CHARACTERIZATION OF WHEAT AND QUINOA FLOUR BLENDS IN RELATION TO THEIR BREADMAKING QUALITY

Enriquez, N.; Peltzer, M.; Raimundi, A.; Tosi, V.; Pollio*, M.L.
Comisión de Investigaciones Científicas de la Provincia de Buenos Aires - Universidad Nacional de Quilmes, Departamento de Ciencia y Tecnología. Avda. Calchaquí km 23,5 (altura 5800). Florencio Varela, Provincia de Buenos Aires. (1888) Argentina
FAX No. 54-11-4275-7716. e-mail: mlpollio@unq.edu.ar

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Abstract

Bread making properties of blends of quinoa and wheat flours were analysed in order to establish their ability to make molded bread. Blends were made with 5%, 10% and 15% of quinoa integral flour. The percentages of wet and dry gluten, Falling Number and Gluten Index were determined. Protein and lipid content, moisture and ashes were also determined. Alveogram and farinogram parameters were studied. Increasing amounts of quinoa flour produced stronger and less extensible dough. Wet and dry gluten as well as Gluten Index decreased with a higher percentage of quinoa flour. Development time and stability of dough also decreased. Results show that blends containing either 5% or 10% of quinoa flour present good properties to make molded bread. Instead, bread making properties of blends with 15% of quinoa flour were not acceptable. Molded bread was prepared by straight method. There was no difference in bread loaf volume between samples prepared with wheat flour and those prepared with blends with 5% and 10% of quinoa flour.

Resumen

Se analizaron mezclas de harina de trigo y quinua con relación a su aptitud panadera para la elaboración de pan de molde. Las mezclas contenían 5%, 10% y 15% de harina integral de quinua. Se determinaron los porcentajes de gluten húmedo y seco, el Índice de Caída y de Gluten así como el contenido de proteínas, grasa, humedad y cenizas de las dos harinas y de las mezclas. También se realizaron los alveogramas y farinogramas de todas las muestras estudiadas. A medida que aumenta el contenido de harina de quinua en las mezclas, las harinas producen masas más tenaces y menos extensibles. El porcentaje de gluten húmedo y seco y el Índice de Gluten disminuyen con el agregado de harina de quinua. El tiempo de desarrollo y la estabilidad de la masa, disminuyen a mayor porcentaje de quinua. Los resultados muestran que las muestras con 5% y 10% de harina de quinua presentan propiedades aceptables para la elaboración de pan de molde no así la que contiene 15% de harina integral. Los volúmenes de los panes de molde elaborados con las mezclas con 5% y 10% de harina de quinua no presentaron diferencia respecto al volumen del pan elaborado con sólo harina de trigo.

Introduction

Among cereal flours, only wheat flour has the ability to form strong and cohesive dough, capable of retaining gas and of giving spongy product for cooking [1]. Wheat flour aptitude for baking is specifically attributed to gluten proteins. In the preparation of baking products, flour properties determine the obtaining of a good quality product. Flour properties can be evaluated by several chemical and rheological methods. Parameters of these methods determine what kind of bread it is possible to make with the flour. Proteins of other cereal grains, are not supposed to be capable of forming dough. However, in many parts of the world mixtures of wheat flour and other cereals are used in order to obtain bakery products.

The Quinoa (*Chenopodium quinoa* Wild.) was a basic component of the diet of Pre-Columbian populations. The Incas considered the quinoa as a mother grain, and at the present time it is a potential source of food due to the high quality of its proteins [2] [3] [4]. The high content of lysine makes its nutritional values superior to those of the wheat. The supplementation of wheat flour with quinoa flour can effectively enhance the protein quality of the resulting product [5]. However, the absence of wheat gluten proteins, as well as the presence of saponins of a bitter flavor, happen to limit the use of quinoa flour in the preparation of bakery products. These compounds are extracted from the seed by water washing [6]. Saponins affect quinoa color and palatability; however, they do not induce any adverse effect on the nutritional quality of quinoa proteins [7]. Furthermore, quinoa is rich in fatty acids and minerals and it is a source of vitamins such as vitamin E and those of the group B. It presents an exceptional balance between proteins and fat [3].

Many researchers have investigated the protein quality, starch properties and functional characteristics of quinoa seeds. Other aspects related to technological application received less attention. Particularly, the bread making ability of quinoa and wheat flour blends are not common in the bibliography. The addition of quinoa flour increased the nutritional value of wheat flour, as mentioned above.

