BREADMAKING USE OF THE ANDEAN CROPS QUINOA (*Chenopodium quinoa*), KAÑIWA (*Chenopodium pallidicaule*), KIWICHA (*Amaranthus caudatus*), AND TARWI (*Lupinus mutabilis*)

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ABSTRACT

The effect of addition of flours from highly nutritious Andean crops quinoa, kañiwa, kiwicha and tarwi has been investigated in wheat doughs and fresh bread quality. The thermo-mechanical profile of wheat doughs and bread quality thereof has been explored by increasing substitution of wheat flour by Andean crop flours from 0 to 100%. Dough blends were evaluated by using the Chopin Mixolab® device, whereas bread quality assessment comprised sensory (overall acceptability) and physico-chemical (moisture, specific volume, texture, colour) determinations in composite breads.

In general, no breads with aerated crumb structure could be obtained from 100% Andean crop flours with the exception of quinoa breads that deserved overall sensory scores corresponding to 4.5/10 with no significant differences with respect to the breads made from the blends wheat:quinoa 50:50. Replacement of wheat flour by up to 12.5% (tarwi), 25% (kañiwa) and 50% (kiwicha) respectively led to variable coloured breads with good sensory perception coming from doughs with acceptable thermo-mechanical patterns. Partial substitution of wheat flour by Andean crop flours constitutes a viable alternative to improve the nutritional value of breads thereof in terms of quantitative and qualitative protein composition and bioactive components, being the technological performance of dough blends and composite breads acceptable.

Key words. Andean crops-wheat-dough blends-composite breads.

INTRODUCTION

Western diets based on wheat based breads are much less satiating than more traditional grains of less developed countries. Particularly, some alternative crops (buckwheat, oat, quinoa, amaranth grain, and so on) seem to be of great nutritional interest for developing healthier and typical regional foods (Berghofer and Schonlechner 2000; Berti et al 2005).

Quinoa (*Chenopodium quinoa*), kañiwa (*Chenopodium pallidicaule*) and kiwicha (*Amaranthus caudatus*) are indigenous pseudo cereals from Andean region. Tarwi (*Lupinus mutabilis*) is a legume cultivated in Peru, Bolivia and Ecuador since the times of incas and pre-incas. All these crops are highly nutritious and environmentally resistant, and can be cultivated on poor soils and high altitudes. The protein content of quinoa and kañiwa is elevated and they have balanced amino acid composition Repo-Carrasco et al 2003). Kiwicha proteins have also an excellent nutritional value, especially when combined with other cereals (Pedersen et al 1987). Tarwi is extremely rich in protein (45 % protein content) (Ortiz et al 1975) and oil (16 % oil content) (Gross et al 1988), but due to the presence of bitter and toxic alkaloids tarwi must be debittered before consumption. Quinoa contains saponins that have to be eliminated as well. These Andean grains have potential as functional and bioactive ingredients in food products because their high dietary fiber content and natural antioxidants such as phenolic compound (Gorinstein et al 2007). Andean grains have potential agronomic importance across the world because they can adapt to different environmental conditions. In particular, quinoa is a crop exhibiting a range of requirements for humidity and temperature, with specific ecotypes adapted to diverse conditions. The crop has been recently introduced to various European countries and also to North

America, Asia, Africa and Australia (Jacobsen 2003). Quinoa was selected by FAO as one of the crops to offer food security in the current century (FAO 1998).

Partial substitution of wheat flour by flours from Andean crops could improve the nutritional quality of wheat bread since they are rich in lysine and other essential amino acids present in scarce amounts in wheat flour (Berghofer and Schonlechner 2000). These crops contain no gluten which seriously constrains the technological performance of the baking process. The use of composite flours also offers economic advantages for countries, like Peru, where the cultivation of wheat is very scarce for geographical and climate reasons. More recently in Europe, attention has been given to quinoa for people with celiac disease as an alternative to the common cereals like wheat, rye, and barley, which all contain gluten (Schoenlechner et al 2008). Quinoa, and the other Andean crops, could be used to develop nutritious breads with specific functional properties.

Despite the potential improvement that those grains could represent when looking for healthy diets, scarce studies have been focused on the development of bakery goods. Some studies reported the utilization of up to 20% replacement of wheat flour by quinoa or kiwicha (Chauhan et al 1992; Bruemmer and Morgenstern 1992; Morita et al 2001) for making wheat based breads. Even the use of germinated quinoa as breadmaking ingredient in wheat bread formulation has been proposed (Park and Morita 2005). Additionally, a breadmaking trial showed that wheat flour replacement by 10% tarwi gave acceptable bread quality (Lorenz and Coultier 1991; Gross et al 1983). No information has been found regarding the use of kañiwa in breadmaking processes.

A comparison study about the potential breadmaking properties of these four Andean crops is proposed for extending their application and improving the nutritional value of

the existing bakery products. Thus, the aim of this study was to evaluate the effect of increasing substitution of wheat flour by Andean crop flours from 0 to 100% on rhelogical characteristics of bread dough and fresh bread quality. Rheological behavior of the bread doughs was assessed by defining their thermo-mechanical profile using the Mixolab® device. Fresh bread quality study comprised sensory (overall acceptability) and physico-chemical (moisture, specific volume, texture, crumb and crust colour) parameters.

MATERIALS AND METHODS

A commercial blend of breadmaking wheat flour was used. The following varieties of the Andean crops were used: Quinoa (*Chenopodium quinoa*), Rosada, from Huancayo, kañiwa (*Chenopodium pallidicaule)*, Cupi from Puno, kiwicha (*Amaranthus caudatus)*, Centenario from Ancash, tarwi (*Lupinus mutabilis)* from leguminous program of National Agrarian University La Molina (Lima, Peru). Baker's compressed yeast and salt were acquired in the market.

