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Can cassava improve the quality of gluten free breads?

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A R T I C L E I N F O

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A B S T R A C T

The effect of incorporating different forms of cassava (flour, native and sour starch) on the quality of gluten-free breads was evaluated. Ten or 20% of a maize starch/rice flour mixture was replaced by these cassava products. Pasting and hydration properties of the mixtures were analysed. The rheology of doughs obtained was also studied. The breads produced were evaluated for specific volume, weight loss, texture, and sensory characteristics. The rheology of the doughs did not change with the addition of cassava starch, but cassava flour increased the G′ and G″ values. These changes are more related to the cold hydration properties than to the pasting properties of the mixes. Ten percent of cassava products incorporation improved the quality of the bread by increasing their specific volume. However, this increase was smaller when 20% of cassava products were added. The incorporation of 20% of cassava flour in breads reduced their specific volume significantly. Breads with cassava starch were softer after 7 days of storage than control bread. Furthermore, their crumbs were more cohesive and less dry in the mouth, especially for sour starch. Cassava starches and, to a lesser extent, cassava flours can help to improve the quality of gluten-free breads.

1. Introduction

A large part of the population suffers from celiac disease or has some kind of gluten intolerance. Bread is the staple food for a large segment of humanity. In recent years, gluten-free bread production research has increased considerably. However, the organoleptic quality of these breads still has to improve.

Among the starches and flours more widely used in commercial gluten-free breads are rice flour and maize starch. Nevertheless, cassava flour (CF) and starch are also used in many commercial formulations, usually as a supplement (Roman, Belorio, and Gómez 2019). Research on cassava influence in gluten-free bread is low in comparison to research on other flours and starches (Masure, Fierens, & Delcour, 2016). However, López, Guimarães Pereira, & Junqueira (2004) and Sanchez, Osella, and De la Torre (2002) have already studied the optimization of bread formulation with maize starch, rice flour and cassava starch. The study showed that a small part of cassava starch was beneficial for the quality of gluten-free bread. Milde, Ramallo, and Puppo (2012) discussed the possibility of making gluten-free bread with cassava starch as the main ingredient. This starch had also been proposed to improve the quality of sorghum bread (Onyango, Mutungi, Unbehend, & Lindhauer, 2011).

We can also find sour cassava starch (SCS) on the market, apart from native (sweet) cassava starch (NCS) and flour. SCS is obtained by fermenting cassava starch with different microorganisms (Penido et al., 2018) and has distinct properties from NCS. SCS is widely used in Brazil and Colombia for specific recipes such as cheese bread (Rodriguez-Sandoval, Franco, & Manjarres-Pinzon, 2014). The potential of SCS for gluten-free bread production has been studied in recent years (Díaz, Dini, Viña, & García, 2019; Monthe et al., 2019), but until now it has not been compared to other cassava products. Furthermore, it is known that flours and starches have different water absorption properties that influences in the quality and characteristics of gluten-free breads (Mancebo, Merino, Martínez, & Gómez, 2015; Martínez & Gómez, 2017). It was demonstrated that cassava starch has higher absorption capacity than other starches. However, its effects were not compared with other gluten free flours or with the different type of cassava starches (Waterschoot, Gomand, Fierens, & Delcour, 2015). This comparison could be helpful to gluten-free bread making.

This study analyses how substituting a mixture of maize starch and rice flour with up to 20% cassava starch (native or sour) or cassava flour affects bread quality. For this purpose, breads made without cassava (control), and with 10% and 20% of native cassava starch (NCS10, NCS20), sour starch (SCS10, NCS20) or flour (CF10, CF20), were elaborated. The breads produced were analysed for weight loss during baking, specific volume and texture. Dough rheology and flour pasting

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and hydration properties were also analysed, and a focus group was performed to evaluate the sensory characteristics.