In this work, the baking properties of mixtures of wheat and quinoa flours were analyzed with the aim of obtaining a mixture of flours that permits to achieve a bakery product such as molded bread of a good quality and with a higher nutritional value. Chemical and rheological methods of analysis were employed in order to establish flour blends baking ability. Chemical composition of blends was also determined. In order to confirm the baking quality of the blends, molded bread were prepared.

Experimental

Wheat flour type 000 was used. Flour was provided by the North Central Mill. The quinoa seeds were acquired in a local market. Before milling, seeds were washed so as to extract saponins. Washing was carried out by adding cold water and by shaking vigorously for some seconds; this was repeated until the formation of foam was no longer observed [6].

Once the seeds were conditioned, they were grounded with a laboratory grinder (Laboratory Mill, Model 3300). Part of the integral flour was sifted for 30 minutes through a sieve (Zonytest, Model EJR 200) so as to obtain a granulation 200 - 300 mesh. Moisture, ashes, protein, fat, wet gluten, dry gluten, Gluten Index, alveograph and farinograph were determined for wheat flour, quinoa flour and their blends according to the methods described below.

Standards AOAC [8] methods, numbers 925.10, 923.03, 920.87 and 945.16 were used to determine moisture, ashes, total nitrogen and oil content, respectively. The factor of nitrogen conversion to proteins was 6.25 for quinoa flours and blends [2, 5, 9, 10] and 5.7 for wheat flour [9].

Wet and dry gluten percent and Gluten Index were obtained by a Perten equipment (Glutomatic, model 2200) following the methodology established by the IRAM [11] norm number 15864. Falling Number was determined using a Perten equipment (Falling Number, model 1500) by the Hagberg-Perten Method as described in norm number 15862 [11].

All values were expressed on a dry weight basis and they were the average of three determinations and the standard errors were calculated. ANOVA analysis was performed to compare the blends. When differences were detected ($F_{calculated} \geq F_{table}$ (95% level)) multiple comparisons were made using Tukey's method to determine the means between which the equalities and inequalities lie [11]. According to Tukey's test a q value is calculated by:

$$q = \frac{\bar{x}_B - \bar{x}_A}{SE} \qquad (1)$$

where $\bar{X}_A$, $\bar{X}_B$ are the means of each of the groups

$$SE = \sqrt{\frac{s^2}{n}}$$

s^2 is the error mean squared from the analysis of variance and n is the number of data in the groups A and B. If the calculated q value is equal to or greater than the critical $q_{\alpha,k,\upsilon}$ ($\alpha = 0.05$, k = groups number, $\upsilon = N - k$; N = number of data) value, then means (A and B) are not equal. The critical q value was taken from the bibliography [11].

The alveogram was determined with the Chopin alveograph (model 1Vo 1E) according to the IRAM norm number 15857 [12]. According to this norm, tenacity (P) and extensibility (L) are the average of replicates which differ in ± 0.8 or ± 0.5, respectively. The farinogram was determined with a farinograph Brabender Duisburg (model 100603), according to the IRAM norm number 15855 [12]. This norm establishes standard errors. They must be ± 2.5 g in water absorption, ± 1 min in development time, ± 2 min in stability and ± 20 BU (Brabender units) in breakdown.

Breads were baked following the straight method [13, 14]. All ingredients were blended together. Dough was mixed for 3.5 min at 130 rpm in a Philips machine (HR 1555). The bread formulation based on 100% wheat flour (14% humidity) or wheat - quinoa blends was: 1.5 g salt, 2 g sugar, 3.2 g butter, 3.5 g yeast, 55 ml water and 2.5 g dry milk. Water temperature and pH were adjusted to 21 C and 5.20, respectively. In order to obtain the desired pH acetic acid was used. Final dough temperature was 23 C and pH 5.5 [13]. Dough was manually molded into pieces of about 300 g each. Fermentation time was 90 min at 28 C and 80% relative humidity [15]. After fermentation, pieces were baked at 180 C for 40 min [14]. Specific loaf volume was measured by rapeseed displacement. Slices of 2 x 2 x 2 cm were cut from the middle of the loaf. Results are expressed as average of three replicates.

Results and Discussion

Protein content of both sifted and integral quinoa flour was determined. The percentage of protein was 8.75% for sifted quinoa flour and 16.2% for the integral one.

Removal of bran could explain the low value of protein content in the sifted quinoa flour is thought to be due to the, which contains 62% of the total protein [10]. Since our objective was the obtaining of flours with higher nutritional value through the addition of quinoa, mixtures with 5%, 10% and 15% of integral flour were prepared. These mixtures will be henceforth referred to as 5% blend, 10% blend and 15% blend.