Preparation of flours of quinoa, kañiwa, kiwicha and tarwi

Debittering of quinoa was achieved by removing saponins, and the washed grains dried at 50ºC with hot-air dryer for four hours. Quinoa grains were milled in a laboratory mill, Cyclotec 1093 (FOSS Inc. Denmark). The grains of kañiwa and kiwicha were cleaned and milled with the Cyclotec mill. Tarwi that contains bitter alkaloids was dehulled and de-bittered following the modified "Cusco" method described by Gross et al (1983). The de-bittered tarwi was dried at 50 ºC for 12 h in hot-air cabinet dryer and then milled as previously described.

Flour characteristics

The following flours were used: wheat (*Triticum aestivum*), quinoa, kiwicha, kañiwa, and tarwi. Moisture, protein, ash and fat were determined following the corresponding ICC methods (1994). The colour of the milled grains was measured directly in the powder at three different locations by using a Minolta colorimeter (Chroma Meter CR-400/410, Konica Minolta, Japan) after standardization with a white calibration plate (L = 97.64, a = -0.02, b = 1.77). The colour was recorded using Hunter-L a b uniform colour space (Hunter-Lab), where L indicates lightness, a indicates hue on a green (-) to red (+) axis, and b indicates hue on a blue (-) to yellow (+) axis.

Thermomechanical behaviour of flours

Mixing and pasting behaviour of doughs from wheat-Andean crops blends were studied using the Mixolab® device (Chopin, Tripette et Renaud, Paris, France), which measures in real time the torque (expressed in Nm) produced by passage of dough between the two kneading arms, thus allowing the study of its physical behaviour (Bonet et al 2006; Collar et al 2007, Rosell and Collar 2008). Rosell et al (2007) reported a detailed description of the equipment and the parameters registered. The instrument allows analyzing the quality of the protein network, and the starch behaviour during mixing, heating and cooling. For the assays, 50 grams of flour blends were placed into the Mixolab® bowl and mixed. Increasing amounts of Andean crops flours (0, 12.5, 25, 50 and 100%) were used in the flour blends. The amount of water was kept constant for collecting information at constant hydration. The settings used in the study were six minutes at 30ºC, heating rate of 4ºC/min until 90ºC, seven minutes holding at 90ºC, cooling rate of 4ºC/min until 55ºC, and five minutes holding at 55ºC. The mixing speed

during the entire assay was 75 rpm. Recorded curve showed the consistency during mixing, overmixing, pasting and gelling.

Breadmaking process

Wheat-Andean crop flour blends (0, 12.5, 25, 50 and 100%) were used for making small pan breads. Three hundred grams of blends were mixed with water (59%, v/w, blend basis), salt (1.8%, w/w, blend basis) and yeast (2%, w/w, blend basis) in 300 g bowl Brabender Farinograph for four minutes (wheat flour and wheat-quinoa blend), six minutes (wheat-tarwi blends) or eight minutes (wheat-Kiwicha blends and wheat-kañiwa blends). After kneading, doughs were divided into 50 grams pieces and individually placed into aluminium pans. Fermentation was carried out in a proofing cabinet for 45 min at 30 ºC and 85% RH. The dough pieces were baked for 35 min at 165 ºC in an electric oven. Then, loaves were removed from the pans and cooled at room temperature for 30 min.

Bread quality determination

Bread quality was evaluated by assessing volume (rapeseed displacement), weight, specific volume, crust and crumb colour, moisture content and crumb hardness. Crust and crumb colour were determined using a colorimeter (Chroma Meter CR-400/410, Konica Minolta, Japan). Moisture content was determined following the ICC Method. Texture profile analysis (TPA) of the bread crumbs was performed by a Texture Analyzer TA-XT2i (Stable Micro Systems, Surrey, UK). A bread slice of 1 cm-thickness was compressed up to 50% of its original height at a crosshead speed of 1 mm/s with a cylindrical stainless steel probe (diameter 10 mm). Measurements were performed after 30 min of baking. Values were the mean of four replicates. Sensory

perception was performed by a trained panel of judges who scored the overall acceptability of breads using a semi-structured scale (0: extremely dislike, 10: extremely like).

Statistical analysis

Multiple sample comparison procedure was used to determine statistically significant differences among means, and it was performed by using Statgraphics Plus V 7.1 (Statistical Graphics Corporation, UK). The method used to discriminate among means was Fisher's least significant difference (LSD) test with 95% confidence.

RESULTS AND DISCUSSION

The proximate composition and colour tristimulus parameters of the flours used in this study are presented in Table 1. All the Andean cereals had high protein content, specially the tarwi, which was extremely rich in this component (57.4 %). Fat and ash content of the four Andean crops were also higher than the content in wheat flour. Results concerning quinoa, kañiwa and kiwicha were close to the data previously reported by Repo-Carrasco (1992) and Repo-Carrasco et al (2003), and recently by Park et al (2005). Protein and fat content of tarwi flour agree with previous data reported for tarwi or lupine flour debittered by using the "Cuzco method" (Gross et al 1983). *L* (lightness) value of all the Andean flours was lower than that observed for wheat flour, being especially significant for the case of kañiwa that showed strong brown colour. The *a* value for wheat flour was negative (green hue), whereas positive (red hue) values were obtained for all Andean flours. All *b* values were positive (yellow hue), being extremely high in the case of tarwi that has a characteristic yellowish colour. In

consequence, Andean grains-wheat flour blends will lead to a range of coloured bakery products.