2. Materials and methods

2.1. Materials

Gluten-free breads were made with rice flour (Dacsa Atlantic, Lisboa, Portugal), maize starch (Tereos, Syral Iberia SAU, Zaragoza, Spain) and cassava flour, native (sweet) cassava starch or sour cassava starch (Yoki Alimentos SA, Paraná, Brazil). The rest of the ingredients used were refined sunflower oil (Abaco, Tarragona, Spain), sugar (AB Azucarera Iberica, Valladolid, Spain), instant dry baker's yeast (Dosu Maya Mayacilik A.S, Istambul, Turkey), hydroxypropyl methylcellulose K4M (Rettenmaier Iberica, Barcelona, Spain), psyllium husk fibre (Rettenmaier Iberica, Barcelona, Spain), salt (Disal, Madrid, Spain) and tap water.

2.2. Methods

2.2.1. Flour characteristics (hydration and pasting properties)

The hydration properties of the flour and starch mixtures used in bread formulations (Table 1) were studied. Pasting properties of each of the flours and starches were also evaluated. All these measurements were carried out in duplicate.

Water holding capacity (WHC) is the amount of water retained by the sample without the presence of any stress. Swelling volume (SV) is the volume occupied by a known amount of sampling after being hydrated with water. Both properties were evaluated according to de La Hera, Gómez, & Rosell (2013) with modifications. One hundred mL of distilled water were added to a graduated cylinder with 5 g of flour previously weighed. Then, this mixture was kept at room temperature for 24 h to allow flour hydration. After this time, the volume of the hydrated flour was measured; next, the supernatant was decanted, and the residue was weighed. WHC was calculated as grams of water retained per gram of flour (dry basis). SV was determined as the volume of the swollen sample per the initial sample dry weight.

Water binding capacity (WBC) is the amount of water retained by the sample under low-speed centrifugation. It was determined according to the AACC method 56-30.01 (AACC, 1999). Five grams of flour were mixed with 25 mL of distilled water in centrifuge tubes. The mixture was centrifuged at 2000×g for 10 min and the supernatant was removed. WBC was calculated as the amount of water retained per gram of dry sample.

Water absorption index (WAI) was measured following the method described by Cornejo and Rosell (2015) with slight modifications: 1.5 g (±0.01 g) of flour were dispersed in 30 mL of distilled water in centrifuge tubes and, then, heated at 90 °C for 10 min in a water bath. The heated mixture was centrifuged at 3000×g for 10 min. After this, the supernatant was decanted, and the residue was weighed. WAI was calculated by dividing the weight of sediment by the dry weight of the original sample.

The pasting properties were studied using a Rapid Visco Analyser (RVA) (Model RVA-4C, Newport Scientific Pty. Ltd., Warriewood, Australia). Three and a half g (±0.01 g) of the sample (dry basis) were dispersed in 25 g (±0.01 g) of distilled water. The mixture was subjected to heating and cooling cycles according to the AACC method 76-21.02 (AACC, 1997).

Table 1
Formulation of bread doughs (g/100 g of flour-starch blends).

	Control	CF10	CF20	NCS10	NCS20	SCS10	SCS20
Maize starch (g)	50	45	40	45	40	45	40
Rice flour (g)	50	45	40	45	40	45	40
Cassava flour (g)	–	10	20	–	–	–	–
Native cassava starch (g)	–	–	–	10	20	–	–
Sour cassava starch (g)	–	–	–	–	–	10	20
Oil (g)	6	6	6	6	6	6	6
Sugar (g)	5	5	5	5	5	5	5
Yeast (g)	3	3	3	3	3	3	3
HPMC (g)	2	2	2	2	2	2	2
Psyllium (g)	2	2	2	2	2	2	2
Salt (g)	1,8	1,8	1,8	1,8	1,8	1,8	1,8
Water (g)	110	110	110	110	110	110	110

CF (Cassava flour). NCS (Native cassava starch). SCS (Sour cassava starch).

