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Gluten-free breads: a response to a technological challenge

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Abstract

The market of gluten-free foods has exploded in recent years and this growth can be essentially put down to an increasing incidence in celiac disease (about 1% in the world), or other allergic reactions to gluten consumption. The replacement of gluten presents a major technological challenge, as it is a very important component in relation to the overall quality and structure of baked products and this is particularly the case for bread. To date, few studies are published on gluten-free breads, which reflects the difficulty of the technological challenge and explain that most of gluten-free products on the market are poor quality and taste. Hence, the gluten-free sector needs to lose the image of being “better than nothing”, and offers a range of products that choice, taste and quality are improved to satisfy the growing demand. For this purpose, three gluten-free formulation and two baking processes have been defined. These formulations contain a mixture of starches and flours (rice, corn, cassava, potato and chestnut) combined with hydrocolloid and dairy ingredients to produce a gluten-free bread of similar quality than wheat bread. The aim of this work was to assess the effect of these formulations and baking processes on texture and sensory properties of GF breads. Physical properties were carried out on GF breads, textural and sensory analyses were also achieved on crust and crumb. Results showed that formulation and process play a key role on bread textural and sensory evaluation. Increasing amount of starch improved both crust and crumb properties. The crust texture was essentially affected by the baking process and the crumb sensory and textural attributes was more depending on the formulation.

Keywords: gluten free, bread texture, sensory analysis

Introduction

Gluten plays a major role in the overall quality and texture of baked products, especially bread. Gluten has unique viscoelastic properties and is the main structure-forming protein in flour which contributes to the good bread making ability of wheat dough. However, gluten is responsible for serious diseases like celiac disease (CD) or wheat allergy and gluten sensitivity [1]. In recent years, gluten-free (GF) market exploded due to the increasing incidence of these pathologies [2]. To date, a large number of bread-like GF products appears on the market claiming to look like traditional French bread. However, replacement of gluten presents a major technological challenge which explains that most of GF products are of poor quality and taste.

In this study, two baking processes and three formulations based on a mixture of flours and starches with xanthan gum were performed. Textural and sensory analyses were also achieved on crust and crumb of GF breads. The aim of this work was to assess the effect of these formulations and baking processes on texture and sensory properties of GF breads and to establish a correlation between texture parameters and sensory attributes of the final products.

Experimental

Bread making process and bread formulation

Firstly, dry ingredients were blended with oil, vinegar and egg white in a mixer (5KSM150PS, KitchenAid, St Joseph, MI, USA) during 1 minute. In the same time, yeast and sugar were dissolved in warm water (35 °C) and regenerated in the oven (Emeraude Prestige, HMI Thirode, Mitry-Mory, France) at 35 °C during 15 min. This suspension was added to the premixed ingredients. Subsequently, mixing was carried out at medium speed during 3 minutes. The resultant batter was placed in a rectangular pan for 30 minutes at 35 °C in the oven. Following this fermentation, the bread was baked in the oven. All baking was performed in two subsequent steps: (i) under moisture condition (steam 10%) at T1 (°C) during t1 (min), necessary stage creating a smooth and crispy crust and (ii) under dry condition at T2 (°C) during t2 (min) for the evaporation of water. After baking, the bread was allowed to cool down for 60 minutes at 25 °C. Fresh loaves were tested for textural and sensory evaluations. Table 1 summarised the different baking processes used and the three gluten-free formulations.

Table 1: Formulations and baking conditions.

| Samples codes | Ingredients (wt. %) | | | | | | | | | | | | | Moisture condition | | Dry condition | |
|---------------|---------------------|-------|-----------|-------------------------|------------|-------------|---------------|----------------|-------------|-----------|-----------|------|---------|--------------------|----------|---------------|----------|
| | Water | Sugar | Dry yeast | Fermented cassava flour | Rice flour | Corn starch | Potato starch | Chestnut flour | Xanthan gum | Olive oil | Egg white | Salt | Vinegar | T1 (°C) | t1 (min) | T2 (°C) | t2 (min) |
| 1S1P 1S2P | 44 | 0.6 | 1.2 | 2.6 | 20.9 | 0 | 11.4 | 9.6 | 1.1 | 2.1 | 4.7 | 0.8 | 1 | 140 170 | 30 15 | 185 | 75 60 |
| 2S1P 2S2P | 44 | 0.6 | 1.2 | 2.6 | 12.4 | 12.4 | 11.4 | 5.7 | 1.2 | 2.1 | 4.6 | 0.8 | 1 | 140 170 | 30 15 | 185 | 75 60 |
| 6C1P 6C2P | 44 | 0.6 | 1.2 | 8.8 | 12.4 | 6.2 | 11.4 | 5.7 | 1.2 | 2.1 | 4.6 | 0.8 | 1 | 140 170 | 30 15 | 185 | 75 60 |