Thermomechanical behaviour of Andean grains-wheat flour blends

Plots of thermomechanical behaviour of doughs obtained from wheat-Andean crop blends recorded in the Mixolab device are reported in Figure 1. Additionally, plots obtained for wheat flour and Andean crops flour were included for gaining information about the Andean crops viscometric profile associated to heating-cooling processes. First part of the curve corresponding to mixing and initial heating (up to 52-58ºC) has been associated to proteins that undergone the following processes: hydration, changes induced by mechanical input, thermally induced aggregation and unfolding (Rosell et al 2007). Further heating and cooling result in starch gelatinization and gelling, respectively; with the consequent increase in dough consistency, initially due to starch swelling and then due to starch recrystallization (Rosell et al 2007). Andean crops studied modified the thermomechanical behaviour of wheat flour, and regardless tarwi, significant changes were detected in the part of the curve associated to starch changes.

The plots for quinoa-wheat dough (Figure 1.A) showed that blends had intermediate behaviour between pure wheat flour and quinoa flour, and the presence of quinoa flour induced higher effect than the level added. Quinoa flour led to very low consistency dough, and the minimum torque was observed when dough temperature was 57ºC, whereas wheat dough reached that minimum around 55ºC, which indicates that quinoa starch requires higher temperature for pasting. Nevertheless, it has been reported that exists great variation in both thermal and pasting properties of quinoa starch ascribed to genetic variability (Lindeboom et al 2005). Maximum peak torque during heating was

reached at 72ºC and after that temperature a pronounced torque decrease was observed. That result reflects the fragility of the swollen granules that after swelling they break down under continuous stirring (Tipples et al 1980). Quinoa flour gave very low consistency during cooling, which indicates very low recrystallization or setback (Rosell et al 2007; Collar and Rosell 2009). When quinoa-wheat blends were used, initial dough consistency increased with increasing proportion of quinoa flour (0 to 50 %) in the dough, but a dramatic drop was observed when wheat replacement was complete (100 % of quinoa flour). Dough stability during mixing decreased with increasing percentage of quinoa flour, due to gluten dilution when partial wheat replacement. The maximum torque produced during the heating stage, showed a steady decrease with increasing amount of quinoa flour in the dough. In addition, further heating induced rapid torque decrease associated to low thermal stability of the starch, that effect was intensified in the presence of increasing amount of quinoa flour. The same trend was observed with the torque obtained after cooling at 50ºC.

Very similar pattern was observed when blends consisted of kañiwa and wheat flour (Figure 1.B), despite that kañiwa flour led to dough with very low torque during mixing. The unique difference was observed during mixing, overmixing and initial heating, where dough containing kañiwa-wheat blends showed lower torque than wheat flour dough, indicating that kañiwa proteins decrease dough stability. Kañiwa showed very low mechanical stability and consistency could only be recorded during a short period; when overmixing and heating no torque could be detected, neither starch gelatinization. Doughs with kañiwa were very fragile and easily disintegrated.

Kiwicha-wheat blends generated dough with mechanical behaviour similar to wheat flour (Figure 1.C). Overlapped Mixolab® plots were obtained in the presence of

kiwicha flour along mixing, overmixing and initial heating. Divergence started when gelatinization of starch begins, and in contrast with quinoa-wheat blends, the effect was greatly dependent on both the presence of kiwicha and the level of addition. The progressive dilution of wheat starch with kiwicha flour reduced the maximum torque during heating and cooling, which could be ascribed to the low amylose contents of kiwicha starch (ranging from 3.0% to 12.5%) that has been related to low pasting viscosity and setback (Kong et al 2009; Uriyapongson and Rayas-Duarte 1994). By contrast to the other Andean grains, kiwicha flour was able to develop dough with measurable torque, but consistency decay was observed as heating started, being impossible to detect any further consistency.

Tarwi-wheat blends had opposite behaviour to the other Andean crops blends (Figure 1.D). The presence of increasing amount of tarwi flour in tarwi-wheat blends augmented dough consistency, which could be expected considering the protein content of this flour (57.4% tarwi vs 9.8% wheat). Proteins are hydrated during mixing and lupin proteins significantly affect dough consistency and water absorption (Bonet et al 2006). Generally, the dough with tarwi flour was very difficult to manipulate due to its high consistency. The minimum torque produced by dough passage subjected to mechanical and thermal constrains showed progressive increase in the presence of tarwi. During the first part of the curve (mixing, overmixing and initial heating) plots are governed by proteins changes, and the extent of the modification is greatly dependent on the protein content and nature (Bonet et al 2006). Again, in contrast to the other Andean crops, the presence of tarwi hardly affected wheat starch gelatinization. Very high amount of tarwi flour (50% tarwi flour in the blends) was needed to modify pasting plots. The effect of wheat starch dilution was not evident in the presence of tarwi, likely masked by the

proteins. The nature of the proteins has been reported as responsible of modifying pasting and gelling properties of cereal starches (Marco and Rosell 2008), due to the thermal induced gelation process of the proteins after the aggregation of the polymer chains that induces huge modifications in the rheological behaviour of the proteins, being the gelation process temperature sensitive for each protein (Ngarize et al 2004). The presence of tarwi flour in the blends (up to 25%) increased the torque during cooling, probably due to the interactions between wheat amylose and lipids from tarwi (second major component of the tarwi flour), as it has been previously observed for surfactant-supplemented wheat doughs (Collar 2003). Blends obtained with 50% tarwi showed completely different thermomechanical plot, with extremely high dough consistency during mixing and wheat starch gelatinization was completely masked, likely the thermomechanical plot was governed by both tarwi proteins and lipids. Tarwi flour showed very erratic thermomechanical behaviour yielding very low torque plot during mixing, and undetectable torque during heating and cooling.

