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Andean Ancient Grains: Nutritional Value and Novel Uses †

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Abstract: Quinoa, kañiwa, kiwicha and tarwi are ancient native crops from the Andes highlands of South America. Due to their remarkably high nutritional value, they offer major promise as ingredients in various food products. The aims of this study were to determine the nutritional value of certain varieties of quinoa, kañiwa, kiwicha and tarwi and to use these grains to develop novel, nutritious prototypes of products such as a malted beverage, extruded porridge, gluten-free bread and culinary dishes. The proximate, mineral and phenolic compound contents were evaluated in the Andean grains and final products. Two gluten-free breads were prepared, one made with quinoa and another made with kañiwa. An instant porridge prototype for child nutrition was developed. It had a protein content of 16% and it could, therefore, be considered to be a source of protein. The protein had a high in vitro digestibility (96.3%) and the chemical score was 0.92. The malted beverage prepared with quinoa and kiwicha had a protein content of 7.7%, which represents a value of 1.5 to 2 times more protein than dairy milk. The quinoa-amaranth beverage developed in this study is an excellent locally grown alternative to commercially available plant-based beverages usually made with soy, almond or oat, all of which are imported into Peru. Quinoa, kañiwa, kiwicha and tarwi are innovative, nutritious and tasty alternatives for restaurants seeking new ingredients for their recipes.

Keywords: *Amaranthus chenopodium*; extrusion; gluten-free; Lupinus; malted beverage

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1. Introduction

The Andean region of South America is an important centre of domestication of food crops. This region has a great diversity of agroecological zones due to several climate and altitude differences (1500–4200 m). The use and cultivation of many of these plants decreased dramatically as a result of European colonization. The diets of Andean inhabitants changed and native grains were replaced by imported crops such as wheat, soy and rice. This change had long term effects and has affected the nutritional status in Peru and other Andean countries where malnutrition is common.

During the past decades, Andean crops have been "re-discovered" and attracted worldwide interest due to their remarkably high nutritional value and environmental adaptability. The most notable Andean grains are quinoa (*Chenopodium quinoa* Willd.), kañiwa (*Chenopodium pallidicaule* Aellen), kiwicha (*Amaranthus caudatus* L.) and tarwi (*Lupinus mutabilis*). These crops have adapted perfectly to the harsh environmental conditions of the Andes, being very resistant against drought, the salinity of the soil and frost. After the FAO declared 2013 as the "International Year of Quinoa", the cultivation and use of quinoa has extended beyond its area of origin [1].

Quinoa, kañiwa and kiwicha are pseudocereals whereas tarwi is a leguminous plant. The Andean pseudocereals have a relatively high protein content with an excellent biological quality [2,3]. Andean grains are gluten-free and could be used as ingredients in

products for people suffering from coeliac disease [4]. Gluten-free products that are currently commercially available in Latin America lack the high nutritional value of Andean grains. In recent years, there has been a remarkable global interest in Peruvian haute cuisine, which has been ranked as one of the world's best. Since 2013, most Peruvian gourmet restaurants have included quinoa in their menu; however, other less-known crops are usually not included.

With the purpose of causing an impact on the Peruvian food sector, the aims of this study conducted under the Project Protein2Food were to determine the nutritional value of several varieties of quinoa, kañiwa, kiwicha and tarwi and to use these Andean native grains to develop novel and nutritive prototypes of products such as a malted beverage, extruded porridge, gluten-free bread and culinary dishes.

2. Materials and Methods

2.1. Materials

The following varieties of Andean grains were used to develop the prototypes: the Pasankalla and Chullpi varieties of quinoa and the Oscar Blanco and Centenario varieties of kiwicha, all of which were provided by "El Programa de Cereales y Granos Nativos de la Universidad Nacional Agraria La Molina". The variety of kañiwa was Illpa Inia from Puno. For tarwi, the variety Yunguyo was acquired from Agroinversiones Ogoríz S.R.L.-Cajamarca. For culinary dishes, the following quinoa varieties were used, all acquired from INIA: Blanca de Junin, Kancolla, Amarilla de Sacaca and CICA-18.

The following food products were developed: an extruded product for porridge, gluten-free bread and a malted beverage.

2.2. Methods

An analysis of the protein, carbohydrates, fat, ash, moisture and crude fibre was performed using the Official Methods of Analysis [5].

The total, soluble and insoluble dietary fibre were analysed by an enzymatic-gravimetric method according to the Official Method of the AOAC [5]. The total phenolic (TP) content was measured by spectrophotometry [6]. The chemical score of the protein for the selected pasta was evaluated based on the amino acid requirements for adults.