Texture of bread

The puncture test (PT) was carried out with a TA-XT plus texturometer (Stable Micro Systems, Godalming, United Kingdom) with a 5 kg load cell, to evaluate the texture of crust by punching the sample at 3 different levels of the crust isolated from the crumb of 3 slices of cold bread, with a cylindrical probe of 2 mm-diameter at 2 mm.s⁻¹ cross-speed. The compression used was 80% with a trigger force of 5 g. The failure force, calculated as the peak force, and the failure deformation, defined as the deformation at the peak point, were determined according to studies by Jackman and Stanley [3]. The average value was calculated for each bread.

Crumb texture profile analysis (TPA) was performed using the same device. A 2 cm-thick slice was compressed in dual cycle using a 25 mm cylinder probe with the maximum compression of 40% with a trigger force of 5 g at a crosshead speed of 2 mm.s⁻¹ and the waiting time between the first and second compression cycle was 5 s. Hardness, cohesiveness, springiness, adhesiveness, resilience and chewiness were calculated from the TPA curve [4]. Each sample was assessed 6 times at different points and mean response for the crumb properties recorded.

Sensory quantitative descriptive analysis (QDA)

Then, descriptive analysis was conducted in the sensory laboratory of UMR Qualisud (CIRAD, Montpellier, FRANCE). 13 trained panellists (3 males and 10 females including 3 celiac people) were selected for their sensory ability and availability for the study. Training was conducted with 4 different breads on 2 sessions. The first one was to define an appropriate descriptive vocabulary to characterise the crust and the crumb. Finally, 7 quantitative attributes were selected for the crust and 7 different for the crumb (Table 2) and in the same time, each term should be given a definition by consensus. The second one was to score on a structured discrete scale (0-10) with “low intensity” corresponding to 0 and “high intensity” to 10, each attribute previously selected.

Descriptive analysis was conducted on 6 breads cooked with different formulations and processes. The samples (crust and crumb separately) were cut into 1 cm slices, served monadically according to Williams’ Latin square designs and were coded with random numbers. The analyses were realised in duplicate. The room was temperature and humidity controlled (22 °C and 45% respectively) and white light was used.

Table 2: List of sensory attributes.

| Sense | Attribute | |
|---------------------|---------------|------------|
| | Crust | Crumb |
| <u>A</u> pppearance | Brownness | |
| | Thickness | Alveolate |
| | Heterogeneity | |
| <u>O</u> dor | Bread | Bread |
| | | Cereal |
| <u>M</u> outh feel | Crispy | Soft |
| | | Wet |
| | | Stickiness |
| <u>A</u> roma | Cereal | Cereal |
| | Grilled | |

Experimental design and statistical analysis were established using XLSTAT software (2019, Addinsoft, USA).

Results and discussion

For the crust texture, the failure force, related to the crust hardness, was significantly affected by the formulation and the process (Table 3). Significant crust softening was observed when decreasing the corn starch content. Furthermore, the 1P process significantly increased the crust hardness: temperature and duration of the first step of the baking process were relevant for the crust formation. For the failure deformation, low values were associated to firmer and elastic crust, while high values suggesting soft and plastic-like crust. When the 1P process was used, no significant ($p \leq 0.05$) difference was observed among the three formulations. However, regarding the 2P process, a significant reduction of the failure deformation was noticed when decreasing the corn starch content.

Table 3: Textural parameters of bread crust and crumb.