Bread quality parameters

Breads obtained by substituting wheat flour with increasing Andean crops flour produced a range of loaves with different sensory and technological characteristics (Figure 2).

The colour tristimulus parameters of the breads obtained from wheat-Andean crops flour blends are detailed in Table 2. Crust lightness (*L*) decreased when the proportion of the Andean flours increased in the blends. Breads with higher proportions of Andean flours had darker crust (Figure 2), due to the darker color of the Andean crops flour and also the growing content of reducing sugars and proteins with lysine residues present on those flours (Repo-Carrasco et al 2003) that react during baking producing non-

enzymatic Maillard browning. The *a* values for crust were always positive (red hue), but with the exception of kañiwa containing breads, no clear tendency was observed with the increasing substitution of wheat flour. The *b* values for bread crumbs were also positive (yellow hue), and a significant decrease was always observed when increasing the amount of Andean crops flours in the blends.

Regarding the crumb, the *L* values showed significant reduction when increasing proportion of Andean grains flours were present, yielding darker crumbs. Nevertheless, with the exception of kañiwa, levels of Andean grains flour higher than 12.5% in the blends, or 25% in the case of quinoa and tarwi, were necessary to produce significant reduced lightness (Figure 2). The *a* values ranged from negative values (green hue) to positive values (red hue). The *a* values significantly increased when the proportion of Andean flours was higher than 25% in the blends, with the exception of kañiwa. The *b* values were all positive indicating yellowish colour. The bread with 100 % of tarwi displayed the highest *b* value, which was visually evident in the crumb picture (Figure 2).

Moisture content of quinoa breads augmented with increasing substitution of wheat flour (Figure 3). In the case of kañiwa and kiwicha, breads showed increasing moisture content with the level of wheat flour substitution, but when breads were obtained from the Andean grain flour (100%) a decrease in moisture content was observed. Breads containing up to 25% tarwi flour showed an increase in the moisture content, but higher levels of wheat replacement significantly reduced the moisture content. Likely the distinct flour composition, rich in proteins and lipids, was responsible of this result. Wheat flour substitution by Andean crops flour had significant effect on bread specific

volume (Figure 4). The presence of 12.5% Andean crops flour did not significantly affect the specific volume of the breads, even an increase of this parameter was induced by kañiwa flour. It has been reported that kañiwa flour contains more fermentable sugars than quinoa and kiwicha, favouring yeast fermentation and in consequence increased gas production (Repo-Carrasco et al 2003). Kiwicha and kañiwa allowed obtaining good specific volume breads containing up to 25% Andean crop flour, higher levels of those flours induced a significant reduction in the specific volume. Regarding quinoa and tarwi, substitution levels superior to 12.5% of wheat flour resulted in a detrimental effect on the specific volume of the loaves, primarily associated to gluten dilution. It has been previously reported that substitution of 7.5%-10% wheat flour with quinoa increased loaf volume, but further substitution, higher than 15% resulted in decreased volume (Morita et al 2001). The reduction of the gluten content in the dough might be responsible for the volume effect, nonetheless, kañiwa and kiwicha flours with similar proximate composition to quinoa did not respond to that rule. In the case of quinoa, microscopic analysis revealed that doughs containing 30% quinoa flour were unable to form a well-developed gluten matrix showing aggregated starch granules (Park et al 2005).

Results of texture profile and sensory perception (overall acceptance) of bread crumbs with increasing proportion of Andean flours are compiled in table 3. The presence of 25% quinoa in the blends yielded significantly harder crumbs compared to the control (wheat bread), and that hardness progressively increased at higher substitution levels. Similar findings were reported by Park et al (2005) that substituted up to 30% quinoa flour for wheat flour, obtaining poor extensible gluten network that lead to hardening of bread crumbs. Up to 25% wheat substitution with kañiwa or kiwicha did not

significantly modify the crumb hardness, obtaining comparable crumbs to the ones attained with wheat breads. In the case of tarwi, crumb hardness increased with all substitution levels of wheat flour. Tarwi flour has high percentage of proteins and lipids, whereas the amount of starch is limited compared with the other Andean crops flour, which might be responsible for the hardness results. In all cases, springiness, cohesiveness and resilience decreased when the proportion of Andean flours was increased, with the exception of kañiwa containing breads that did not show any significant variation in springiness. Chewiness increased when rising the percentage of Andean flour in all breads, although significant increase was only observed when levels of quinoa or tarwi flour were higher than 12.5%, and 25% in the case of kañiwa and kiwicha. Quinoa was the unique Andean grain that allowed obtaining breads in the absence of wheat, although with very compact macrostructure. The other Andean grains, kañiwa, kiwicha and tarwi, gave very hard doughs unable to retain the gas released during fermentation, and thus very compact and hard structures were obtained (Figure 2).

Substitution of wheat flour by Andean crops flour resulted in breads with diverse sensory characteristics. Breads containing 12.5% kiwicha obtained the highest score for overall acceptance, being preferred over wheat bread. Breads containing 25% quinoa or kañiwa showed the same overall acceptance than the reference bread (wheat bread). Moreover, sensory acceptable breads were obtained in the presence of up to 50% quinoa and kiwicha. In the case of tarwi, the overall acceptance decreased with increasing substitution of wheat flour with tarwi flour. In general, the breads with tarwi flour had the lowest overall acceptance of all breads. Gross et al (1983) studied the use of lupine flour for supplementation of wheat breads and found that 10% supplementation of

wheat flour, using either whole lupine flour or dehulled lupine flour, yielded an acceptable product in the case of both *Lupinus albus* and *Lupinus mutabilis* (tarwi), although smell and taste were affected. However, studies of the protein efficiency ratio showed that supplementing wheat flour with 10% lupine flour allows increasing the protein quality from 28% (wheat flour) to 76% (with 10% lupine flour) considering casein as a reference (100%) (Gross et al 1983).

