Gluten-free cheese bread from frozen dough: effect of modified cassava starch

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Abstract

The freezing process in dough is widely used to improve fresh product availability for the consumer. The aim of the study was to assess the effect of different modified cassava starches on the quality and textural properties of gluten-free (GF) cheese bread made from frozen GF cheese dough. Three sour cassava starches (extra, express and yucauca) and two chemically modified starches (Expandex® (MCS) and Gel®Baking (OCS)) were used. Samples with sour cassava starches showed higher hardness and number of crumb pores than those with chemically modified starches. Furthermore, a better overall appearance was observed for samples with OCS. Hence, triangle test was carried out between samples with OCS and samples made from fresh dough (control). The consumer panelists identified differences between samples because the GF cheese breads with OCS showed higher compaction and hardness, and they were less salty in taste than the control samples.

Keywords: gluten-free product; cheese bread; freezing; frozen dough; sour starch.

Practical Application: Shelf-life of GF cheese bread could improve by including a freezing step during the process.

1 Introduction

Gluten-free (GF) cheese bread is very popular in some countries of South America (Colombia and Brazil) and is marketed in United States, England, Italy, Portugal, Spain, Argentina and Paraguay (Rodriguez-Sandoval et al., 2014; Silva et al., 2017). GF cheese bread is made by mixing cheese with modified cassava starch, water or milk, salt, sugar and fat. This product is not undergone yeast fermentation before baking, and it is baked immediately once the dough is made. Its rise while baking does not imply a protein-gluten network or the production of carbon dioxide by yeast (Rodriguez-Sandoval et al., 2014). The dough expansion of the GF cheese bread while baking involves the formation of a foam structure with separate gas cells within a sponge structure with interconnected (Bertolini et al., 2001). Thus, this GF product has a spongy texture and low density. The shelf-life of GF cheese bread is short (less than 3 days) due to its physical and sensory properties, especially its rapid increase in hardness (López-Tenorio et al., 2015).

Sour cassava starch is naturally fermented, after which it is sun-dried. This modification causes the macromolecular degradation of cassava starch, which generates a higher ability to capture gases and to expand while cooking, being an important characteristic for different breadmaking products (Franco et al., 2010). The fermentation process itself causes changes in the cassava starch that help to oxidize it and an oxidative degradation or oxidative-reductive depolymerization of starch can also be activated by sunlight (intense visible or UV sources) during drying (Dias et al., 2011; Mestres & Rouau, 1997). Some sour cassava starches might not support the desirable alveolar structure of this product. Thus, GF cheese bread can be found on the market with a firm, alveolar and dry mass or a soft, non-alveolar, and gummy mass (Marcon et al., 2009). Furthermore, some modified cassava starches have unique expansion features similar to those found in sour cassava starch and with a more standardized quality. Among the starches modified for application in bakery products, especially in GF cheese bread, are the oxidized cassava starches (Aplevicz & Demiate, 2007). Oxidized starch is obtained by the reaction of an oxidizing agent with the free hydroxyl groups in the glucose monomer, resulting in the formation of carbonyl and/or carboxyl groups and the depolymerization of starch molecules by scission of glycosidic bonds (Dias et al., 2011).

On the other hand, an alternative to obtaining fresh GF cheese breads could be to incorporate a freezing step during the breadmaking process, as has been done in wheat breadmaking. A freezing process is used in the food industry to make fresh bread available in retail stores, after baking, or to provide a frozen dough that the consumer can bake at home (Mezaize et al., 2010). However, the freezing storage causes physical and chemical damages in the product. The freezing step had a negative impact on GF bread characteristics; one study found GF breads to be denser, with a hard crumb and homogenous gas cells distribution (Mezaize et al., 2010).

Despite the studies conducted using GF frozen dough, there is no information in the literature concerning GF cheese bread from frozen dough. For this reason, the aim of this study was to determine the effect of different modified cassava starches, which had been fermented and chemically modified, on the quality and textural characteristics of the GF cheese bread prepared from GF frozen dough. Furthermore, sensory analyses were implemented to compare the samples from GF frozen dough with the better quality attributes and the GF cheese bread from fresh dough.