2.2.2. Bread formulation

Bread formulations are shown in Table 1. All ingredients, except dry yeast and tap water, were mixed at speed 1 for 1 min using a KitchenAid Professional mixer (Kitchen Aid, St. Joseph, Michigan, USA) with a dough hook (K45DH). The yeast was mixed with water for its rehydration; then, it was mixed with the rest of the ingredients for 8 min at speed 2; 150 g portions of bread dough were placed into oil-coated aluminium pans (159 × 109 × 39 mm) and fermented at 30 °C and 90% RH for 60 min. Doughs were baked at 190 °C for 40 min after fermentation. The aluminium pans were removed and the breads were allowed to cool for 60 min at room temperature and later placed in polyethylene bags. They were stored at 22 °C for 7 days. Texture was analysed after 24 h and after seven days of storage 7 (hardness) after elaboration. All the bread elaborations were performed twice.

2.2.3. Evaluation of dough rheology

The rheological behaviour of bread doughs without yeast was studied after a 2 min rest using a Thermo Scientific Haake RheoStress controlled strain rheometer (Thermo Fisher Scientific, Schwerte, Germany), at a constant temperature (25 °C) controlled by a Phoenix II P1-C25P water bath (Thermo Fisher Scientific, Schwerte, Germany). The rheometer was equipped with a parallel-plate geometry (60 mm diameter titanium serrated plate-PP60 Ti) at a 3 mm gap. First, a strain sweep test was performed with a strain range of 0.1–100 Pa and a constant frequency of 1 Hz to identify the linear viscoelastic region. Then, a strain value included in the linear viscoelastic region was chosen, and it was used in a frequency sweep test with a frequency range of 10 to 0.1 Hz. Values of elastic modulus (G' [Pa]) and viscous modulus (G'' [Pa]) were obtained based on angular frequency values (ω [Hz]). Each dough was analysed in duplicate.

2.2.4. Bread characteristics

Bread characteristics were evaluated 24 h after baking.

The weight loss of bread during baking was determined in four pieces of bread from each batch. Bread volume was measured in the same four pieces of bread of each elaboration using a Volscan Profiler volume analyser (Stable Microsystems, Surrey, UK). Specific volume was calculated dividing bread volume by bread weight and then expressed as cm^3/g.

Crumb texture was determined by a Texture Profile Analysis (TPA) double compression test using a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK). A 25-mm diameter cylindrical aluminium probe was used. The experimental conditions were a penetration depth of 15%, a trigger force of 5 g, a test speed of 1 mm/s, and a 10 s delay between the first and second compression. Two pieces of bread from each elaboration were sliced into loaves of 30 mm thick. The two central slices were used in the measurement. Hardness (N) and cohesiveness were calculated. The hardness was also measured after 7 days to evaluate its behaviour during storage.

2.2.5. Focus group

To evaluate gluten-free bread texture, flavour, and sensory differences between each sample, a focus group evaluation was performed. It was conducted by five experts aged between 24 and 60. The focus group evaluation took place in a room with proper space and luminosity where drinking water was available for the participants. Samples were presented for each expert, codified with numbers of 4 digits. Experts evaluated each sample and wrote their notes in individual sheets of papers. In the end, all the notes were discussed in group and final decisions were registered.

2.2.6. Statistical analysis

The results were evaluated by one-way analysis of variance (simple ANOVA) using Statgraphics Centurion XVII software (StatPoint Technologies, Warrenton, USA). The Fisher's least significant differences (LSD) test was used to differentiate the means with significance level of 95% ($p < 0.05$).

3. Results and discussion

3.1. Starch and flour properties

The hydration properties are shown in Table 2. Concerning cold hydration properties, no significant differences were observed when SCS and NCS were incorporated to maize starch and rice flours. However, when CF was added, WHC and WBC increased. Similar results were found in other study with mixes of flour, starch and protein (Mancebo, Rodriguez, & Gómez, 2016), since the plant protein, presented in cassava flour, has a higher hydration capacity than starch. On the other hand, in terms of hot hydration properties (WAI), no significant differences were observed when CF was added. Although there were some differences with the addition of NCS, no clear trend was observed. Gelatinized starch characteristics, rather than cold starch ones, account for these differences. When SCS was added, WAI was reduced, which may be related to the starch degradation in the fermentation and acidification processes (Díaz, Dini, Viña, & García, 2018). These authors observed that sour starch pastes showed lower apparent viscosities related to their lactic and/or butyric acid content. Starch degradation also influenced starch gelatinization, as can be seen in the pasting properties results.