CONCLUSIONS

Wheat flour replacement at different levels (from 0 up to 100%) by flours from different Andean crops yielded doughs of different thermo-mechanical profiles and breads with variable sensory acceptability and physico-chemical features depending on both the degree of wheat flour substitution and on the Andean crop. In general, no breads with aerated crumb structure could be obtained from 100% Andean crop flours with the exception of quinoa breads that deserved overall sensory scores corresponding to 4.5/10 with no significant differences with respect to the breads made from the blends wheat: quinua 50:50. Replacement of wheat flour by up to 12.5% (tarwi), 25% (kañiwa) and 50% (kiwicha) respectively led to variable coloured breads with good sensory perception coming from doughs with acceptable thermo-mechanical patterns.

Addition of Andean crop flours to wheat flours constitutes a viable alternative to improve the nutritional value of breads thereof in terms of quantitative and qualitative protein composition and bioactive components.

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FIGURE CAPTIONS

Figure 1. Plots of thermomechanical behaviour of dough obtained from wheat-Andean crops blends recorded in the Mixolab® device. Numbers in legend are referred to percentage of Andean crops in the flour blends. A: Quinoa; B: Kañiwa; C: Kiwicha; D: Tarwi.

Figure 2. Photographs of breads obtained from wheat-Andean crops flour blends (0, 12.5, 25, 50, 100%).

Figure 3. Specific volume of breads obtained from wheat-Andean crops flour blends. Number in legend refers to the percentage of Andean crop flour in the blend. Error bars indicate the standard deviation.

Figure 4. Moisture content of breads obtained from wheat-Andean crops flour blends. Number in legend refers to the percentage of Andean crop flour in the blend. Error bars indicate the standard deviation.

Table 1. Proximate composition (g/100 g, as is) and colour tristimulus parameters of flours used in this study. Means of the triplicates ± standard error, moisture basis.

	Wheat	Quinoa	Kañiwa	Kiwicha	Tarwi
Moisture content	14.21±0.09	8.31±0.06	11.46±0.10	11.57±0.09	6.14±0.07
Protein*	9.81±0.10	13.83±0.23	14.75±0.19	12.34±0.09	57.36±0.59
Ash	0.53±0.08	2.09±0.09	3.27±0.06	1.73±0.08	2.61±0.09
Fat	0.92±0.09	5.04±0.14	6.40±0.15	6.36±0.12	25.40±0.33
Colour					
L	89.96±2.09	81.74±2.51	44.70±1.96	76.12±2.41	73.92±2.09
a	-0.73±0.09	0.35±0.10	5.01±0.08	1.90±0.09	2.68±0.15
b	10.48±0.23	14.48±0.81	13.50±0.94	17.09±1.03	70.99±2.15

*Protein conversion N x 6.25, with exception of wheat (N x 5.7).

Table 2. Colour tristimulus parameters of breads obtained from wheat-Andean crops flour blends (0, 12.5, 25, 50, 100%).

Sample	Dose [a]	Crust colour			Crumb colour		
	% in blend	*L*	*a*	*b*	*L*	*a*	*b*
Quinoa	0	55.9 d	10.5 b	23.9 c	60.3 c	-1.0 a	11.4 a
	12.5	39.7 c	12.7 c	16.5 d	60.4 c	-0.8 a	13.6 b
	25	37.1 c	12.7 c	14.9 c	59.5 c	-0.2 b	15.9 c
	50	34.0 b	12.2 c	13.2 b	55.7 b	1.2 c	17.8 d
	100	21.1 a	8.5 a	9.4 a	46.7 a	1.8 d	16.1 c
Kañiwa	0	55.9 d	10.5 c	23.9 d	60.3 e	-1.0 a	11.4 b
	12.5	43.1 c	10.8 c	17.7 c	45.7 d	1.9 b	10.5 b
	25	34.5 b	8.4 b	12.5 b	38.2 c	3.8 c	10.8 b
	50	37.8 b	6.6 a	12.3 b	30.1 b	4.9 c	8.2 a
	100	23.0 a	6.4 a	8.3 a	23.2 a	5.0 c	7.9 a
Kiwicha	0	55.9 c	10.5 a	23.9 c	60.3 c	-1.0 a	11.4 a
	12.5	42.5 b	12.7 b	18.4 b	58.4 c	-0.5 a	12.4 a
	25	37.7 b	11.7 b	15.3 a	54.8 b	-0.4 a	13.0 a
	50	34.3 a	11.9 b	13.4 a	54.4 b	1.0 b	15.9 b
	100	32.8 a	9.9 a	14.1 a	45.2 a	3.2 c	16.0 b
Tarwi	0	55.9 b	10.5 b	23.9 b	60.3 c	-1.0 a	11.4 a
	12.5	49.3 a	12.5 c	22.4 b	63.0 c	-0.8 a	17.3 b
	25	47.6 a	12.9 c	22.3 b	63.4 c	-0.7 a	21.4 c
	50	51.2 a	10.6 b	24.3 b	56.6 b	3.5 b	23.8 c
	100	45.3 a	6.6 a	20.0 a	45.3 a	6.6 c	20.0 c

[a] Dose of Andean crops flour in the blend

Means in columns within each Andean crop not sharing the same letter are significantly different ($p<0.05$) (n=4).

