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**ASSESSMENT OF QUINOA FLOURS EFFECT ON WHEAT FLOUR  
DOUGH RHEOLOGY AND BREAD QUALITY**

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The aim of the research was to evaluate the effect of addition of white and red quinoa whole flours (15% and 30%) on the physical-chemical and rheological parameters of white and dark wheat flours, in order to optimize the mixtures for bakery products. Flours were analysed in terms of moisture, protein and ash content, wet gluten, gluten index, falling number, dough farinographic and alveographic parameters. In addition bread specific volume, porosity, crumb moisture and technological water absorption were determined. The optimum bakery potential of wheat flour mixtures with quinoa flours was decided based on the high extensibility and low resistance of dough. For additions up to 15% white quinoa flour, the breads had the highest specific volumes (3.8 ml/g dark flour; 2.5 ml/g white flour).

*Keywords: bread, quinoa flour, physico-chemical parameters, dough rheological parameters, wheat flour*

## **Introduction**

Quinoa (*Chenopodium quinoa*) is a South American pseudocereal, considered one of the solutions to the challenges of ensuring human food security in the context of climate change and demographic growth. The plant is characterized by a high ecological plasticity and a unique nutritional and phyto-pharmaceutical profile.

The efficacy coefficient of quinoa proteins is appreciated by the literature as being casein-like, and their digestibility can be increased by thermal treatments (Ranhotra

*et al.*, 1993; Chauhan *et al.*, 1992; Ruales *et al.*, 1992). A series of low molecular weight peptides, obtained from the enzymatic hydrolysis of quinoa proteins, have anti-hypertensive, anti-oxidative (Aluko and Monu, 2003) and cholesterol-lowering potential (Takao *et al.*, 2005).

The carbohydrates composition is similar to other cereals (73.0-74.0% D.M.), the major component being starch (52-70% D.M.). The total dietary fibers content varies from author to author in the range of 7.0-10.0% D.M. (Wright *et al.*, 2002; Mundigler, 1998; Ranhotra *et al.*, 1993). Quinoa polyglucides have hypoglycaemic effects and are involved in reducing the fatty acids level in blood (Berti *et al.*, 2004). In vitro digestibility of whole starch from quinoa was reported to be 22% and may increase up to 73% depending on the applied type of thermal treatments (Ruales and Nair, 1992).

The amount of quinoa seeds lipids is estimated to be between 1.8-9.5%. Relative to the D.M. quinoa seeds have an amount of lipids (7%) superior to maize (4.5%) and the quinoa fatty acids profile is similar to corn oil or soybean (Koziol, 1993). Linoleic acid (C18:2) is one of the most abundant polyunsaturated fatty acid identified in quinoa. It has positive effects regarding the protection of the cardiovascular system (Abeywardena *et al.*, 1991). Also, in the lipid fraction of quinoa seeds there is a significant amount of tocopherols (0.6-2.6 mg/100 g) that prevents the oxidation of flour lipids and ensures their stability up to 30 days (Ryan *et al.*, 2007; Su-Chuen *et al.*, 2007). In the unsaponifiable lipid fraction, significant amounts of squalene (34.0-58.0 mg/100g) and phytosterols ( $\beta$ -sistosterol 63.7mg/100g, campesterol 15.6mg/100g and stigmasterols 3.2 mg/100g) have been identified (Ryan *et al.*, 2007; Park *et al.*, 2005). These substances have an indirect (as precursors of bioactive compounds) or direct effect on maintaining the cardiovascular system health. At the same time their antitumoral, antioxidative, anti-inflammatory and blood cholesterol regulation effect was proven. The concentration of these bioactive compounds in quinoa seeds is higher than in the case of pumpkin, barley or corn seeds and supplements the recommended daily dietary quantities of phytosterols required for food (0.8-1 g/day) (Moreau *et al.*, 2002; Ryan *et al.*, 2007; Berger *et al.*, 2004).

Quinoa is also an important source of vitamins, especially B vitamins. An amount of 100 g of quinoa seeds can supplement vitamin B6 and folic acid daily requirements, respectively 80% of daily riboflavin requirements for adults (Ranhotra *et al.*, 1993).