2 Materials and methods

2.1 Properties of starches

The following starches were used in the preparation of the GF cheese bread: oxidized cassava starch (OCS) (Gel®Baking, Poltec SAS, La Estrella, Colombia), modified cassava starch (MCS) (Expandex®, Ingredion Colombia SA, Cali, Colombia) and sour cassava starches: Yucauca (Todoyuca Ltda, Candono, Cauca, Colombia), express and extra (Dismapan SAS, Medellín, Colombia). The starch, ash, amylose, amylopectin, moisture contents for each starch were determined (American Association of Cereal Chemists, 2000; Association of Official Analytical Chemists, 1997; ISO 10520 - International Organization for Standardization, 1997; McGrance et al., 1998). Tests were run in triplicate.

The pasting properties of the starches were determined using a Micro-Visco Amylograph (Brabender® GmbH & Co. KG, Duisburg, Germany) (Quayson et al., 2016). The samples (5 g starch db) were suspended in 110 mL of distilled water and stirred at 250 rpm. The temperature profile in Celsius degrees (°C) was reported previously (Rodriguez-Sandoval et al., 2017b). The following indices were considered: Peak, breakdown, setback and final viscosities, which were expressed in Brabender Units (BU). The test was run in triplicate for each sample.

2.2 Preparation of GF cheese bread

The formula of GF cheese bread was 225 g of "costeño" cheese (Quesitos Maya Ltda, Medellin, Colombia), 102 g of starch, 25.5 g of corn starch (Dismapan S.A.S., Medellin, Colombia), 25.5 g of pre-cooked corn flour (Molinos del Atlántico S.A.S., Barranquilla, Colombia), 51 g of margarine (Astra, SIGRA S.A., Bogotá, Colombia), 15.3 g of sugar and 127.5 g of whole milk. The grated "costeño" cheese, the dry ingredients and the margarine were blended in a mixer (Professional Series 600-KP26M1XER, KitchenAid, St. Joseph, MI, USA) for 3 min. The whole milk was slowly added to form a soft and homogeneous dough, which was divided into equal portions (30 g) and rounded manually and rapidly to avoid surface drying of the samples. The dough pieces were stored at -20 °C in a vertical freezer (Industrias Tecnifríos, Medellín, Colombia) for 7 days. Once the storage time was reached, frozen samples were thawed at room temperature for 1 h before baking. The dough samples were baked in a gas oven at 235 °C in the upper part and at 225 °C in the lower part for 17 min (GFO-4B, Guangzhou Youjia Machinery Co., China). The GF cheese breads were rested for 1 h before analysis.

2.3 Freezable water

The freezable water content of the fresh GF cheese dough made with each of the modified cassava starches was determined using a DSC (DSC-Q2000, TA Instruments, New Castle, DE, USA). The samples (3 mg) were weighed in aluminum pans and the DSC temperature program used was based on the literature method (Leray et al., 2010). The freezable water, in g/g of dough, was calculated by dividing the ice melting enthalpy (J/g of product) by the latent heat of ice fusion (334 J/g). Then, this freezable water quantity was calculated as a % of total water by dividing the result by the percentage of total water in the dough (Leray et al., 2010). The transitions associated with the processes of water crystallization and melting were characterized by the initial temperature (To), the peak temperature (Tp) and the change in enthalpy (ΔH) (Almeida & Chang, 2014). An empty pan was used as a reference. All the measurements were carried out in duplicate.

2.4 Quality and textural properties of the GF cheese bread

Specific volume (mL/g) by millet displacement, weight loss (g/100g) and height (mm) were measured in sixteen (16) GF cheese bread samples for each treatment (López-Tenorio et al., 2015). Crumb and crust moisture contents were measured in three (3) samples per treatment according to AACC 44-15.02 (American Association of Cereal Chemists, 2000). Water activity (A_w) of the crumb of two (2) samples per treatment was measured using a dew point hydrometer at 25 °C (Aqualab series 3TE, Decagon, Devices, Pullman, WA, USA) (Zapata et al., 2019).

The crumb color of GF cheese bread samples was measured using a sphere spectrocolorimeter (Model SP60, X-Rite Inc., MI, USA). Four samples were taken from each treatment and the color values of crumb samples were recorded at triplicate (Zapata et al., 2019). The hardness (N), springiness, cohesiveness and chewiness (N) of GF cheese bread were assessed using a texture analyzer (TA-XT2i, Stable Micro Systems, Godalming, U.K.) equipped with a 50 kg load cell and a 100 mm diameter cylindrical aluminum probe (SMSP/100) (Rodriguez-Sandoval et al., 2017b). Twelve (12) samples were measured from each batch.