Pasting properties are shown in Fig. 1. A higher gelatinization peak (almost double) in cassava starch in comparison to other starches and flours, was shown. Monthe et al. (2019) had already observed this difference between cassava starch and cereal starches. SCS presented lower gelatinization peak than NCS. This evidence was due to the degradation of starch granules and molecules in the fermentation/acidification (Díaz et al., 2018). The lower peak of CF compared to starch was related to the lower starch content, about 80%, of cassava flour due to the presence of other components such as minerals, protein, lipids and fiber (Chisenga, Workneh, Bultosa, & Alimi, 2019). A later gelatinization peak was also

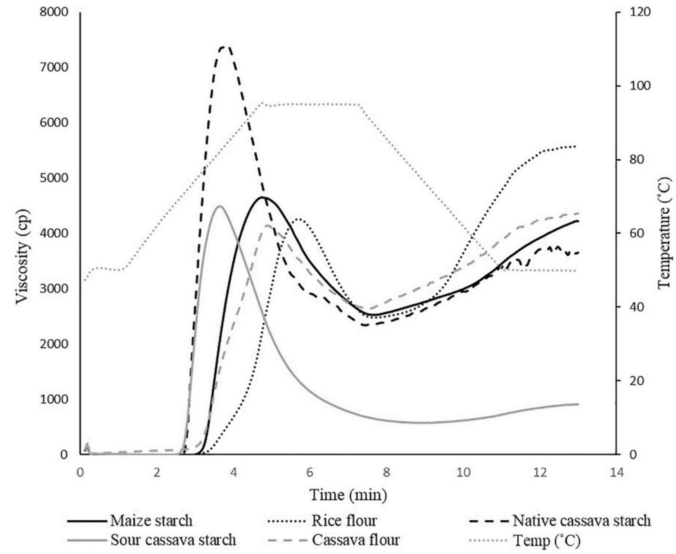

Fig. 1. Pasting profile of flours and starches used in gluten-free bread elaborations.

noticed for maize starch and rice flour, which was already observed in other researches (Onyango et al., 2011a). Different characteristics of starches explained this evidence, including the starch granules size, the presence of damaged and native starch and the concentration of amylose:amylopectin (Roman, Gómez, & Martínez, 2021). But in the case of flours, including cassava flours, the larger particle size (compared to starches) and the protection of starches by outer layers of other components also play a role. This fact hinders the water absorption and delays gelatinization (Roman, Gómez, Li, Hamaker, & Martínez, 2017). Finally, cassava products (flours or starches) showed less retrogradation than maize starches or rice flour, confirming the observations of other authors (Chisenga et al., 2019; Waterschoot et al., 2015). Jane et al. (1999) attributed these differences to the influence of the length of the amylopectin chains on retarding retrogradation.

3.2. Rheology of bread doughs

The rheological properties of gluten-free bread doughs are shown in Table 3. As in the cold hydration properties, no significant differences were observed in G′, G″ and G* values between control dough and those incorporating NCS and SCS. NCS20 doughs slightly increased tan δ. However, when using cassava flour, G′, G″ and G* values were enhanced, and tan δ was reduced. This occurred to a greater extent rising the percentage of cassava flour incorporated into the dough. Other studies had already shown that the higher the WHC or WBC values of the ingredients, the greater was the increase in the rheological values of

Table 2
Hydration properties of flour-starch blends prepared with rice flour, maize starch and 10% or 20% of cassava flour, native cassava starch or sour cassava starch.