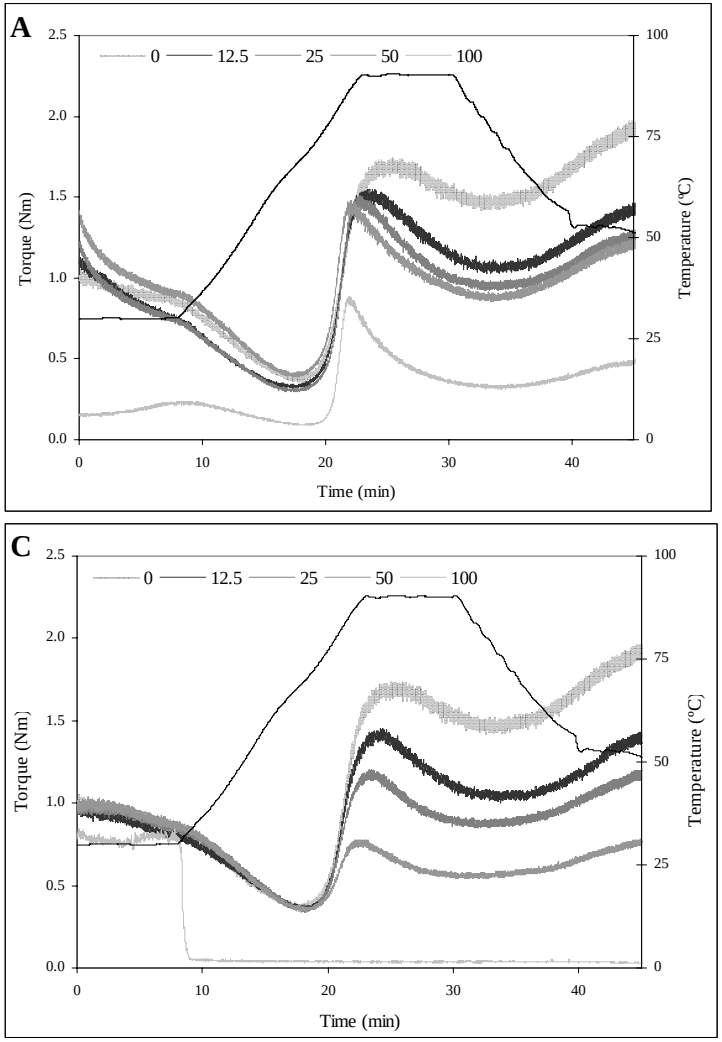
Table 3. Texture profile analysis and sensory perception of crumbs from breads obtained from wheat-Andean crops flour blends (0, 12.5, 25, 50, 100%).

Sample	Dose [a] % in blend	Hardness g force	Springiness	Cohesiveness	Chewiness g force	Resilience	Overall Acceptance 1-10
Quinoa	0	508 a	0.999 b	0.811 b	414 a	0.446 b	7.3 b
	12.5	461 a	0.999 b	0.838 b	462 a	0.470 b	8.0 b
	25	1013 b	0.999 a	0.808 b	817 b	0.434 ab	7.5 b
	50	2815 c	0.938 a	0.702 a	1859 c	0.362 a	5.5 a
	100	4249 d	0.967 a	0.769 a	3160 d	0.390 a	4.5 a
Kañiwa	0	508 a	0.999 a	0.811 c	414 a	0.446 b	7.3 c
	12.5	497 a	0.999 a	0.821 c	405 a	0.367 b	7.5 c
	25	645 a	0.996 a	0.773 b	478 a	0.388 b	7.0 c
	50	3886 b	0.954 a	0.585 a	2163 b	0.221 a	3.8 b
	100	nd	nd	nd	nd	nd	0.7 a
Kiwicha	0	508 a	0.999 c	0.811 b	414 a	0.446 b	7.3 c
	12.5	455 a	0.999 c	0.803 b	366 a	0.410 b	8.3 d
	25	454 a	0.998 c	0.805 b	258 a	0.394 b	7.3 c
	50	1520 b	0.901 b	0.646 a	880 b	0.183 a	5.8 b
	100	2599 c	0.602 a	0.540 a	829 b	0.153 a	2.0 a
Tarwi	0	508 a	0.999 c	0.811 b	414 a	0.446 b	7.3 d
	12.5	1014 b	0.983 b	0.667 a	665 a	0.315 b	6.3 c
	25	2427 c	0.944 b	0.647 a	1483 b	0.280 ab	3.3 b
	50	6105 d	0.874 a	0.637 a	3422 c	0.241 a	1.0 a
	100	nd	nd	nd	nd	nd	0.3 a

[a] Dose of Andean crops flour in the blend. nd: not determined.

Means in columns within each Andean crop not sharing the same letter are significantly different ($p<0.05$) (n=4).

Figure 1.


A
0
12.5
25
50
100
Torque (Nm)
Temperature (ºC)
Time (min)
C
0
12.5
25
50
100
Torque (Nm)
Temperature (ºC)
Time (min)