In order to measure the pores number in the GF cheese bread crumb, a slice of crumb (1 mm thickness) was placed over the glass of a scanner (HP Photosmart D110a, Hewlett Packard, Beijing, China). Scanning was performed with a resolution of 300 dpi. The scanned images were analyzed using the software ImageJ (Research Services Branch, 2017; Turabi et al., 2010). Four samples were measured from each batch.

2.5 Sensory analysis

The GF cheese breads made from frozen dough, which exhibited the best quality and textural attributes, were chosen for triangle test, along with the samples made from fresh dough. This sensory analysis was used to determine whether any difference results between a GF cheese bread made from frozen and that from fresh dough. The 36 consumers for the triangle test were from Universidad Nacional de Colombia-Campus Medellin and in age ranges from 21 to 50 years old. Three samples, two of which were from a single batch of products (samples from fresh dough), were presented in a plastic tray and coded with 3-digit random numbers (Kim et al., 2005). The aim was to determine which one of the three sampled products was perceived to be different from the other two. No information was given to the panelists about the origin of the samples..

2.6 Statistical analysis

A one-way ANOVA was carried out to assess differences in the physical and textural characteristics of GF cheese breads (type of starch) and to evaluate the differences of the pasting and

physicochemical properties in starches. The statistical analysis was performed using Statgraphics Plus 5.1. The data are given as means ± standard deviation (SD). Moreover, the triangle test data were analyzed by matching the number of correct responses from the number of trials conducted to a probability table (Kim et al., 2005).

3 Results and discussion

3.1 Properties of starches

The pasting and physicochemical properties of modified cassava starches are shown in Table 1. The pasting temperatures of MCS and OCS were significantly (p<0.05) lower than those of the sour cassava starches. The peak viscosity was lower for yucauca and OCS, while extra had the highest value. MCS reported a significantly lower breakdown and higher setback and final viscosities, except for extra, in which the final and setback viscosities had similar values. These results indicated that the starch granules of MCS had higher shear strength during gelatinization, and also that its starch molecules had a high degree of re-association. The pasting characteristics of these starches are in agreement with results reported elsewhere (Franco et al., 2010; Rodriguez-Sandoval et al., 2014). The starch contents of sour cassava starches were significantly lower than those of chemically modified starches (OCS and MCS). The amylose contents of yucauca, express and OCS were significantly higher than those of extra and MCS; meanwhile; the amylopectin content had an inverse relation to the amylose content. Moreover, the amylose contents obtained in this study were lower than those

of the literature (Alvarado et al., 2013; Franco et al., 2010). The different treatments, fermentation and chemical modification, can affect the amylose content of starches (Franco et al., 2010). High loaf expansion in breadmaking appears to depend on the lower amylose contents of starches, which may be related to the formation of less amylose–lipid complexes (Alvarado et al., 2013). There were no significant differences in ash content, except for MCS. The samples had below 1.5% ash content, complying with the requirements in the regulatory standard (Onitilo et al., 2007). The moisture content ranged from 10.5% for OCS to 17.5% for express. Material containing more than 12% moisture has less storage stability than that with lower moisture content (Onitilo et al., 2007).

3.2 Freezable water

Table 2 shows the onset temperature (To), peak temperature (Tp) and freezable water of fresh dough made with modified cassava starches. There were no statistical differences among the values for the onset and peak temperatures among the samples with different modified cassava starches. The onset and peak temperatures were in the range of -5.27 °C to -5.50 and -2.37 to -2.52, respectively. The extra samples presented the lowest enthalpy of ice melting; meanwhile, the samples with yucauca starch had the highest values. The enthalpy ranged from 60 to 74 J/g. Furthermore, the moisture content of GF cheese dough was the highest for extra samples and the lowest for yucauca samples. The extra samples had the lowest content of freezable water, followed by MCS, whereas the highest value

Table 1. Pasting and physicochemical properties of modified cassava starches*.