| Sample code | Puncture test parameters of crust | | | Texture profile analysis parameters of crumb | | | | |
|-------------|-----------------------------------|--------------------------|-------------------------|--|---------------------------|---------------------------|--------------------------|---------------------------|
| | Failure force (N) | Failure deformation (mm) | Hardness (N) | Adhesiveness (N.s) | Springiness ¹ | Cohesiveness ¹ | Chewiness (N) | Resilience ¹ |
| 1S1P | 10.02(4.39) ^b | 3.32(0.93) ^{ab} | 4.56(0.73) ^b | -0.31(0.08) ^b | 0.61(0.07) ^{bc} | 0.74(0.02) ^{bc} | 2.06(0.48) ^b | 0.31(0.02) ^{bcd} |
| 2S1P | 13.84(3.23) ^a | 3.44(0.87) ^{ab} | 2.14(0.32) ^c | -0.06(0.07) ^a | 0.61(0.03) ^{abc} | 0.81(0.03) ^a | 1.06(0.18) ^c | 0.38(0.03) ^a |
| 6C1P | 10.92(2.41) ^{ab} | 3.55(0.59) ^{ab} | 4.65(0.89) ^b | -0.35(0.11) ^b | 0.69(0.03) ^a | 0.74(0.02) ^{bc} | 2.36(0.45) ^{ab} | 0.29(0.02) ^{cd} |
| 1S2P | 4.36(2.02) ^c | 3.79(1.13) ^a | 5.92(0.85) ^a | -0.39(0.06) ^b | 0.66(0.07) ^{ab} | 0.70(0.03) ^c | 2.77(0.59) ^a | 0.28(0.02) ^d |
| 2S2P | 7.45(2.13) ^{bc} | 1.67(0.49) ^c | 2.75(1.45) ^c | -0.046(0.05) ^a | 0.63(0.09) ^{ab} | 0.79(0.07) ^a | 1.38(0.71) ^c | 0.34(0.05) ^{ab} |
| 6C2P | 5.88(1.79) ^c | 2.54(0.72) ^{bc} | 2.92(1.46) ^c | -0.12(0.09) ^a | 0.55(0.08) ^c | 0.79(0.05) ^{ab} | 1.21(0.59) ^c | 0.34(0.05) ^{bc} |

For each parameter values followed by the same letter are not significantly different at $p \leq 0.05$. Standard deviations are given within brackets. ¹Dimensionless terms

The sample 1S2P, which contains less starch and is defined by an overall shorter cooking duration and a higher temperature of the first stage, presented higher mean of crumb hardness and was statistically ($p \leq 0.05$) different from the others. The adhesiveness was separated into two significant different groups depending on the quantity of corn starch in the formulation: a reduction of this latter resulted in a significant decrease in adhesiveness. The springiness is an indicator of crumb elasticity and hence of fresh bread quality. This parameter appeared to be influenced both by the process and the formulation (cassava flour content) as the sample 6C1P presented higher mean of springiness and was statistically ($p \leq 0.05$) different from the others. The cohesiveness reflects the internal cohesion of the material and, therefore, is an indicator of bread quality. High cohesiveness is desirable because the crumb disintegrates less during mastication. The sample with higher starch content (2S), regardless the process, presented higher mean of cohesiveness and was statistically ($p \leq 0.05$) different from the others. The chewiness is related to the energy required to masticate a solid food product to a state ready for swallowing [4]. Chewiness is consequently an indicator of bread quality: an increase of this parameter is associated to a decline of crumb properties. This parameter appeared to be influenced both by the process and the formulation. The resilience, like springiness, is commonly related to the loss of crumb elasticity and the decline of crumb properties of breads [5]. The sample 2S1P presented the highest mean of resilience and was statistically ($p \leq 0.05$) different from the others. A reduction of this parameter was observed when decreasing the corn starch content in the formulation.

Increasing concentration of starch improved both crust and crumb properties. Starch plays a key role on the bread texture, through its gelatinization and gel-forming properties. Starch gives to dough adequate viscosity to retain gas bubbles and a sufficient elasticity to allow the bubbles to expand during baking. On the other hand, the baking process could also have a negative effect on the bread texture. The findings suggested that the impact of the process was enhanced when the formulation contains high amount of cassava flour (6C).

For the sensory analysis, the panel's performance was assessed and was good in terms of agreement, reliability and repeatability for all the attributes. ANOVA results showed sensory descriptors that could statistically discriminate 6 different breads samples.

The correlation of instrumental parameters with sensory attributes was performed by a Principal Component Analysis (PCA). The PCA of the crust (Figure 1) represents 93.53% of the variance carried by 7 sensory attributes. Figure 2 shows the PCA for the crumb which represent 80.24% of the total variation.

For the crust (Figure 1), instrumental attributes "PT_Failure deformation" and "PT_Failure force" were well correlated ($p \leq 5\%$) with the sensory attributes "Ar_Grilled", "Ap_Brownness" and "Ap_Thickness", "M_Crispy", respectively. PC1 was positively correlated to "Ar_Grilled", "Ap_Brownness" and "PT_Failure deformation" (and negatively with "Ap_Heterogeneity"). The score plot shows that these qualities predominated for 1S formulations. Indeed, these formulations contain (i) lower starch that could explain a high failure force deformation by the softening of the crust and (ii) higher chestnut contents giving darker color and grilled taste of the crust. The second dimension of the PCA was positively correlated with "Ap_Thickness", "M_Crispy" and "PT_Failure force" (and negatively with "Ar_Cereal"). These characteristics are related to the 1P process: a longer primary cooking time at a lower temperature improved crust texture by increasing crust hardness and thickness. Also, a shorter second cooking time at higher temperature gave a more intense cereal aroma.