The functional properties of quinoa flour, such as solubility, water binding, gelatinization, foaming or emulsifying properties, are described in a series of studies. It is appreciated that the solubility of quinoa flour proteins is increased when exposed to thermal treatments (baking), respectively at pH 6 and maximum at pH 10 (Ogungbenle, 2003; Oshodi *et al.*, 1999). The water retention capacity is estimated to be about 147%, lowered by the presence of salt. The gelatinization capacity, defined as the "minimum amount of quinoa flour in a certain volume of distilled water necessary for the mixture to gelatinize", was evaluated at 16% (Ogungbenle, 2003; Ogungbenle *et al.*, 2009). The foam formation capacity is

considered poor, but the emulsifying capacity and the stability of the formed emulsions are considered good. Thus, a number of authors estimate this capacity as 46%, expressed as an absorption capacity of the oil. These features highlight the excellent potential of using quinoa flour in technologies for making beverages, sauces, desserts, sausages etc. (James, 2009).

The quinoa whole flour is obtained by dry milling of quinoa seeds, after a prior removal of saponins from the pericarp (by rinsing in cold or alkaline water or mechanical abrasion). Quinoa milling technologies are oriented towards selection of seeds varieties, poorer in saponins (sweet taste varieties and less intense bitter flavor) (Jancurová *et al.*, 2009). The presence of saponins in seeds pericarp is considered the main nutritional disadvantage of the plant, as they were extremely toxic, according to classical medical literature. However, more recent researches suggest that the saponins may be involved in lowering the plasma cholesterol level, or in the decrease of gallbladder salts concentration (Valencia-Chamorro, 2003).

The aim of the research was to evaluate the effect of two types of quinoa whole flours on the physical-chemical and rheological parameters of wheat flours, in order to optimize the usable amounts in the bakery products recipes.

## Materials and methods

Two types of wheat flours and two types of quinoa flours were analyzed, as follows: dark wheat flour (M1), white wheat flour (M2), whole white quinoa flour (WQ) and whole red quinoa flour (RQ), obtained by dry milling of quinoa seeds, purchased from the Romanian market. Milling was performed on a Perten 1500 laboratory mill, to average particle sizes of less than 500  $\mu$  (in table 3 one can see the flours mineral content).

The experimental plan included the testing of wheat flours, as well as their mixtures with 15% and 30% of quinoa flours, according to Table 1. The tests were performed in three repetitions, taking into consideration the mean values ( $n=3$ ).

Recipes and the methodology used to obtain finished products, respectively breads, are shown in Table 2.

### *Statistical analysis*

Interpretation of results was performed using computer-assisted statistical analysis (descriptive statistics, t test) Microsoft Excel programs have been used to run dispersion calculations. Significance tests were performed using Statistica software from StatSoft, Inc.

## Results and discussion

### *Characterization of the flours*

Table 3 presents the results of the physical-chemical analysis for the wheat flours and mixtures of wheat flours with white and red quinoa flours ( $n=3$ ).

**Table 1.** Experimental variants and tested quality parameters

Variant	Wheat dark flour%	Wheat white flour%	WQ flour (%)	RQ flour (%)	Methods used for estimating quality parameters
M1 (control 1)	100	0	0	0	<i>Wheat flours and mixtures with quinoa flours:</i> Moisture (M%, 130 <sup>0</sup> C, thermobalance Precisa XM 60), protein content P% (NIR method, Perten INFRAMATIC 8600), Ash content (A% SR ISO 2171:2007 at 900 <sup>0</sup> C), wet gluten content WG% and gluten index GI (ICC no. 155 method), falling number FN (ISO 3093); farinogram (ISO 5530-1:2013), alveogram (ISO 27971:2015).
M1-15WQ	85	0	15	0	
M1-30WQ	70	0	30	0	
M1-15RQ	85	0	0	15	
M1-30RQ	70	0	0	30	
M2 (control 2)	0	100	0	0	
M2-15WQ	0	85	15	0	
M2-30WQ	0	70	30	0	
M2-15RQ	0	85	0	15	
M2-30RQ	0	70	0	30	