Properties		Starch**				
		Extra	Yucauca	Express	OCS	MCS
Micro-Visco Amylograph test	Pasting temp. (°C)	69.2 ± 0.28[bc]	70.3 ± 0.42[c]	70.0 ± 0.00[c]	67.8 ± 1.63[ab]	66.0 ± 0.14[a]
	Peak (BU)	340.0 ± 2.83[d]	213.0 ± 2.83[a]	311.5 ± 4.95[c]	208.5 ± 4.95[a]	245.0 ± 4.24[b]
	Breakdown (BU)	210.5 ± 0.71[c]	138.0 ± 4.24[b]	217.0 ± 4.24[c]	128.5 ± 6.36[b]	115.0 ± 0.00[a]
	Setback (BU)	32.5 ± 0.71[bc]	21.5 ± 0.71[a]	22.5 ± 0.70[a]	31.0 ± 0.00[b]	34.0 ± 1.41[c]
	Final (BU)	178.0 ± 2.83[c]	103.5 ± 0.71[a]	126.0 ± 1.41[b]	120.5 ± 2.12[b]	180.5 ± 6.36[c]
Physicochemical properties	Amylose (%)	9.64 ± 0.87[a]	15.3 ± 0.36[b]	14.9 ± 0.36[b]	16.5 ± 1.13[b]	12.2 ± 1.40[a]
	Amylopectin (%)	78.1 ± 0.86[c]	71.8 ± 0.36[a]	72.2 ± 0.36[a]	75.0 ± 1.13[b]	77.1 ± 1.39[bc]
	Starch (%n)	87.7 ± 0.02[a]	87.1±0.04[a]	87.1 ± 0.02[a]	91.5 ± 0.02[b]	89.3 ± 0.06[b]
	Ash (%)	0.20 ± 0.01[b]	0.20±0.02[b]	0.20 ± 0.01[b]	0.15 ± 0.02[a]	0.65 ± 0.01[c]
	Moisture (%)	15.4 ± 0.31[c]	14.4 ± 0.02[b]	17.5 ± 0.15[d]	10.5 ± 0.11[a]	13.8 ± 0.17[b]

Different superscripts in the same row indicate significant differences (p <0.05) according to the LSD test; *Values are means ± the standard deviation of the measurements; **OCS: oxidized cassava starch, MCS: modified cassava starch.

Table 2. DSC measurements and freezable water for fresh dough made from five modified cassava starches*.

Sample**	To (°C)	Tp (°C)	ΔH (J/g)	FW (%)	Moisture (%)
Extra	-5.27 ± 0.01[a]	-2.51 ± 0.00[a]	60.43 ± 0.21[a]	38.69 ± 0.14[a]	46.76 ± 0.84[c]
Yucauca	-5.44 ± 0.29[a]	-2.51 ± 0.26[a]	74.60 ± 1.60[c]	50.78 ± 1.09[d]	43.98 ± 1.45[a]
Express	-5.34 ± 0.05[a]	-2.52 ± 0.03[a]	69.26 ± 1.32[b]	46.04 ± 0.87[c]	45.02 ± 0.67[ab]
OCS	-5.26 ± 0.17[a]	-2.44 ± 0.21[a]	70.23 ± 0.07[b]	45.93 ± 0.05[c]	45.78 ± 0.75[bc]
MCS	-5.50 ± 0.13[a]	-2.37 ± 0.08[a]	67.49 ± 1.68[b]	43.07 ± 1.07[b]	46.92 ± 0.61[c]

*Values are means ± standard deviation of the measurements. Different superscripts in the same column indicate significant differences (p <0.05) according to the LSD test; **Moisture values from the fresh gluten-free (GF) cheese dough, To: initial temperature, Tp: peak temperature, and ΔH: enthalpy of the ice melting, OCS: oxidized cassava starch, MCS: modified cassava starch, FW: Freezable water (% of total water).

was for yucauca. This finding is in accordance with the results of enthalpy of ice melting. Thus, less ice crystal formation during freezing would probably occur in the samples with lower freezable water content (Leray et al., 2010). The freezable water content of the samples ranged from 38 to 50% (0.28 and 0.22 unfreezable water fraction, respectively) and was higher than those reported for partially baked bread crumbs (Hamdami et al., 2004; Ribotta & Le Bail, 2007) and lower than GF dough and pre-baked bread crumbs (Almeida & Chang, 2014; Leray et al., 2010).

3.3 Quality properties of the GF cheese bread

The quality characteristics of GF cheese bread samples, including weight loss (g/100g), height (mm), specific volume (mL/g), water activity (Aw) and crust and crumb moisture contents are presented in Table 3. There were no significant differences in Aw and crumb moisture content of samples. The height of OCS samples and the crust moisture content of MCS samples were the highest out of all samples. Moreover, the OCS samples also had the lowest weight loss. The specific volume of GF cheese breads with MCS and extra were significantly higher than those of OCS, yucauca and express samples.