	WHC (g/g)	SV (mL/g)	WBC (g/g)	WAI (g/g)
Control	1.46 ± 0.02a	2.43 ± 0.31 ab	0.97 ± 0.01a	7.99 ± 0.02d
CF10	2.27 ± 0.17b	2.74 ± 0.16 ab	1.25 ± 0.04b	7.93 ± 0.18cd
CF20	2.52 ± 0.13b	3.09 ± 0.62b	1.53 ± 0.08c	8.02 ± 0.05d
NCS10	1.57 ± 0.17a	2.31 ± 0.16a	0.94 ± 0.04a	7.74 ± 0.12c
NCS20	1.25 ± 0.07a	2.09 ± 0.16a	0.93 ± 0.05a	8.37 ± 0.12e
SCS10	1.53 ± 0.24a	2.40 ± 0.31 ab	0.93 ± 0.02a	7.28 ± 0.11b
SCS20	1.41 ± 0.07a	2.19 ± 0.00b	0.91 ± 0.02a	6.53 ± 0.07a

WHC (Water holding capacity). SV (Swelling Volume). WBC (Water binding capacity). WAI (Water absorption index). CF (Cassava flour). NCS (Native cassava starch). SCS (Sour cassava starch). The values with the same letter in the same column do not present significant differences, according to Fisher's test ($p < 0.05$). Two replications.

Table 3
Rheological parameters of gluten-free bread doughs with 10% or 20% of cassava flour, native starch or sour starch.

	G’ (Pa)	G’ (Pa)	tan δ	G* (Pa)
Control	3078 ± 40a	1356 ± 46a	0.441 ± 0.009c	3363 ± 55a
CF10	9053 ± 584b	3196 ± 194b	0.353 ± 0.001b	9601 ± 615b
CF20	23018 ± 633c	6459 ± 104c	0.281 ± 0.003a	23907 ± 637c
NCS10	2804 ± 923a	1266 ± 10a	0.452 ± 0.020cd	3077 ± 80a
NCS20	2756 ± 13a	1278 ± 8a	0.465 ± 0.000d	3037 ± 16a
SCS10	2828 ± 397a	1276 ± 193a	0.450 ± 0.010cd	3102 ± 441a
SCS20	2736 ± 175a	1222 ± 107a	0.446 ± 0.011cd	2997 ± 203a

G’ (elastic modulus), G’’ (viscous modulus), tan δ (G’‘/G′), G* (complex modulus). CF (Cassava flour). NCS (Native cassava starch). SCS (Sour cassava starch). The frequency sweep test was evaluated with frequency range of 10 to 0.1 Hz. The values with the same letter in the same column do not present significant differences, according to Fisher's test ($p < 0.05$).

gluten-free bread doughs (Roman, Reguilón, Martínez, & Gómez, 2020). Additionally, these authors found no correlation between hot absorption or pasting properties and dough rheology. This is logical since the gelatinization temperature of the starch is not reached in the dough elaboration process, as is the case in the analysis of WAI or pasting properties.

3.3. Gluten-free bread characteristics

Physical characteristics of gluten-free bread are shown in Table 4. In terms of specific volume, adding 10% of cassava starch or flour increased the specific volume of gluten free breads compared to the control. However, specific volume was reduced when 20% of these ingredients were added, compared to 10%, although in the case of NCS it was still higher than the control. This reduction was smaller for NCS, slightly higher for SCS, and drastic for CF. These results confirm what Sanchez et al. (2002) observed, namely the beneficial effects on the specific volume of a small amount of cassava starch by means of a response surface design. The CF20 bread had a much lower specific volume than the control bread (Fig. 2). Specific volume is influenced by the water absorption capacity of the components, as well as by dough rheology. Usually, the lower the rheological values, G′, G″ and G*, the higher the specific volume up resulting in a point where dough collapses and falls (Mancebo, Martínez, Merino, de la Hera, & Gómez, 2017). This evidence can explain the lower volume of CF20 bread, but not the rest of the differences. The volume and expansion during fermentation and baking may also be influenced by the internal structure of the doughs, that is related to the manner in which different starchy substances are compacted into this structure (Martínez & Gómez, 2017). Thus, it is known that bread with maize starch develops higher volumes than those made with rice flour (Belorio & Gómez, 2020; Mancebo et al., 2015). In this way, partial substitution of rice flour by cassava starch can be used to increase the specific volume of breads, since starch granules has a smaller size and a more regular shape than flour particles (Roman et al., 2021; Xiao et al., 2020; Jackson, 2003). But it seems that the differences between cassava starches, mainly in pasting and hot hydration properties, do not affect the specific volume of the breads, at least with additions of up to 20%. Thus, the cold properties of starches and flours, and therefore, their effect on dough rheology and on gas retention during fermentation, affect the specific volume to a greater extent than hot properties. A rise in dough hydration can be used to compensate high rheological values. However, with increasing hydration (**120%)** of CF20 bread the specific volume softly rose, although these breads were smaller than the control and the alveoli were much bigger and more heterogeneous (data not shown).". This fact confirmed the effect of the internal structure on expansion during fermentation and baking.