**Table 2.** Recipes and technological process for baking tests

Recipe	Technology
<b>2.5 % dry yeast</b> Pakmaya <b>1.5 % salt</b> <b>water</b> - variable, depending on farinographic water absorption% (WA), in order to obtain a normal consistency of dough <b>0.3 % baking conditioner</b> – Pan Up T-Max (manufacturer: Orkla, ingredients: wheat flour, antioxidant E300, enzymes: xylanase, lipase, amylase, oxidase, cellulase, dextrose)	<b>kneading:</b> 10 minutes on a single-speed mixer (100 rpm) with fork-type mixing arm; <b>dough resting:</b> 20 min; <b>partition:</b> 355-365 g; <b>round moulding;</b> <b>resting:</b> 5 min; <b>long moulding;</b> <b>fermentation:</b> under controlled conditions: 35 min at 37° C, 78% moisture; <b>baking:</b> 220 ° C, 20 min.

The control flours moisture was characterized by values ranging from 13.95% for dark wheat flour to 14.9% for white wheat flour. The moisture of white quinoa flour was significantly higher than that of the red quinoa flour (13.83% vs. 13.60%,  $t=3.491^*$ ;  $p<0.05$ ).

The protein content between wheat flours had significant different values. Thus, between dark and white wheat flour there was an extremely significant difference in the protein content of about 5.74% ( $t=152.093^{***}$ ;  $p<0.001$ ). The two quinoa flours also differed in terms of protein content, which was extremely significant higher in red quinoa (17.3%) than in white quinoa flour (11.47%) ( $t=66.105^{***}$ ). Quinoa whole flours have a protein content similar to whole wheat flours (about 16% D.M.), but higher than those obtained from barley (11.0% D.M.), rice (7.5% D.M.) or corn (11.5% D.M.) (Abugoch *et al.*, 2008; Ando *et al.*, 2002). Compared

to other cereals, quinoa seeds are characterized by a higher content of lysine (amino acid considered limitative to most conventional cereals), methionine and histidine (James, 2009; Repo-Carrasco *et al.*, 2003; Wright *et al.*, 2002).

**Table 3.** Physical and chemical quality parameters of wheat flours and mixtures (n=3)

Parameter/ Flour type	M, %	P, %	A, %	WG, %	GI	FN, s
Dark wheat flour (M1)	13.950 ± 0.050	17.567 ± 0.058	0.993 ± 0.030	42.400 ± 0.529	86.000 ± 2.000	421.667 ± 7.637
Type 480 wheat flour (M2)	14.900 ± 0.264	11.833 ± 0.058	0.480 ± 0.010	30.233 ± 0.208	68.667 ± 3.512	412.000 ± 13.115
White quinoa flour (WQ)	13.833 ± 0.058	11.466 ± 0.115	1.010 ± 0.01	ud	ud	> 1000
Red quinoa flour (RQ)	13.600 ± 0.100	17.300 ± 0.100	3.370 ± 0.040	ud	ud	> 1000
M1-15 WQ	13.900 ± 0.100	17.233 ± 0.153	1.000 ± 0.010	37.500 ± 0.300	85.333 ± 0.577	564.333 ± 14.361
M1-30 WQ	13.700 ± 0.100	16.267 ± 0.252	1.010 ± 0.010	30.933 ± 0.551	89.000 ± 1.000	838.333 ± 5.033
M1-15 RQ	13.867 ± 0.058	17.733 ± 0.058	1.420 ± 0.030	35.667 ± 0.321	86.333 ± 1.527	500.667 ± 10.066
M1-30 RQ	13.800 ± 0.100	17.633 ± 0.115	1.760 ± 0.040	31.600 ± 0.300	87.000 ± 1.000	557.667 ± 9.849
M2-15 WQ	14.733 ± 0.058	12.233 ± 0.153	0.600 ± 0.020	26.267 ± 0.416	79.000 ± 3.605	440.000 ± 12.490
M2-30 WQ	14.633 ± 0.058	12.100 ± 0.100	0.710 ± 0.030	21.300 ± 0.300	69.667 ± 4.509	552.667 ± 8.737
M2-15 RQ	14.667 ± 0.115	12.400 ± 0.100	1.070 ± 0.020	26.467 ± 0.351	79.667 ± 0.577	400.667 ± 12.503
M2-30 RQ	14.700 ± 0.100	12.700 ± 0.200	1.560 ± 0.060	21.300 ± 0.100	70.333 ± 1.527	486.000 ± 15.100

