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Development of Gluten-Free Breads Using Andean Native Grains Quinoa, Kañiwa, Kiwicha and Tarwi †

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Abstract: The aim of this study was to develop gluten-free breads using the flours of Andean native grains. The following native grains were used: quinoa (*Chenopodium quinoa*) Pasankalla variety, kiwicha (*Amaranthus caudatus*) Centenario variety, kañiwa (*Cheopodium pallidicaule*) Illpa Inia variety and tarwi (*Lupinus mutabilis*) Blanco de Yunguyo variety. The formulations of the breads with Andean grains flours were optimized using the Mixture Design and the Central Composite Rotational Design, analyzing the dough's textural properties (firmness, consistency, cohesiveness and viscosity index), specific volume and crumb texture. Potato starch and xanthan gum were used in the preparation of the breads. The optimized formulations of the gluten-free breads with Andean grain flours were composed of quinoa (46.3%), kiwicha (40.6%), kañiwa (100%) and tarwi (12%) flours. The gluten-free breads developed showed acceptable specific volume and low crumb firmness and could help to improve the nutrition of celiac patients.

Keywords: quinoa; kiwicha; kañiwa; tarwi; gluten-free bread

1. Introduction

The gluten-free products market has increased throughout Latin America, especially in Peru, where there has been an increasing demand for gluten-free bread products in supermarkets, due to the increase in patients diagnosed with celiac disease and consumers seeking "healthier" alternatives. However, these are not necessary healthier, because the gluten-free bakery products on the market are made from starches or white rice flour, which are lacking in high quality proteins and important micronutrients.

Andean grains such as quinoa, kiwicha, kañiwa and tarwi do not contain peptides similar to wheat gluten; therefore, they are raw materials appropriate for consumption by celiacs. Likewise, these grains are sources of starches (more than 70% of their composition) [1–3], which are necessary to create bread structure [4]. On the other hand, tarwi is a legume also known as the Andean soybean because of its high protein and oil content (almost 50% and around 20%, respectively). The oil of tarwi could function as a natural emulsifier to retain the gas produced during the fermentation of gluten-free breads [5]. Quinoa is appreciated because of its high protein quality, having a balanced essential amino acid composition, and it is also considered a source of fiber and minerals [6,7]. Kiwicha is a very good source of iron, calcium and zinc. It contains more zinc and iron than conventional maize and beans [8]. Kañiwa, the least studied Andean grain, grows mainly in Peru and Bolivia, between 3500 and 4200 m above sea level where the climatic conditions are extreme [9]. Its small grains contain

more protein than the common cereals; it has a good content of essential amino acids; it is rich in lysine, the first limiting amino acid in all cereals; it is rich in unsaturated fatty acids; and it is an excellent source of dietary fiber and an important source of minerals, especially iron, calcium, phosphorus and vitamins such as riboflavin [10].

The inclusion of these grains in the formulations of gluten-free breads is promising. Therefore, the aim of the research was to develop gluten-free breads with quinoa, kiwicha and kañiwa flours, and a bread with the mixture of quinoa and tarwi, using the response surface methodology, in order to find the proportions of the ingredients that can produce bread with acceptable quality.

2. Materials and Methods

2.1. Conditioning and Characterization of Raw Materials

Quinoa (*Chenopodium quinoa*) Pasankalla variety and kiwicha (*Amaranthus caudatus*) Centenario variety were supplied by the Cereals and Native Grains Program at the National Agrarian University La Molina, kañiwa (*Cheopodium pallidicaule*) Illpa Inia variety was supplied by ILLPA Puno Peru Agricultural Experimental Station, and tarwi (*Lupinus mutabilis*) Blanco de Yunguyo variety was bought from the local market of Cajamarca-Peru. Tarwi grains were conditioned, in order to eliminate the alkaloids, according to the procedure described by Jacobsen & Mujica [11]. All the grains were milled using a hammer mill (Retsch SR 300, Haan, Germany), and the proximal composition of the flours was determined following the procedures of the AOAC (2000) [12].

2.2. Experimental Design

The mixture design was used to optimize the textural properties (firmness, consistency, cohesiveness and viscosity index) of the gluten-free doughs with quinoa and kiwicha flours. For the inclusion of tarwi in the gluten-free bread formulation, the Central Composite Rotational Design (CCRD) was used; under the same principle of optimizing the dough textural properties and for the case of kañiwa bread, the CCRD was used to optimize the bread volume and backing loss.

The variables for the mixture design were the proportions of water (70–110%), xanthan gum (0.5–2%) and quinoa or kiwicha flour (10–50%). In the case of CCRD, the variables were the proportions of water (75–160%) and tarwi flour (10–30%).