Table 4
Specific volume, weight loss after baking and textural parameters of gluten-free bread with 10% or 20% of cassava flour, native starch or sour starch.

	Specific volume (cm^3/g)	Weight loss (%)	Hardness 24 h (N)	Hardness 7 days (N)	Cohesiveness 24 h
Control	5.10 ± 0.00b	24.58 ± 0.65b	2.36 ± 0.33a	4.37 ± 0,54b	0.62 ± 0.04a
CF10	5.39 ± 0.11c	25.73 ± 0.59bc	1.39 ± 0.08a	2.27 ± 0,12a	0.68 ± 0.01abc
CF20	2.08 ± 0.11a	22.57 ± 0.62a	14.10 ± 1.52b	21.59 ± 0,95c	0.68 ± 0.01abc
NCS10	5.70 ± 0.12d	26.28 ± 0.02c	1.36 ± 0.15a	2.38 ± 0,51a	0.72 ± 0.01cd
NCS20	5.39 ± 0.08c	25.50 ± 0.33bc	1.26 ± 0.03a	3.04 ± 0,30a	0.74 ± 0.01d
SCS10	5.77 ± 0.04d	26.17 ± 0.35c	1.50 ± 0.16a	2.63 ± 0,22a	0.67 ± 0.02 ab
SCS20	5.28 ± 0.12bc	25.19 ± 0.78bc	1.79 ± 0.16a	3.46 ± 0,68 ab	0.65 ± 0.01 ab

CF (Cassava flour). NCS (Native cassava starch). SCS (Sour cassava starch). The values with the same letter in the same column do not present significant differences, according to Fisher's test ($p < 0.05$).

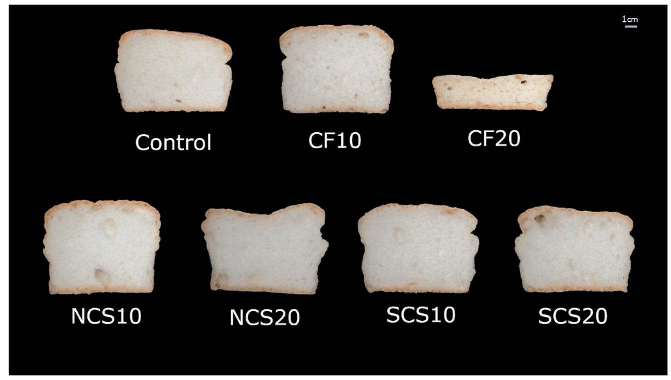

Fig. 2. Gluten-free bread central slices. CF (Cassava flour). NCS (Native cassava starch). SCS (Sour cassava starch).

Regarding weight loss during baking, the correlation between specific volume and weight loss was also confirmed, in agreement with other works (de La Hera, Rosell, & Gómez 2014; Mancebo et al., 2017). This can be explained by the larger surface area of bread with more volume. It entailed a greater exchange between the surface and the outside.

With regard to hardness, despite the fact that the breads with cassava starch present lower values than the control, no significant differences were observed between control bread and breads with NCS, SCS or CF10. The addition of 20% of NCS and SCS did not change the hardness either. Nonetheless, the CF20 bread showed higher hardness values. This fact could be related to the lower specific volume since the literature usually finds a correlation between hardness and specific volume (Jafari, Koocheki, & Milani, 2018; Mancebo et al., 2017; Martínez & Gómez, 2017).