ud – undetermined

The mineral content (ash) differed significantly between the controls, but also between the two quinoa flours. Thus, the mineral content was extremely significant higher in red than white quinoa (3.37% vs. 1.01%;  $t=99.140^{***}$ ). Quinoa flours, both white and red, had a significantly higher content of minerals than white flour. In terms of mineral content, quinoa flour can be considered an important source of phosphorus, potassium, magnesium and zinc. It is estimated that 100 g of quinoa seeds can cover the daily needs of magnesium, manganese, copper and iron for children and adults, respectively up to 40-60% of their daily phosphorus and zinc requirements (Konishi *et al.*, 2004).

The control flours wet gluten was characterized by high values (42.40% for dark flour and 30.23% for white flour), so they can be characterized as having superior

bakery potential. The addition of quinoa flours resulted in a corresponding decrease in wet gluten content of the mixtures, at a rate dependent on the amount of added quinoa flour. The decrease was strong enough in the large additions of quinoa flours, when wet gluten fell to values incompatible with the bakery qualities (ex. in the case of white wheat flour, the addition of 30% quinoa flour, determined the decrease of wet gluten to 21.3%). This effect underlines the importance of the wet gluten parameter in choosing wheat flour to be used in the making of quinoa added bakery products. It is preferable that the value of wheat flour gluten, to which quinoa flour is added, should be as high as possible.

The gluten index value was very significantly higher in dark wheat flour (86.000) than in white wheat flour (68.667;  $t=7.514^{**}$ ;  $p<0.01$ ). The addition of quinoa flours to dark flour did not significantly alter the value of the gluten index, regardless of the quinoa flour type used for the tested variants (15 vs. 30%) ( $t$  values of max. 2.169 is-insignificant). In the case of white wheat flour, characterized by a lower initial value of the gluten index, for both variants of 15% white or red quinoa flour addition, the results showed a significant increase in the gluten index. This increase was from 68.667 to 79.000 in the case of white quinoa addition ( $t=3.100^*$ ) and to 79.667 for red quinoa addition ( $t=4.193^*$ ). White wheat flours treatments with 30% quinoa flour did not significantly alter the gluten index value.

The wheat flours used as control did not differ significantly in terms of the falling number value (421.7 sec for dark wheat flour, respectively 412 s for white wheat flour;  $t=1.103$  is). On the other hand, the values of this parameter for quinoa flours were very high, beyond the usual values of wheat flours (over 1000 sec). Thus, it can be said that quinoa flours quickly form more consistent and stable gels than wheat flours. The effect of quinoa flours addition differed, depending on the type of wheat flour and depending on the type of quinoa flour.

Thus, in the case of dark wheat flour, the addition of quinoa flours results in significant increases in the falling number parameters, corresponding to the used quantities. The increasing effect was more pronounced in the case of white quinoa whole flour addition (increase of +416.6 sec compared to the control, in 30% variant), compared to the red quinoa whole flour addition (increase of +136 sec compared to the control, in 30% variant). It is possible that the differences between the two quinoa flours are due to the higher fibers, protein and mineral content of the red quinoa flour, a composition profile that corresponds to a lower starch content, compared to white quinoa flour. Thus, it would also be a lower gelling ability of red quinoa flour.