The specific volume and height of GF cheese bread are characteristics that indicate the baking expansion capacity of the starch. The specific volume of samples was lower compared to GF cheese bread from fresh dough with Expandex® starch and sour cassava starch (Aplevicz & Demiate, 2007). Whereas, the height values were similar to those reported in previous studies (López-Tenorio et al., 2015; Rodriguez-Sandoval et al., 2014). The GF dough freezing process could affect product quality due to the mechanical damage of starch produced by the formation of ice crystals (Leray et al., 2010). The loss of specific volume on dough due to freezing is a critical process for GF bread because GF dough loses its gas retention capacity in the baking processes (Mezaize et al., 2010).

It is worthwhile to note that different interactions of modified cassava starch, either fermented or chemically modified, with other product ingredients, such as casein from cheese and milk and fat content from dairy products and margarine, can play important roles on the quality of GF cheese bread. The interactions between the starches and casein might involve hydrogen bonding, electrostatic adhesion and steric stabilization, which depend on the type and modification of the starch (Sun et al., 2016). The starch could contribute to the formation of a more compact and continuous network structure with a casein gel.

3.4 Images of crumb GF cheese breads

Scanned images of GF cheese breads are shown in Figure 1. Moreover, the number of crumb pores is summarized in Table 3. The type of modified cassava starch significantly affected the total number of crumb pores (p<0.05). Most of the pore areas were less than 0.3 cm^2 for all samples (results not shown). The lowest number of pores was for the GF cheese breads with OCS, meanwhile samples with extra showed the highest number of pores. The changes in the dough structure and the way the type of starch acted during freezing were different. The scanned images of the crumbs depicted this behavior (Figure 1).

The fat content (from the cheese, milk and margarine) and the gelatinized starches may stabilize the gas bubble interface. During baking, fat crystals melt and are incorporated into the surface of the bubble as it expands. The crumb network is formed in the cooling period, when surface temperature becomes lower than transition temperature of the starch, and most of the water evaporates at this stage, steam pressure stabilizes and crust is formed (Bertolini et al., 2001; Zapata et al., 2019). Among the factors involved in the expansion of GF cheese bread while baking are the steam pressure of trapped water that induces bubble growth, the modification of dough thermomechanical properties and water loss that influences the characteristics of the crumb network (Rodriguez-Sandoval et al., 2014). The crumb of samples with sour cassava starches (extra, express and yucauca) is made of more small gas cells. Thawed dough cannot retain the steam produced during the baking process in the same way due to the damage to the structure produced by the formation

Table 3. Quality characteristics and crumb color parameters and of gluten-free (GF) cheese breads from frozen dough with different modified cassava starches*.

Properties	Sample**				
	Extra	Yucauca	Express	OCS	MCS
Weight loss (g/100 g)	7.4 ± 0.3[c]	7.1 ± 0.3[bc]	7.2 ± 0.2[bc]	6.5 ± 0.3[a]	7.0 ± 0.2[b]
Height (mm)	27.8 ± 1.2[a]	27.0 ± 0.2[a]	27.0 ± 1.2[a]	31.3 ± 1.8[b]	28.6 ± 1.7[a]
Specific volume (mL/g)	4.4 ± 0.2[c]	4.2 ± 0.1[a]	4.2 ± 0.1[a]	4.1 ± 0.1[a]	4.4 ± 0.2[c]
Crumb pores number	72 ± 5.4[d]	67 ± 1.6[c]	66 ± 1.5[c]	35 ± 4.7[a]	43 ± 2.8[b]
A$_w$	0.96 ± 0.0[a]	0.96 ± 0.0[a]	0.96 ± 0.0[a]	0.96 ± 0.0[a]	0.95 ± 0.0[a]
Crumb moisture content (%)	67.8 ± 3.4[a]	65.0 ± 2.7[a]	66.4 ± 2.0[a]	66.5 ± 0.5[a]	66.4 ± 1.6[a]
Crust moisture content (%)	23.2 ± 2.3[a]	25.8 ± 1.0[a]	25.0 ± 3.3[a]	23.2 ± 1.5[a]	29.4 ± 2.3[b]
L*	66.6 ± 8.5[a]	67.1 ± 3.2[a]	65.5 ± 4.8[a]	67.3 ± 6.3[a]	65.6 ± 6.8[a]
a*	2.8 ± 0.8[a]	3.1 ± 0.3[a]	4.1 ± 1.1[a]	2.5 ± 1.5[a]	3.6 ± 2.7[a]
b*	26.7 ± 2.8[a]	27.9 ± 0.4[ab]	26.6 ± 1.9[a]	29.0 ± 2.9[ab]	29.9 ± 0.9[b]
C*	29.8 ± 2.7[a]	28.1 ± 0.4[ab]	26.9 ± 1.8[a]	29.2 ± 2.7[ab]	30.2 ± 1.1[b]
*h	83.9 ± 2.5[a]	83.6 ± 0.6[a]	81.2 ± 2.8[a]	84.8 ± 3.7[a]	83.2 ± 4.8[a]