In the case of the gluten-free breads with quinoa, kiwicha and tarwi, the target was to find the optimal levels of the variables that could imitate the textural properties of a dough control (3.69 ± 0.2 N of firmness; 56.5 ± 3.7 N.s of consistency; 2.7 ± 0.2 N of cohesiveness and 36.2 ± 2.1 N.s of viscosity index), which was previously developed and showed good quality properties [13].

In the case of the gluten-free bread with kañiwa, the variables were the proportions of water (75–125%), xanthan gum (0.35–0.65%) and kañiwa flour (40%). The optimization criteria were the maximization of the specific volume of the bread and the minimization of the baking loss.

2.3. Dough and Bread Preparation

For the mixture designs (doughs with quinoa and kiwicha flours), 16 formulations were used for each experiment with different proportions of water, xanthan gum, and quinoa or kiwicha flour; the other ingredients for the dough preparation were potato starch, sugar (3%), salt (2%), soybean oil (6%) and yeast (3%). For the CCRD (doughs with tarwi flour), 13 formulations with different proportions of water and tarwi flour were used; these were mixed with potato starch, quinoa flour (46%), sugar (3%), xanthan gum (0.5%), salt (2%), soybean oil (6%) and yeast (3%). For bread with kañiwa flour, the same levels of sugar, salt, soybean oil and yeast were used.

All ingredients were mixed at two different speeds for 3 min in total and used to fill aluminum molds (300 g); then, they were fermented for 30 min at 30 °C and 85–90% RH, and finally, they were baked at 200 °C for 60 min.

2.4. Dough Textural Properties

The texture analysis of the doughs (without yeast) was carried out using the Back Extrusion accessory of the INSTRON universal texturometer (Model 3365, Canton, MA, USA), where a portion of dough was deposited in the Back Extrusion cylinder (diameter, 50 mm; height, 70 mm) and penetrated up to 50% with a plunger (diameter, 42 mm) at a speed of 1 mm/s and with a trigger force of 10 gf; finally, the plunger returned to its original position at the same speed. The textural properties determined were the firmness (N), consistency (N.s), cohesiveness (N) and viscosity index (N.s).

2.5. Specific Volume

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

2.6. Textural Properties of Bread

The texture profile analysis (TPA) was carried out on breads 24 h after baking using an Instron Universal Testing Machine (Model 3365, Instron Co., Canton, MA, USA), according to the procedure described by Vidaurre-Ruiz et al. (2019).

3. Results and Discussion

The proximal composition of the quinoa, kiwicha, kañiwa and tarwi flours was 8.0–11.0% of moisture, 14.0–53.0% of protein, 6.0–22.0% of fat, 2.0–3.0% of ash, 2.5–9.0% of fiber and 12.8–69.5% of carbohydrates, respectively.

The gluten-free dough optimized with quinoa flour that was able to imitate the textural properties of the dough control was composed of quinoa flour (46.3%), potato starch (53.7%), xanthan gum (0.5%) and water (75.2%). In the case of the dough with kiwicha flour, the optimized formulation consisted of kiwicha flour (40.6%), potato starch (59.4%), xanthan gum (0.5%) and water (80.9%). The dough optimized with tarwi flour was composed of tarwi flour (12%), quinoa flour (46), potato starch (42%) and water (102%). The optimized formulation of the gluten-free bread with kañiwa flour was kañiwa flour (100%), xanthana gum (0.9%) and water (140%). The rest of the ingredients remained constant, according to the type of dough, as explained above.

The quality properties of the optimized breads, such as the specific volume and crumb texture, are shown in Table 1, where it can be seen that the gluten-free breads with Andean grains had acceptable specific volumes, as well as soft crumbs (Figure 1). According to Alvarez-Jubete et al. [14], the components of Andean grains such as the fats and starches, which include low levels of amylose, significantly help to improve the quality of gluten-free breads, producing breads with soft crumbs and with a lesser tendency to retrograde, therefore increasing the shelf life of the products.

The formulation optimized with 100% kañiwa flour demonstrates that the starches of this grain are propitious for baking and that when they are mixed with the appropriate levels of water and xanthan gum, they can produce breads of good physical and nutritional quality. Likewise, tarwi flour can be included in a smaller proportion (12%) due to its high content of proteins, which have a great capacity to absorb water [5].

The inclusion of xanthan gum was minimal (0.5–0.9%) in doughs with Andean grains; this shows that the ingredients of the grains can function as natural emulsifiers; however, the use of gums is still necessary to achieve the stability of the emulsion during baking.

Table 1. Characteristics of gluten-free breads (GFB) made with Andean grains.