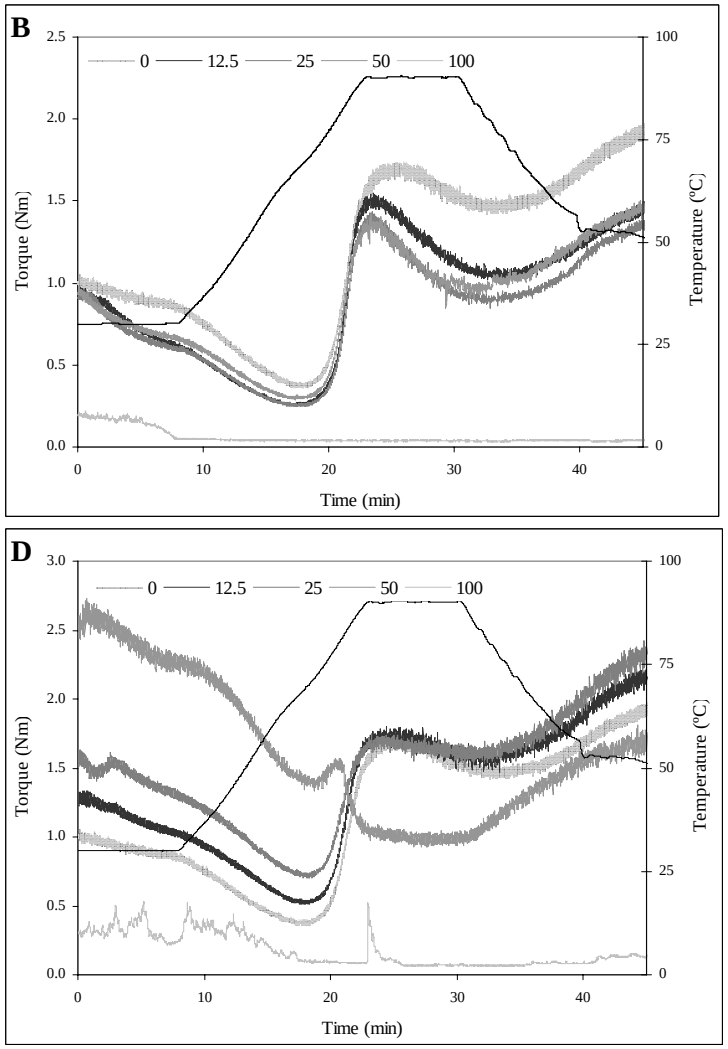

B
0
12.5
25
50
100
Torque (Nm)
Temperature (ºC)
Time (min)
D
0
12.5
25
50
100
Torque (Nm)
Temperature (ºC)
Time (min)

Figure 2.

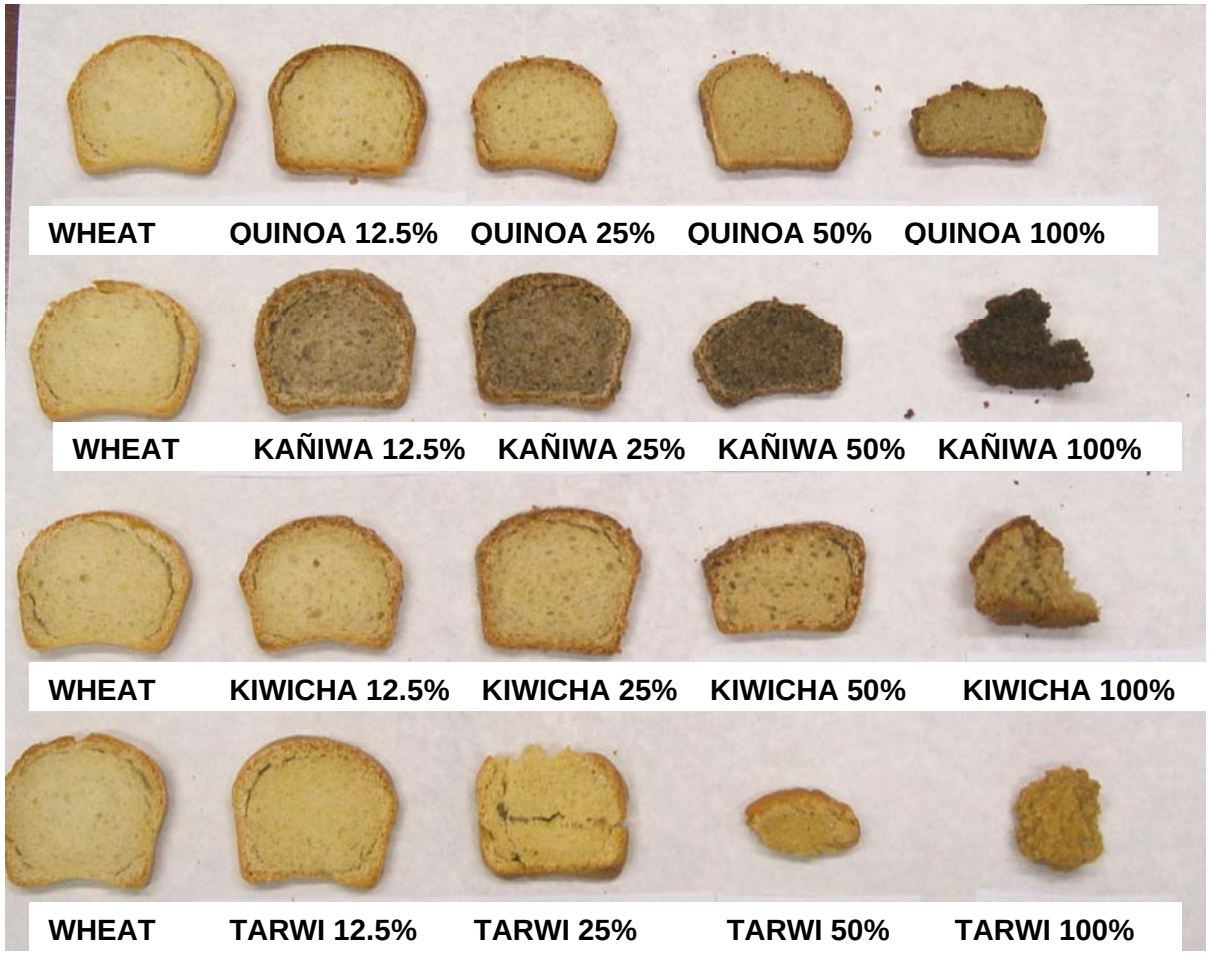

WHEAT
QUINOA 12.5%
QUINOA 25%
QUINOA 50%
QUINOA 100%
WHEAT
KAÑIWA 12.5%
KAÑIWA 25%
KAÑIWA 50%
KAÑIWA 100%
WHEAT
KIWICHA 12.5%
KIWICHA 25%
KIWICHA 50%
KIWICHA 100%
WHEAT
TARWI 12.5%
TARWI 25%
TARWI 50%
TARWI 100%

Figure 3.