In the case of white wheat flour, the addition of 15% quinoa flour did not significantly change the value of the falling number (from 412.0 sec. to 440.0 sec. in the case of white quinoa flour addition  $t=2.678$ , respectively at 400.7 sec. in case of red quinoa flour addition  $t=1.080$  in). The addition of 30% quinoa flour has led to a significant increase in the value of the falling number to 552.7 sec (WQ), respectively 486.0 sec. (RQ). It was also noted that the addition of white quinoa flour had a more intense increasing effect than that of red quinoa flour.

The farinograph analysis results of wheat flours and of mixtures with quinoa flours are presented in table 4.

**Table 4.** Farinograph analyzes for wheat flours and mixtures

Parameter/ Flour type	Water absorption (%)	Development time (min)	Stability (min)	Dough softening (10 min UF)	Dough softening (12 min UF)
Dark wheat flour (M1)	65.633 ± 0.252	7.267 ± 0.305	11.867 ± 0.153	18.333 ± 3.512	55.667 ± 4.041
Type 480 Wheat flour (M2)	56.100 ± 0.300	2.267 ± 0.305	12.067 ± 0.513	20.667 ± 1.155	31.000 ± 3.605
White quinoa flour (WQ)	ud	ud	ud	ud	ud
Red quinoa flour (RQ)	ud	ud	ud	ud	ud
M1-15 WQ	68.133 ± 0.231	6.700 ± 0.264	5.833 ± 0.115	27.000 ± 6.245	72.667 ± 4.726
M1-30 WQ	66.933 ± 0.651	6.533 ± 0.153	3.500 ± 0.115	45.000 ± 5.000	93.333 ± 5.132
M1-15 RQ	66.300 ± 0.300	8.967 ± 0.115	8.833 ± 0.378	6.667 ± 2.887	0
M1-30 RQ	65.633 ± 0.252	7.633 ± 0.153	4.067 ± 0.451	33.667 ± 5.507	79.000 ± 3.606
M2-15 WQ	56.767 ± 0.252	4.667 ± 0.115	8.133 ± 0.416	28.667 ± 1.155	46.667 ± 2.887
M2-30 WQ	59.433 ± 0.404	2.300 ± 0.100	4.200 ± 0.529	78.333 ± 10.408	99.333 ± 4.509
M2-15 RQ	57.400 ± 0.264	1.767 ± 0.252	5.267 ± 0.252	73.333 ± 2.887	87.333 ± 2.516
M2-30 RQ	57.467 ± 0.153	5.967 ± 0.503	6.000 ± 0.200	38.000 ± 2.000	97.333 ± 6.429

ud – undetermined; \*significant,  $p < 0.05$ ; \*\*very significant,  $p < 0.01$ ; \*\*\*extremely significant,  $p < 0.001$

The water absorption of the two control flours was significantly different, being higher in the case of dark wheat flour compared to white wheat flour (65.6% vs. 56.1%). The only conclusion that could be drawn from the analysis was that the addition of quinoa flours did not worsen this parameter.

The effect of these additions was dependent on the type of wheat flour and of quinoa flour. E.g. the addition of 15% white quinoa flour to dark wheat flour resulted in an extremely significant increase of the water absorption, from 65.6% to 68.1% ( $t=12.166^{***}$ ,  $p < 0.001$ ), while 30% white quinoa flour addition caused only a significant increase (from 65.6% to 66.9%,  $p < 0.05$ ). The addition of 15% white quinoa flour to white wheat flour significantly changed the dough water absorption (from 56.1 to 56.8;  $t=0.949^*$ ), while the addition of 30% white quinoa flour led to an extremely significant increase (to 59.433;  $t=11.473^{***}$ ).