Quality Parameters	GFB-Quinoa	GFB-Kiwicha	GFB-Kañiwa	GFB-Tarwi
Baking loss (%)	26.9 ± 0.5	27.3 ± 0.8	28.2 ± 0.7	30.2 ± 0.8
Specific volume (mL/g)	2.3 ± 0.0	2.4 ± 0.1	2.73 ± 0.0	2.13 ± 0.00
Crumb hardness (N)	1.8 ± 0.3	3.6 ± 0.3	1.4 ± 0.2	2.3 ± 0.3
Cohesiveness	0.31 ± 0.0	0.21 ± 0.0	0.32 ± 0.00	0.39 ± 0.00
Springiness	0.8 ± 0.1	0.65 ± 0.00	0.87 ± 0.00	0.89 ± 0.00
Gumminess (N)	0.5 ± 0.1	0.8 ± 0.1	0.5 ± 0.1	0.9 ± 0.1
Chewiness (N)	0.45 ± 0.1	0.49 ± 0.0	0.38 ± 0.1	0.80 ± 0.1

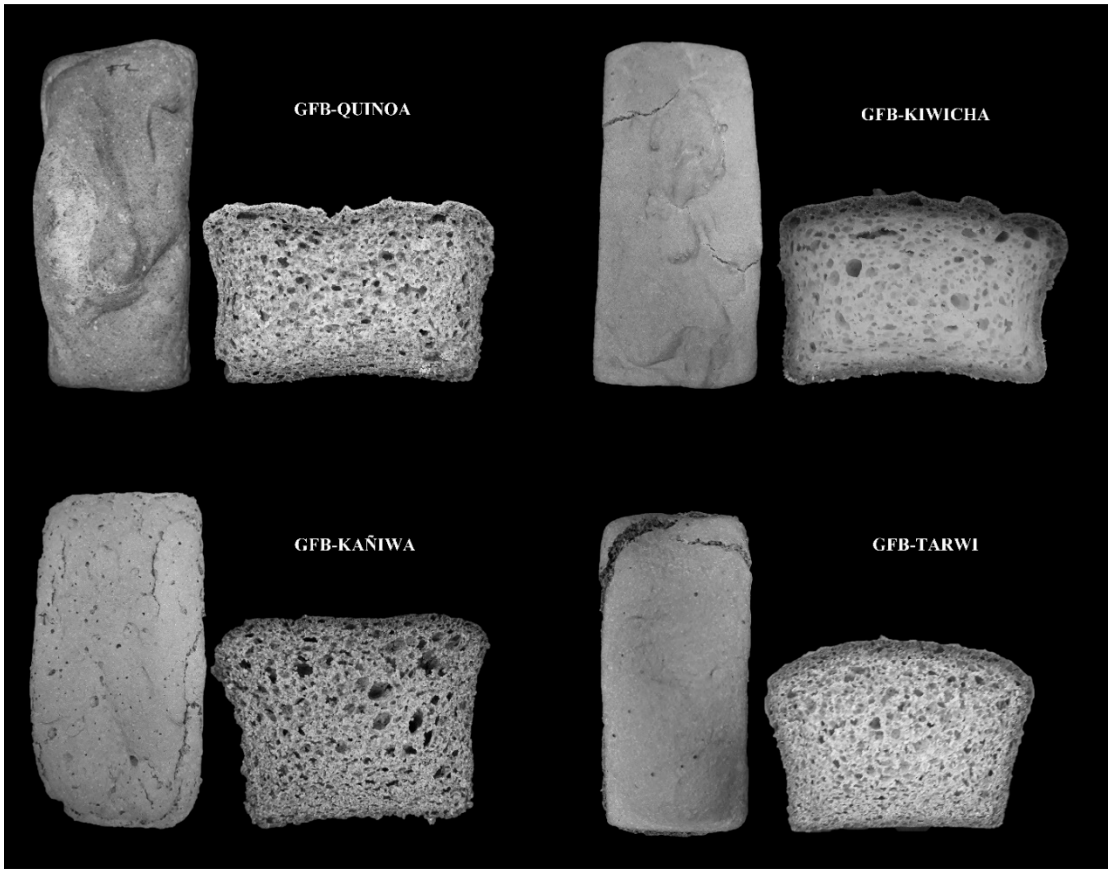

Figure 1. Representative images of gluten-free breads (GFB) with quinoa, kiwicha, kañiwa and tarwi.

4. Conclusions

It was possible to develop gluten-free breads with quinoa (46.3%), kiwicha (40.6%), kañiwa (100%) and tarwi (12%) flours. The components of the Andean grains such as the lipids and starches help to improve the quality properties of gluten-free breads, producing soft crumbs and breads with acceptable specific volumes. The inclusion of xanthan gum in the gluten-free doughs with Andean grain flours was minimal, but its use is still necessary to achieve the stability of the emulsion during the baking process. The gluten-free breads developed contained a good amount of Andean grain flours and could help improve the nutrition of celiac patients.

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