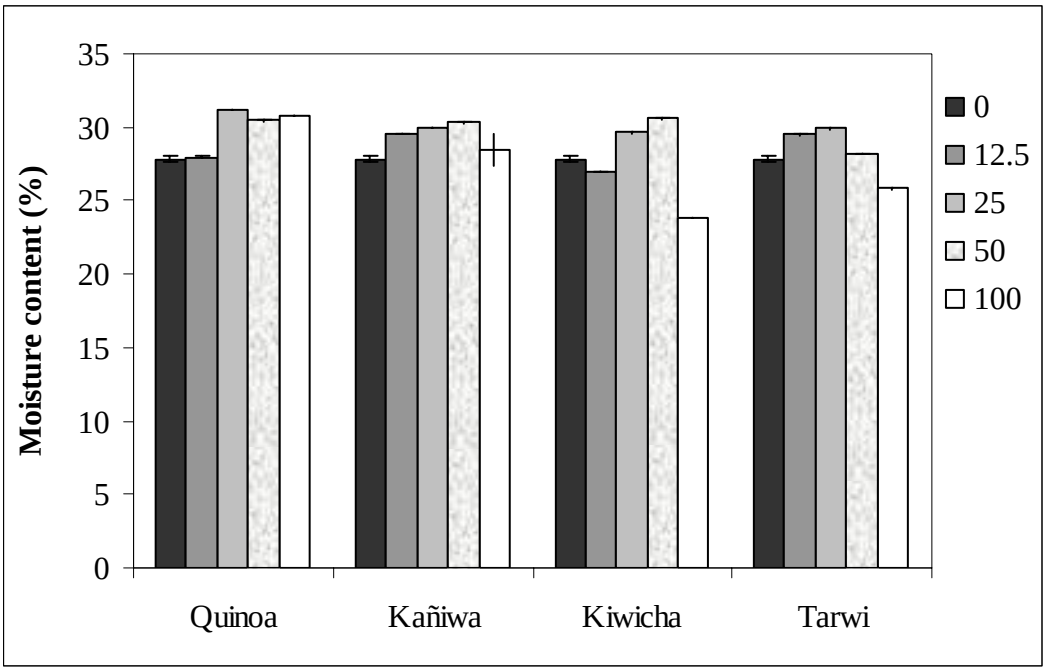
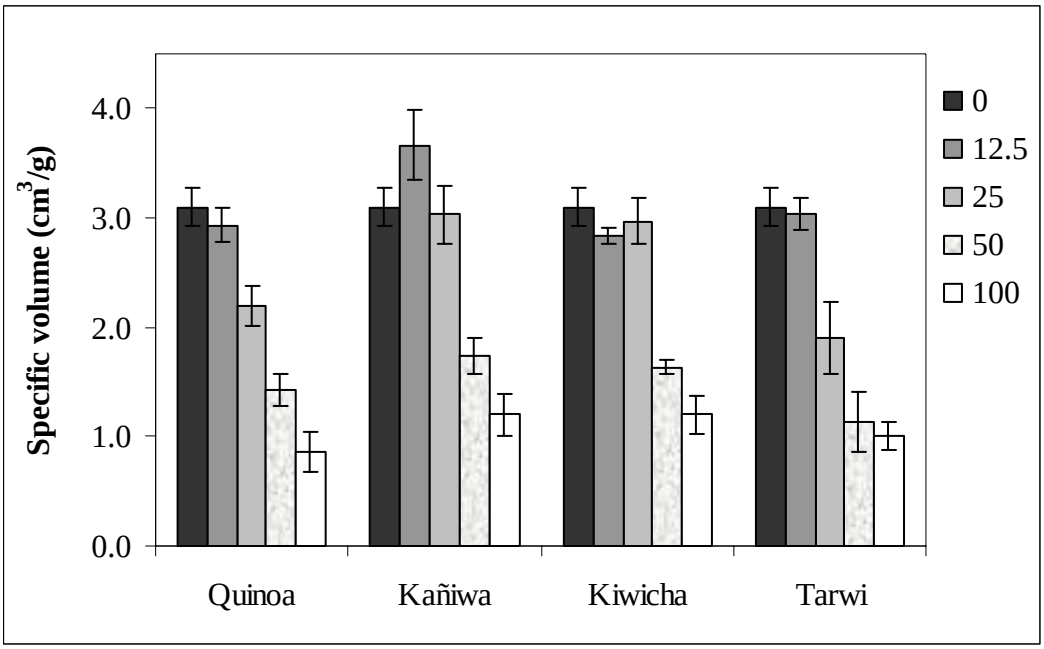

Moisture content (%)
35
30
25
20
15
10
5
0
Quinoa
Kañiwa
Kiwicha
Tarwi
0
12.5
25
50
100

Figure 4.


Specific volume (cm3/g)
4.0
3.0
2.0
1.0
0.0
Quinoa
Kañiwa
Kiwicha
Tarwi
0
12.5
25
50
100