Moisture, ashes, protein and fat contents of wheat flour, quinoa flour and their blends were determined. All values and their standard deviations are shown in Table 1. In all cases, significant differences were detected. Both wheat flour and 5% blend present equal protein content. On the other hand, 10% and 15% blends have higher protein contents. Nevertheless, there is not a considerable increase in protein content. This is because the protein content of quinoa is slightly higher than that of wheat flour. This has also been established by Ranhotra et al. [5]. However, the supplementation of wheat flour with quinoa flour may contribute towards a better protein quality. Calculated q value by equation 1, demonstrated that differences in protein content between 10 and 15% blends are not significant.

Table 1: *Protein, moisture, ash and fat content of wheat and quinoa flours and their blends. 1: dry basis; 2: wet basis; ±: standard deviation*

Material	Protein (%)^1	Moisture (%)^2	Ash (%)^1	Fat (%)^1
Wheat flour	10.1±0.1	14.3±0.3	0.600±0.060	1.2±0.15
Quinoa flour	16.2±0.2	12.2±0.2	2.203±0.100	5.0±0.10
5% blend	10.2±0.1	13.0±0.3	0.600±0.060	1.3±0.30
10% blend	11.1±0.3	13.0±0.2	0.710±0.060	1.4±0.30
15% blend	11.6±0.2	13.2±0.3	0.912±0.050	2.0±0.20

As increasing the quinoa content in the blends, there is an increase in the ashes content, due to the fact that quinoa flour is an integral one. The percentage of ashes we have found for the quinoa flour (2.20 %) is smaller than the 3.11 % reported by Lorenz and Coulter [16]. The difference may be attributed to pericarp removal. Wheat flour and 5% blend show lower ashes contents than those of a triple zero flour (0.650) [10]. The increase in ashes content for 15% blend is significant when compared with that for wheat flour, 5% and 10% blend (calculated q value is greater than critical q value). As regards moisture content, there are no differences between blends. Fat content shows an increment in 15% blend, which is not a significant one (Tukey's test).

Wet and dry gluten, Gluten Index, Falling Number, alveogram and farinogram were determined in order to establish the baking aptitude of blends. These parameters determine the flour quality and it is generally assumed that flours with a high content of gluten will give a product of a big volume. The preparation of molded bread requires the so-called great force flour. For this type of flour the wet gluten content must be within the range of 25.0% - 30.0%, and the Falling Number between 250 - 325 seconds [13]. Wet gluten percentages are appropriate for wheat flour, 5% and 10% blends (Table 2). Only 15% blends show a significantly different wet gluten content, which is about three times higher than dry gluten content, as noted elsewhere [14] (Table 2). There are no differences between blends.

Gluten Index is a parameter indicative of wet gluten quality [17]. It represents the percentage of total wet gluten retained in a standard sieve. The greater the Gluten Index value, the greater the force of the gluten, although this fact is not always associated with a big bread volume [18]. The values obtained for the different mixtures, except for that of 15%, indicate an acceptable bread making ability (Table 2). According to Perten [17] the optimum Gluten Index value for baking purposes should be between 60 and 90. Blend with 5% of quinoa and wheat flour show no differences. Unlike results obtained by Hömö et al. [19] for wheat flours, it can be argued that the smaller the wet gluten content, the smaller the Gluten Index. On the other hand, Perten [17] has established that there is not any correlation between wet gluten and Gluten Index. With respect to Falling Number, it is expected that an increase in the amount of quinoa flour will produce an increase in Falling Number values. The decrease in 5% and 10% blends may be the result of a dilution effect. Nevertheless, Tukey's test demonstrated that there are no differences between the means of each of the groups. These parameters cannot be determined for quinoa flour, since it is not possible to form dough with it.

Table 2: *Dry and wet gluten, Gluten Index and Falling Number values of wheat and quinoa flour and their blends. %: dry basis; ±: standard deviation; (1) Difference among values must be minor than 2% (Norm No. 15864); (2) Difference among values must be minor than 3% (Norm No. 15864); (3)Triplicates must not differ in more that ± 5% of average value (Norm No. 15862).*

Material	Wet Gluten (%)$^{(1)}$	Dry Gluten (%)$^{(2)}$	Gluten Index	Falling Number (s)$^{(3)}$
Wheat flour	25.9 ± 0.5	8.3 ± 0.2	92 ± 4	248 ± 10
Quinoa flour	-	-	-	-
5% blend	25.5 ± 0.3	8.2 ± 0.2	91 ± 3	213 ± 6
10% blend	25.0 ± 0.3	8.1 ± 0.2	89 ± 2	223 ± 9
15% blend	20.7 ± 0.3	7.1 ± 0.2	54 ± 2	246 ± 10