The effect of red quinoa flour addition on the water absorption of the two wheat flours was less intense than in the case of white quinoa flour addition. Thus, in the

case of dark wheat flour, the addition of 15% red quinoa flour caused only a slight increase in the water absorption (from 65.6% to 66.3%), while the addition of 30% did not cause a significant change compared to control flour. In the case of white wheat flour, the addition of red quinoa flour had the same effect on the water absorption, regardless of the dose used (15 or 30%), namely: a very significant increase from 56.1% to 57.4% ( $t=5.634^{**}$ ,  $p<0.01$ ). The way in which the addition of the two quinoa flours has changed the water absorption influenced the value evolution of the other farinograph parameters. Thus, although the dough development time of the control flours (wheat flours) were extremely different: 7.3 minutes for dark flour, respectively 2.3 minutes for white flour, the effect of the quinoa flour addition on the development time was not homogeneous. Where the addition of quinoa flours led to small changes in the absolute value of the water absorption (between 0 and +1.37%) compared to the control flour (M1-15 RQ, M1-30 RQ, M2-15 WQ, M2-30 RQ) the dough development times increased (between 0.37 and 2.4 min). In this case, we can see the increasing effect of the time required to incorporate quinoa flour components (fibers, proteins, mineral substances) into the dough. Where the addition of quinoa flour has led to large changes in the absolute value of the water absorption (between 1.3 and +3.33%) compared to the control flour (M1-15 WQ, M1-30 WQ, M2-30 WQ, M2-15 RQ), the dough development times decreased or were very close to those of the control (between 0.03 and 0.734 min). In this case, the higher quantity of water initially available led to a faster hydration of the components of wheat flour compared to quinoa flour and to a faster reaching of the viscosity of 500 FU.

#### ***Characterization of the dough samples***

The addition of quinoa flours to wheat flours caused a decrease in dough stability. We mentioned the high values of the two control flours dough stability (11.9 min. for dark wheat flour, respectively 12.1 min. for white wheat flour). As a general feature, the effect on the dough stability decreasing was more intense in the case of white quinoa flour addition and less intense in the case of red quinoa flour addition.

The addition of quinoa flour determined the increase of dough softening, compared to its values in the control flours. The parameter increase was higher in the case of white quinoa flour addition, compared to red quinoa flour.

The results of the alveograph analysis of wheat flours and of the mixtures with Quinoa flours are presented in table 5 (n=3).

It is observed that the dark wheat flour was characterized by a very high value of extensibility (185.3 mm) and a low value of resistance (46.7 mm. P/L=0.25). White wheat flour had a balanced resistance/extensibility ratio, the two values being moderate. The addition of quinoa flours resulted in a significant decrease of dough extensibility and a corresponding increase of resistance. The magnitude of these changes was determined by the initial values of the two parameters in the control flours. White quinoa flour had a lower effect of decreasing the dough extensibility, in mixtures with wheat flours, compared to red quinoa flour. Instead, red quinoa flour had a lower effect of increasing the doughs resistance, compared to white quinoa flour, in mixtures with wheat flours.



**Table 5.** Alveograph analyzes for wheat flours and mixtures

Parameter/ flour type	Resistance P (mm)	Extensibility L (mm)	Mechanical		Elasticity index Ie (%)
			work, W (10 <sup>-4</sup> J/g)	P/Lratio	
Dark wheat flour (M1)	46.667 ± 2.082	185.333 ± 10.016	155.00 ± 5.000	0.252 ± 0.050	41.600 ± 0.200
Type 480 Wheat flour (M2)	83.667 ± 3.605	88.667 ± 2.309	222.667 ± 4.619	0.944 ± 0.006	49.600 ± 0.259
White quinoa flour (WQ)	ud	ud	ud	ud	ud
Red quinoa flour (RQ)	ud	ud	ud	ud	ud
M1-15 WQ	94.000 ± 3.605	102.667 ± 3.786	270.333 ± 6.028	0.916 ± 0.065	49.533 ± 0.252
M1-30 WQ	125.333 ± 5.033	52.667 ± 2.515	241.333 ± 3.214	2.380 ± 0.020	47.232 ± 0.681
M1-15 RQ	80.667 ± 2.082	74.667 ± 4.163	188.333 ± 10.408	1.080 ± 0.020	47.200 ± 2.820
M1-30 RQ	93.000 ± 2.646	36.333 ± 0.577	134.333 ± 4.041	2.560 ± 0.040	0
M2-15 WQ	79.000 ± 3.605	36.000 ± 4.000	113.000 ± 2.646	2.194 ± 0.004	0
M2-30 WQ	95.667 ± 4.041	24.333 ± 1.527	95.667 ± 5.131	3.932 ± 0.006	0
M2-15 RQ	61.333 ± 3.055	42.667 ± 2.082	95.667 ± 2.082	1.437 ± 0.002	37.800 ± 2.200
M2-30 RQ	81.000 ± 3.605	24.000 ± 1.000	82.000 ± 2.000	3.375 ± 0.005	0

