gluten free bread. *J Food Sci Technol* 53:571–580. <https://doi.org/10.1007/s13197-015-2043-5>
- Hüttner EK, Bello FD, Arendt EK (2010) Rheological properties and bread making performance of commercial wholegrain oat flours. *J Cereal Sci* 52:65–71. <https://doi.org/10.1016/j.jcs.2010.03.004>
- Houben A, Höchstötter A, Becker T (2012) Possibilities to increase the quality in gluten-free bread production: An overview. *Eur Food Res Technol* 235:195–208. <https://doi.org/10.1007/s00217-012-1720-0>
- Cappa C, Barbosa-Cánovas GV, Lucisano M, Mariotti M (2016) Effect of high pressure processing on the baking aptitude of corn starch and rice flour. *LWT - Food Sci Technol* 73:20–27. <https://doi.org/10.1016/j.lwt.2016.05.028>
- Romano A, Toraldo G, Cavella S, Masi P (2007) Description of leavening of bread dough with mathematical modelling. *J Food Eng* 83:142–148. <https://doi.org/10.1016/j.jfoodeng.2007.02.014>
- Gularte MA, Rosell CM (2011) Physicochemical properties and enzymatic hydrolysis of different starches in the presence



- of hydrocolloids. *Carbohydr Polym* 85:237–244. <https://doi.org/10.1016/j.carbpol.2011.02.025>
26. Ragaei S, Abdel-Aal E-SM (2006) Pasting properties of starch and protein in selected cereals and quality of their food products. *Food Chem* 95:9–18. <https://doi.org/10.1016/j.foodchem.2004.12.012>
  27. Lee HY, Jo W, Yoo B (2017) Rheological and microstructural characteristics of rice starch–tara gum mixtures. *Int J Food Prop* 20:1879–1889. <https://doi.org/10.1080/10942912.2017.1354884>
  28. Chaisawang M, Supphantharika M (2006) Pasting and rheological properties of native and anionic tapioca starches as modified by guar gum and xanthan gum. *Food Hydrocoll* 20:641–649. <https://doi.org/10.1016/j.foodhyd.2005.06.003>
  29. Achayuthakan P, Supphantharika M (2008) Pasting and rheological properties of waxy corn starch as affected by guar gum and xanthan gum. *Carbohydr Polym* 71:9–17. <https://doi.org/10.1016/j.carbpol.2007.05.006>
  30. Rodriguez-Sandoval E, Cortes-Rodriguez M, Manjarres-Pinzon K (2015) Effect of hydrocolloids on the pasting profiles of tapioca starch mixtures and the baking properties of gluten-free cheese bread. *J Food Process Preserv* 39:1672–1681. <https://doi.org/10.1111/jfpp.12398>
  31. Liu X, Mu T, Sun H et al (2018) Influence of different hydrocolloids on dough thermo-mechanical properties and in vitro starch digestibility of gluten-free steamed bread based on potato flour. *Food Chem* 239:1064–1074. <https://doi.org/10.1016/j.foodchem.2017.07.047>
  32. Numfon R (2017) Effects of different hydrocolloids on properties of gluten-free bread based on small broken rice berry flour. *Food Sci Technol Int* 23:310–317. <https://doi.org/10.1177/1082013217690064>
  33. Encina-Zelada CR, Cadavez V, Monteiro F et al (2018) Combined effect of xanthan gum and water content on physicochemical and textural properties of gluten-free batter and bread. *Food Res Int* 111:544–555. <https://doi.org/10.1016/j.foodres.2018.05.070>
  34. Conte P, Del Caro A, Balestra F et al (2018) Bee pollen as a functional ingredient in gluten-free bread: a physical-chemical, technological and sensory approach. *LWT Food Sci Technol* 90:1–7. <https://doi.org/10.1016/j.lwt.2017.12.002>
  35. Demirkesen I, Kelkar S, Campanella OH et al (2014) Characterization of structure of gluten-free breads by using X-ray microtomography. *Food Hydrocoll* 36:37–44. <https://doi.org/10.1016/j.foodhyd.2013.09.002>

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.