*Values are means ± standard deviation of the measurements. Different superscripts in the same row indicate significant differences (p <0.05) according to the LSD test; **OCS: oxidized cassava starch, MCS: modified cassava starch, A$_w$: Water activity. L*: lightness, a*: green chromaticity (-) to red (+), b*: blue chromaticity (-) to yellow (+), h*: hue angle and C*: chroma.
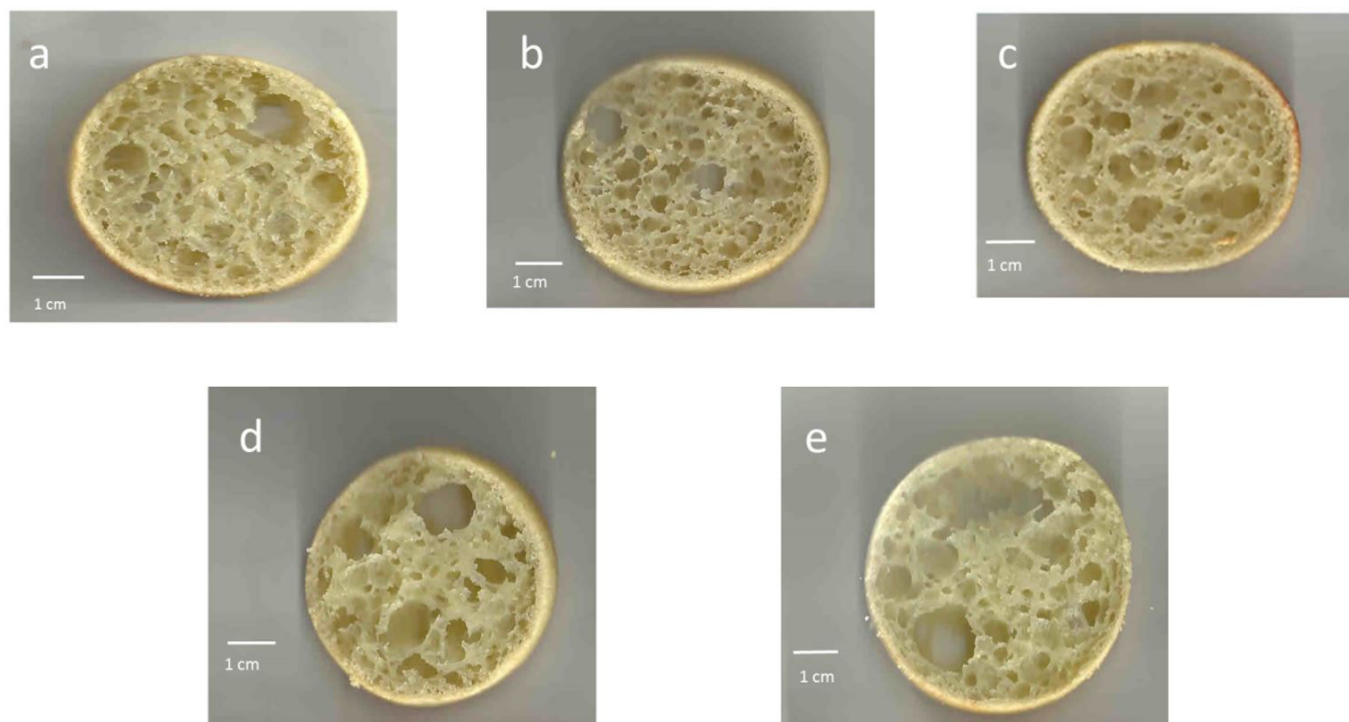
Figure 1. Digital images of GF cheese breads from frozen dough with different modified cassava starches: extra (a), yucauca (b), express (c), oxidized cassava starch (d) and modified cassava starch (e).

of ice crystals. In addition, dough porosity is affected by storage conditions such as cold air currents, relative humidity and temperature fluctuations (Zapata et al., 2019). They also affect the sensory perception and textural characteristics of the final product.