For the crumb (Figure 2), the first dimension of the PCA correlates the instrumental attributes "TPA_Adhesiveness", "TPA_Cohesiveness", "TPA_Resilience" with the sensory attributes "Ap_Alveolate". On

the opposite, this first dimension also correlates “TPA_Chewiness”, “TPA_Hardness” with “M_Stickyness” and “M_Wet”. So, the crumb sensory and textural attributes were more depending on the formulation: corn starch improved crumb characteristics and fermented cassava flour has an incidence on crumb taste. The overall quality was rating for the bread and no significant difference were observed, between 6.02 (6C2P) and 6.79 (2S1P).

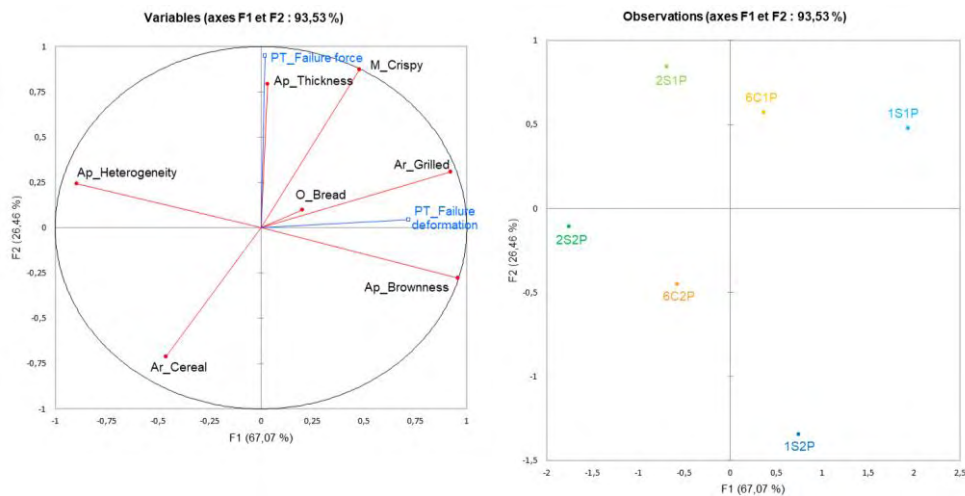


Figure 1: Principal Component Analysis (PCA) biplot of the 7 sensory attributes (in dark) and the 2 instrumental parameters (supplementary variable in blue) on the crust.

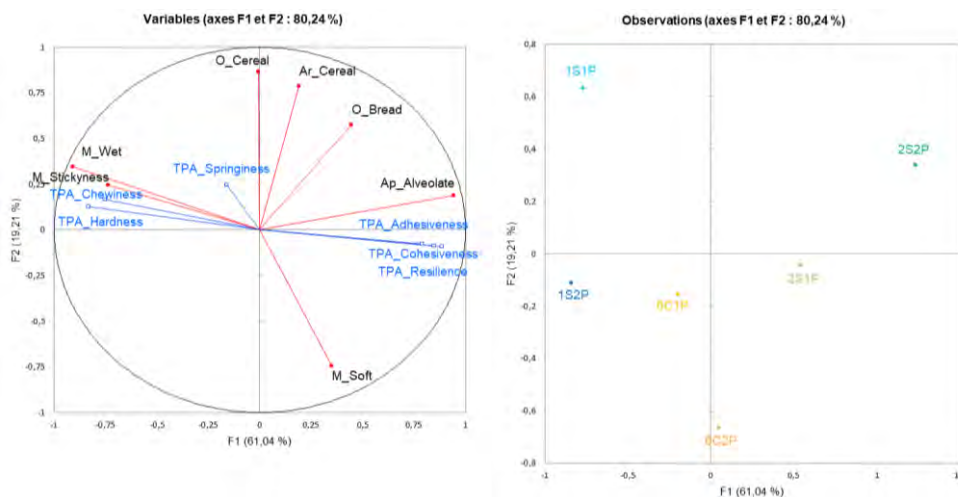


Figure 2: Principal Component Analysis (PCA) biplot of the 7 sensory attributes (in dark) and the 2 instrumental parameters (supplementary variable in blue) on the crumb.

Conclusion

The textural and sensory results showed that formulation and process play a key role on bread textural and sensory evaluation. The substitution of gluten is possible and results show that GF breads obtained from these formulations and processes have a good overall quality. Based on these results, new formulations and processes for GF bread have potential in new recipes to improve the quality of GF market products.

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