Alveogram and farinogram are two rheological methods that indicate flour plasticity properties. The alveograph tries to reproduce the tensions the gluten net supports during fermentation and cooking. Tenacity (P) and extensibility (L) are important parameters but it is P/L relationship what matters, in that it indicates flour equilibrium. A good balance in the flour (a proper P/L) will produce a proper loaf volume and internal structure of bread. For great force flour the following values are recommended: P between 100 –120 mm of water; L between 80-100mm; G between 22 and 25; P/L between 1.0-1.3 and W above 250 10^{-4} Joules [13]. The wheat flour used in this work has a very low P value, although it is well balanced (Table 3). The addition of quinoa flour has a positive effect. Tenacity increases as much as quinoa content does. Nevertheless, the decrease in extensibility leads to a very high P/L relationship and produces ill-balanced flours (Table 3). The low values of the swelling degree (G) imply greater difficulties for dough development. Parameters G and L are the most affected by the absence of gluten-like proteins in quinoa flour. Besides, low deformation works are observed in all blends.

The farinogram establishes the flour behavior during baking processes. It represents the elasticity and plasticity of dough when undergoing continuous mixing at constant temperature. Quaglia [14] has established that good quality flour will have breakdown values (mixing tolerance index) between 30 and 50 BU and stability values no lower than 7 minutes. Results (Table 4) show greater water absorption and breakdown values for wheat - quinoa blends than wheat flour, especially for 15% blend. Similar results were obtained by Chauhan et al. [7]. High breakdown values are not appropriate for flours used in the elaboration of molded bread. Nevertheless, the stability value might be acceptable.

Table 3: *Alveograph parameters of wheat flour and flour blends of wheat and quinoa. Alveograph repeat the determinations until four ones have standards deviations of P ± 0.8 and L ± 0.5*

Parameter	Material			
	Wheat flour	5% blend	10% blend	15% blend
Tenacity (P) (mmH_2O)	89	100	110	115
Extensibility (L) (mm)	83	54	35	32
P/L Relationship	1.07	1.86	3.09	3.60
Swelling (G)	21.5	16.3	13.2	12.6
Deformation work ($J\ 10^4$)	280	214	163	161

Table 4: *Farinograph parameters of wheat flour and flour blends of wheat and quinoa. *BU: Brabender units*

Parameter	Material			
	Wheat flour	5% blend	10% blend	15% blend
Absorption (g/100g) ± 2.5 g	56.3	57.3	57.4	57.3
Development time (min) ± 1 min	2.5	2.0	2.0	2.5
Stability (min) ± 2 min	10.0	9.0	8.0	7.0
Breakdown (BU)* ± 20 BU	60	70	80	90

Quinoa content does not affect the development time. Differences are of a standard deviation order. Development time of the dough correlated quite positively with the amount of wet gluten but not with wheat flours Gluten Index [19]. The results obtained in this research show that wet gluten and Gluten Index values diminish whereas the development time is almost the same (Tables 2 and 4). This opposite effect is due to the addition of quinoa flour. The stability decreases along with Gluten Index (Tables 2 and 4). This is in agreement with the results of Hömö et al. [19].

Table 5: *Bread specific volume*

Flour	Bread specific volume (cc/g)
Wheat flour	4.0 ± 0.3
5% quinoa	3.9 ± 0.4
10% quinoa	4.0 ± 0.3
15 % quinoa	2.5 ± 0.2

Bread loaf volumes are shown in Table 5. The replacement of 5% and 10% of wheat flour with quinoa flour does not affect the specific loaf volume. In spite of the fact that blends are not balanced flours, breads are acceptable. Quinoa has a slightly high amylase activity [20], which results in an increase in gas production and in loaf volume. Loaf volume decreases with quinoa replacement levels of 15%. Reduction in loaf volume may be due to a gluten dilution effect, since, unlike wheat flour, quinoa flour has not got gluten.

Conclusions

The addition of quinoa integral flour to wheat flour diminishes the aptitude of the latter for making dough. The sample with 15% of quinoa flour shows inappropriate values for making bread as indicated by alveogram and farinogram parameters. There is little difference between 5% blend and wheat flour. Furthermore, there is not an important improvement in protein content. An acceptable baking aptitude, as well as higher protein content, was founded for 10% blend. Molded bread baked with 5% and 10% blends presented good loaf volumes, just like bread prepared with wheat flour.

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