3.5 Crumb color parameters

The crumb color parameters of GF cheese breads from frozen dough with different modified cassava starches are also presented in Table 3. The crumb color was generally similar to the color of the ingredients because the crumb did not reach as high of temperatures as the crust (Rodriguez-Sandoval et al., 2017a). There were no significant differences (p<0.05) in L*, a* and hue values (h*) of samples. Furthermore, the chroma (C*) and b* values for samples with MCS were slightly higher than those for samples with the other starches. The GF cheese breads showed a crumb with the tendency to yellow according to these color parameters, which was similar to GF cheese breads observed in other studies (Lemos et al., 2012; López-Tenorio et al., 2015; Silva et al., 2017). The reported color parameters are characteristic of this product mainly due to the addition of cheese to the formulation.

3.6 TPA properties of GF cheese bread

The texture of baked products has an important role in determining their eating qualities, sensory acceptability and shelf-life. There were no significant differences (p<0.05) in cohesiveness (0.32–0.38) of the GF cheese breads (Table 4), which indicates that the crumbly texture of the GF cheese

breads from frozen dough was not affected by the type of starch. The cohesiveness informs about sensory crumbliness as well as perceptions related to denseness and energy required to chew the food piece (Sanz et al., 2009). The MCS sample had lower springiness than those with the other starches (Table 4). Thus, the incorporation of MCS decreased the ability of the sample to recover its height during the time that elapsed between the end of the first compression and the start of the second (Sanz et al., 2009). This textural property is important because consumers expect the products to have lower springiness and more smoothness.

GF cheese breads from frozen dough with sour cassava starches exhibited higher hardness and chewiness than those with chemically modified starches, while there were no significant differences among the samples with chemically modified starches for these textural properties (Table 4). The number of pores in GF cheese breads and the existence of a denser matrix are related to an increase in hardness (Table 3). In a previous research with GF cheese breads prepared from different types of cheeses, it was evidenced that samples with a more uniform distribution of air cells and a higher percentage of smaller air cells had higher firmness (López-Tenorio et al., 2015). Freezing produced a denser product with a harder crumb and homogeneous gas cells distribution, yielding greater hardness in the GF cheese bread (Mezaize et al., 2010). In addition, when a frozen food is thawed for consumption, the moisture is separated from the matrix causing a different texture compared to the fresh food (Lorenzo et al., 2009; Selomulyo & Zhou, 2007). Likewise, the hardness of GF cheese breads varied widely in a frozen system, which could be attributed to the influence of the starch pasting

Table 4. TPA properties of gluten-free (GF) cheese breads from frozen dough with different modified cassava starches*.

Sample**	Hardness (N)	Springiness	Cohesiveness	Chewiness (N)
Extra	12.9 ± 2.0[b]	0.77 ± 0.07[b]	0.32 ± 0.04[a]	3.1 ± 0.6[b]
Yucauca	14.2 ± 1.4[b]	0.82 ± 0.01[b]	0.38 ± 0.02[a]	4.3 ± 0.3[c]
Express	15.2 ± 1.6[b]	0.81 ± 0.01[b]	0.38 ± 0.05[a]	4.5 ± 0.5[c]
OCS	9.6 ± 2.1[a]	0.73 ± 0.67[ab]	0.34 ± 0.04[a]	2.3 ± 0.4[a]
MCS	10.0 ± 1.4[a]	0.67 ± 0.09[a]	0.33 ± 0.04[a]	2.3 ± 0.6[a]

*Values are means ± the standard deviation of the measurements. Different superscripts in the same column indicate significant differences ($p < 0.05$) according to the LSD test; **OCS: oxidized cassava starch, MCS: modified cassava starch.

characteristics, especially the breakdown viscosity (Table 1). The chemically modified starches, with lower breakdown viscosity, had more resistance to ice crystallization and thus the products with these starches were less affected by the freezing step.

3.7 Sensory analysis

The GF cheese bread with OCS was chosen for sensory evaluation, along with the samples from fresh dough (control). This selection was made by taking into account the hardness results and the number of crumb pores. Although this sample did not have the highest specific volume, and its hardness and chewiness were not significantly different with respect to the MCS sample, a better overall appearance was observed in both its crust and crumb.