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

The potentiometric method of the AOAC [5] was used where the sample was diluted with distilled water (1:10) and the pH was measured using a pH meter (Hanna Instruments, HI2020). The acidity, in terms of succinic acid, was determined using a titrimetric method.

Statistical Analysis

All experimental analyses were performed in triplicate. The results were expressed as a mean ± standard deviation.

3. Results and Discussion

In Table 1, the chemical composition of the grains is presented. The protein content of the different quinoa varieties was 9.6–15.2%. In the case of kiwicha and kañiwa, this value was 14.3–15.4%. Tarwi had an extremely high protein content of 52%. Cordoba et al. [7] analysed the protein content of three tarwi varieties and they reported an average value of 54.4%, which is in accordance with our results.

The chemical composition of the final products can be seen in Table 1. The protein content for the gluten-free breads was 7.7% for the quinoa bread and 16.3% for the kañiwa bread. This high protein content for the kañiwa bread was due to the fact that this bread was made of 100% kañiwa flour without adding starch whereas the quinoa bread contained potato starch. The kañiwa bread could be considered to be a source of protein according to the nutrition claims of the European Union because more than 12% of the energy value

of the food was provided by protein. It was possible to obtain a good quality bread with kañiwa without adding any starch (see pictures 1 and 2 for quinoa and kañiwa bread, respectively). This was interesting and indicated that kañiwa starch is different from quinoa starch and helps in the formation of gluten-free dough. Kañiwa has a high dietary fibre content that can help to strengthen the flour and has a positive influence on the final product. Kañiwa is reported to have a low amylose content; Cornejo and Rosell [8] reported that grain varieties with low amylose contents present low gelatinisation temperatures and soft gels, which is beneficial for baked products. Both breads could be considered to be high fibre because the content of this component was superior to 6 g/100 g of product. This is important because commercially available gluten-free products generally lack dietary fibre; they are made mainly of starch and white rice flours.

Table 1. Proximate compositions of Andean grains and products.

Grain Sample	Moisture g/100 g	Protein g/100 g	Fat g/100	Crude Fibre g/100	Ash g/100	Carbohydrates g/100	Ironm g/kg	Calcium mg/kg
Quinoa Pasankalla	8.03 ± 0.11	14.37 ± 0.06	5.77 ± 0.28	17.24 ± 0.04 *	2.34 ± 0.06	69.49	38.63 ± 3.35	1134.1 ± 44.5
Quinoa Chullpi	10.67 ± 0.31	9.64 ± 0.37	15.19 ± 1.09	6.22 ± 0.05	5.51 ± 0.37	64.58	n.d.	n.d.
Quinoa Blanca de Junin	10.46 ± 0.06	14.03 ± 0.19	7.88 ± 0.16	3.15 ± 0.13	2.68 ± 0.09	72.27	77.33 ± 5.508	1100 ± 10.3
Quinoa Kancolla	10.25 ± 0.08	14.41 ± 0.07	7.57 ± 0.23	3.31 ± 0.13	2.35 ± 0.04	72.37	83.00 ± 9.539	1100 ± 20.3
Quinoa Amarilla Sacaca	11.20 ± 0.14	14.10 ± 0.14	7.21 ± 0.73	3.82 ± 0.09	2.29 ± 0.16	72.58	86.33 ± 10.01	1300 ± 20.5
Quinoa CICA-18	10.75 ± 0.11	15.22 ± 0.13	7.23 ± 0.16	4.02 ± 0.02	2.48 ± 0.15	71.05	116.33 ± 24.02	1200 ± 30.3
Kañiwa	11.83 ± 0.07	14.68 ± 0.07	8.9 ± 0.11	13.69 ± 0.11 *	2.58 ± 0.08	69.49	104.4 ± 0.2	1528.1 ± 6.05
Kiwicha Oscar Blanco	6.91 ± 0.28	15.39 ± 0.19	13.71 ± 0.52	7.53 ± 0.39	3.80 ± 0.32	57.10	n.d.	n.d.
Kiwicha Centenario	10.25 ± 0.09	14.33 ± 0.05	7.15 ± 0.04	2.52 ± 0.05	2.58 ± 0.03	65.69	48.76 ± 3.20	937.30 ± 21.85
Tarwi Yunguyo	9.0 ± 0.06	52.42 ± 0.21	21.41 ± 0.02	7.47 ± 0.13	2.7 ± 0.02	14.48	162.00 ± 6.79	404.30 ± 8.49
Gluten-free quinoa bread	27.75 ± 0.1	7.74 ± 0.0	4.74 ± 0.0	14.38 ± 0.2 *	3.22 ± 0.0	84.08 ± 0.1	13.51 ± 1.75	453.20 ± 126.01
Gluten-free kañiwa bread	37.62 ± 2.15	16.29 ± 0.99	12.03 ± 0.64	13.16 ± 1.13 *	3.21 ± 0.18	64.94 ± 2.16	103.5 ± 0.28	1639.9 ± 7.66
Extruded porridge	7.1 ± 0.06	16 ± 0.30	7.28 ± 0.05	n.d.	2.6 ± 0.03	67.10	n.d.	n.d.
Malted beverage	90.02 ± 0.13	7.67 ± 0.11	0.28 ± 0.01	n.d.	0.04 ± 0.00	1.05 ± 0.00	n.d.	n.d.