After 7 days, hardness was still much higher in the CF20 breads. However, the breads with cassava starch (sweet or sour) and the CF10 had lower values than the control and, in general, the increase in hardness was not excessive. The hardness increase over time is usually higher as the specific volume is reduced, or as the initial hardness is increased (Pongjaruvat, Methacanon, Seetapan, Fuongfuchat, & Gamonpilas, 2014; Roman, Reguilon, Martinez, & Gomez, 2020), as in this case.

Regarding other textural parameters, a significant increase in cohesiveness was observed when NCS was added; this, however, did not occur with the addition of CF or SCS. The crumb texture was influenced by the specific volume of the breads, but also by the pasting properties of the starches and flours. The differences between the results of cohesiveness could be related to pasting properties given that the lower retrogradation of cassava starches indicates a less hardening of the doughs during cooling after baking. This lower retrogradation avoids the formation of breakable texture, although no significant differences were observed between SCS breads and control. The low specific volume and the high crumb compaction could also affect CF20 bread. This increase in cohesiveness is positive, as, in general, gluten-free breads tend to have a less cohesive crumb than wheat breads.

3.4. Focus group

In terms of the physical characteristics, differences were not found with regard to specific volume, except for CF20 bread and the tasters also confirmed a lower volume and a denser structure for this bread, as shown in Fig. 2. However, the CF20 bread cannot be compared with the rest of the breads because all the analysed parameters are strongly influenced by the specific volume. The focus group also analysed a CF20 bread with modified hydration (120%) which had a slightly higher volume than the one with 110% of hydration. Nevertheless, this bread did not reach the volume of the other breads, but its cell structure was much more open. The tasters also noted that the CF10 bread had a more open grain than the rest, as shown in Fig. 2. Therefore, the addition of cassava flour generates breads with a more open cell structure. That may be related to the particle size of flours and starches. It is a proven fact that starchy products with smaller particle size improve the incorporation of air as small bubbles, generating crumbs with a more closed and uniform cell structure, by avoiding coalescence phenomena (Roman, de la Cal, Gómez, & Martínez, 2018).

In the mouth, the control was defined as dry and brittle, with a not very cohesive crumb that absorbed water from the mouth when crumbling. The NCS breads were more cohesive, as indicated in the previous texture test. In the case of NCS10, there was also a cohesive and a less dry mouth feel. This effect was perceived more slightly in NCS20 so that NCS improved the texture in the mouth, especially at 10%. Regarding SCS breads, they were considered more cohesive and less dry than the rest. This evidence differs slightly from previous texture tests, where the SCS breads were less cohesive than the NCS and had no significant differences with the control. However, sometimes, sensory perception does not coincide with instrumental measurement. In this case, parameters such as the dryness of the breads may also influence this perception. The sensorial evaluation of CF breads was poor due to their excessive dryness and low cohesiveness, although to a lesser extent than the control. A more open cell structure was perceived when chewed.

In terms of taste, in general, no significant differences were observed between the control and NCS breads. The CF bread had a different taste from control bread but with a neutral taste. However, the SCS breads had a marked and more pronounced flavour -between sour and salty- than the other cases. This taste is not unpleasant and is related to the higher acidity of these starches due to the generation of lactic acid in the fermentation process (Penido et al., 2018). The acceptability of these breads will depend on the tastes of each consumer.

4. Conclusions

The addition of cassava to gluten-free breads, in small percentages, can help to improve the quality of the bread, especially its texture and mouth feel, as well as its specific volume. For this purpose, an addition of 10% is usually sufficient. Nonetheless, the way the cassava was incorporated affected the results. It is preferable as starch, since the flour can only be incorporated in low percentages. At these percentages, breads with cassava starch have a higher specific volume. Moreover, breads with cassava flour have a larger cell size than breads with cassava starch. SCS starches give slightly different breads from NCS starches in terms of taste and texture in the mouth. In both cases, the control bread was improved, but the final decision will depend on consumer taste.

CRediT authorship contribution statement

Teresa Sigüenza-Andrés: Data curation, Investigation, Formal analysis, Methodology, Resources, Writing – original draft, Writing – review & editing. **Cristina Gallego:** Data curation, Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. **Manuel Gómez:** Conceptualization, Validation, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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