A triangle test was conducted to determine whether consumer panelists could identify the differences between the control and samples from frozen dough with OCS. Considering this comparison of samples, 23 among 36 panelists correctly recognized the odd sample, which also corresponds to a significant ($p<0.05$) difference. All the panelists that gave the correct response indicated that the GF cheese breads from frozen dough with OCS showed higher compaction and hardness along with less salty taste than the control samples. Moreover, some panelists also stated that they experienced an oily sensation in the mouth for the samples with freezing treatment. It became evident that the number of correct answers for triangle test was significantly influenced by the frozen dough. These findings confirm the dependence of texture and salty taste when the GF cheese dough is subjected to freezing temperatures.

The higher hardness and oily feel of the samples with freezing treatment were unpleasant to consumers. Meanwhile, for the control samples the consumers indicated a soft texture and not very compact crumb. As mentioned above, the ingredients interactions, such as those of starches, casein and fat may also affect the quality and textural characteristics of the product. Breaks in cheese protein structure may be due to local dehydration of proteins and ice crystal formation during freezing and frozen storage, which allow small fat globules to come in contact with each other and form granules (Ribero et al., 2009). In our case, the most pronounced fat or oily feeling of the final product by consumers may be due to the partial rehydration of the protein matrix after thawing the frozen GF cheese dough.

To better relate the textural properties of GF cheese breads, the TPA properties were measured for control samples. The TPA results for the rest of the samples were reported in Table 4. Hardness,

springiness, cohesiveness and chewiness resulted in 3.7 ± 0.4 N, 0.5 ± 0.0, 0.3 ± 0.0 and 0.5 ± 0.0, respectively. Therefore, it was obvious that the panelists found textural differences between both types of samples (frozen vs. fresh) according to these results, since GF cheese bread from frozen dough was about 40% harder than samples from fresh dough. Similar results were found for wheat dough, batter cakes and GF dough (Bhattacharya et al., 2003; Gómez et al., 2011; Mezaize et al., 2010).

The panelists perceived a subtly salty taste in samples from frozen dough, which in a large number of cases turned out to be unpleasant. It appears that too little saltiness in the GF cheese bread taste could reduce its liking. The "costeño" cheese, widely used in the preparation of GF cheese bread, is a fresh cheese with a salty flavor between moderate and strong. The high sodium chloride (NaCl) concentration helps with cheese preservation in tropical climates; taking into account also the use of unpasteurized milk as a raw material. The inhibition of microbial growth, the control of the proteolytic enzymes activity, the effects on water-binding properties of proteins and the impact on the desirable flavor and performance attributes are due to the use of NaCl in cheese (Cervantes et al., 1983; Ganesan et al., 2014). More salted cheese binds more water into the protein matrix. The migration of water from the large and small void spaces into the protein matrix is the result of increased protein hydration, which is also related to cheese matrix increase in volume (Paulson et al., 1998). Salt affects the degree of protein hydration and, thus, would affect the amount of freezable water. The freezing point of the aqueous phase decreases when increasing salt content, and less ice is formed at a given subfreezing temperature in samples with higher salt content since salt is in the aqueous phase (Cervantes et al., 1983). Salted cheese has also fewer large protein groups, a more dispersed protein arrangement, smaller protein aggregates, and less space between them. The increase in interactions between proteins and the surrounding water is given by the addition of NaCl to cheese, which reduces hydrophobic interactions between protein molecules, and this results in less aggregation of protein into protein dense groupings (Paulson et al., 1998). Proteins are unable to completely rebind water after thawing. Consequently, water is less incorporated into the protein matrix, leading to a more porous protein matrix in frozen samples (Ribero et al., 2009). Since the frozen dough of GF cheese bread has a large amount of cheese in its formulation, the aforementioned changes for salt in cheese can also occur in these samples. Perhaps, some salt could have dissolved in the water later during dough thawing.

4 Conclusions

The quality, textural and sensorial properties of GF cheese breads were affected by the freezing treatment of the dough. The chemically modified starches had higher resistance to freezing and resulted in samples with lower hardness and number of pores. The sample with OCS was chosen for the sensorial test along with a control sample prepared from fresh dough due to its higher softness and its general appearance. Sensory panelists detected harder texture and a reduction in salty taste for the samples made from frozen dough. Further study of the addition of hydrocolloids in GF cheese frozen dough is highly recommended to improve its textural and sensorial characteristics, in order to obtain a GF cheese bread more similar to that made from a fresh dough.

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