* Total dietary fibre; n.d.: not determined.

The quality characteristics of the gluten-free quinoa and kañiwa bread are presented in Table 2. The specific volume of the kañiwa bread was 2.96 and 1.82 for the quinoa bread. This high specific volume could be due to the adequate hydration of the dough by the presence of components with a high water absorption capacity such as fibre, protein and lipids that help to maintain the viscosity and fluidity of the dough during fermentation and cooking (the bake loss was 40% and 30 % for kañiwa and quinoa, respectively.

Table 2. Quality characteristics of the optimized gluten-free breads based on quinoa and kañiwa.

Quality Parameters	Gluten-Free Bread	
	Kañiwa (100%)	Quinoa (44.5%)
Specific volume (mL/g)	2.96 ± 0.05	1.82 ± 0.10
Bake loss %	40.08 ± 1.25	30.46 ± 1.80
Crumb hardness (N)	0.77 ± 0.14	1.90 ± 0.30
Cohesiveness	0.42 ± 0.02	0.68 ± 0.00
Springiness	0.76 ± 0.03	0.85 ± 0.10
Gumminess (N)	0.34 ± 0.04	1.28 ± 0.20
Chewiness (N)	0.25 ± 0.03	1.09 ± 0.20

The protein content of the extruded porridge was 16%. This product could be considered to be a source of protein according to the nutrition claims of the European Union

because more than 12% of the energy value of the food was provided by protein. The protein in the in vitro digestibility was 96.3%, which could be considered to be an appropriate value from a nutritional point of view. This value was superior to the value reported by Akande et al. [9] for amaranth-based mixtures. The chemical score was also high (0.92). This was because the Andean grains (quinoa, kiwicha and tarwi) complemented each other in their composition of essential amino acids.

Several culinary dishes were prepared using the different Andean grains in collaboration with chefs of Peruvian gourmet restaurants. In pictures 1–3, a few examples can be seen. These dishes presented excellent nutritional value, especially in their protein, bioactive compounds and dietary fibre content. The results of this research have been published in the cookery book "Andean Native Grains. Superfoods For The Kitchen" (Repo de Carrasco and Solorzano, 2020). It includes recipes of beverages, starters, main dishes and desserts as well as scientific information about the grains and prepared dishes. This book has had a very wide dissemination amongst people working with Peruvian gastronomy and food scientists. The recipes are currently used on the menus of Peruvian gourmet restaurants.

4. Conclusions

All varieties of Andean grains included to this study showed an excellent nutritional value with a high protein content; tarwi was especially rich in this nutrient. In addition, these grains are excellent sources of dietary fibre and phenolic compounds. Amongst them, kañiwa stands out. The oil content of tarwi is high and it could be an excellent source of edible oil. Regarding nutritionally important minerals, quinoa and kañiwa can be considered to be good sources of iron and calcium. These underutilized grains can be used as ingredients for a variety of food products such as gluten-free bread, plant-based beverages and children's food. In gluten-free products, Andean grains improve the nutritional and sensorial qualities.

In this study, two gluten-free formulations were developed, one based on quinoa and another based on kañiwa. Both breads had a particularly good nutritional composition, with high protein and dietary fibre contents and kañiwa was again outstanding in this aspect. Not only was the macronutrient content excellent in the kañiwa bread but also the micronutrient content excelled. Another interesting point is that this bread could be elaborated without adding any starch. It seems that kañiwa starch is different from quinoa starch and helps the formation of gluten-free dough.

The instant porridge based on extruded quinoa, kiwicha and tarwi flour can be considered to be a source of protein with excellent in vitro digestibility and a high chemical score. This product could be used for infant foods by local food industries and offered to governmental food aid programs in Peru in order to replace the use of imported ingredients such as wheat and soy.

The quinoa-amaranth beverage developed in this study offers an excellent locally grown alternative to commercially available plant-based beverages usually made by soy, almond or oat, which are all imported into Peru. Additionally, quinoa, kañiwa, kiwicha and tarwi are innovative, nutritious and tasty alternatives for restaurants seeking new ingredients for their recipes. This is the first time that these four crops have been included in the menu of Peruvian fine food restaurants.

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