As a rule, the addition of 30% quinoa flour has worsened the quality parameters, to the limit of bakery potential. Dark wheat flour, characterized by a very high value of extensibility, had a better rheological behavior, being able to take a larger quantity of quinoa flour by keeping its alveograph parameters at reasonable values.

The effect of quinoa flours addition on the alveograph mechanical work (W) was significantly influenced by the value of the control flours P/L ratio. Although the value of alveograph mechanical work was higher in white wheat flour compared to dark flour ( $222.7 \times 10^{-4}$  J/g compared to  $155 \times 10^{-4}$  J/g), dark flour was the only one that registered significant increases in this parameter when adding quinoa flour. The increase of dark flour alveograph mechanical work, when adding quinoa flour, was due to dough ability to form extensible gluten networks, able to properly integrate quinoa flour components. Another explanation may start from the modification of dough water dynamics, knowing that quinoa flours have different water absorptions, compared to wheat flours and alveograph analysis takes place under constant hydration conditions. Thus, the addition of quinoa flours can lead to the formation of more consistent dough, from rheological point of view.

White quinoa flour had a spectacular effect of increasing the mechanical work, relative to red quinoa flour (from  $155 \times 10^{-4}$  J/g to  $270.3 \times 10^{-4}$  J/g at 15% addition, respectively to  $241.3 \times 10^{-4}$  J/g at 30% addition). Comparative, the results obtained

for red quinoa flour addition were lower (increase at  $188.3 \times 10^{-4}$  J/g at 15% addition, respectively decrease at  $134.3 \times 10^{-4}$  J/g at 30% addition). Red quinoa flour had a higher fibers content than the white one. The fibers exerted probably a mechanical effect of breaking dough gluten films and by default, of reducing their ability to absorb mechanical stress.

In the case of white wheat flour, the addition of quinoa flours had a significant effect of reducing the mechanical work parameter. As shown above, although the white wheat flour mechanical work was higher, because of a small initial extensibility, the ability to preserve or increase the mechanical work absorbed by the dough when adding quinoa flours was extremely low. The effects of the two types of quinoa flours addition to dough were similar and brought the value of the mechanical work below the lower limit of bakery potential ( $150 \times 10^{-4}$  J/g). In the case of white quinoa flour addition the decrease effect was slightly lower than that observed for red quinoa flour addition.

Generally, it is seen that the addition of larger quantities of quinoa flours (30%) resulted in the loss of dough elasticity (Ie % decrease).

#### ***Characterization of the bread samples***

Quinoa flour bakery properties are estimated to be very low compared to wheat flour or other cereals flours containing gluten. Most researches have been directed to obtain products such as: pasta, extruded snacks, gluten-free products (Gallagher *et al.*, 2004; Doğan and Karwe, 2003; Caperuto *et al.*, 2000). Most studies on production of quinoa flour bread aimed at obtaining gluten-free bakery products. In this type of products, the quinoa flour can reach up to 50%, the results being considered positive with respect to other pseudo-cereals flours, due to the presence of natural emulsifiers in quinoa flour. However, the volumes obtained for these products are far from the minimum acceptability limits in the case of the Romanian consumer (about 1.4 ml/g, compared to 4.5-5 ml/g in the usual bread) (Alvarez-Jubete *et al.*, 2010).

Researches have been carried out to investigate the addition of red and white quinoa flour to superior white flour type to obtain bread. The results showed that the optimum quinoa flour amount, for an acceptable quality of the finished products, is in the range of 5-10%, corresponding to bread volumes of 3.0-3.25 ml/g. The addition of 20% quinoa flour decreased the volume of bread below 2.5 ml/g (Codina *et al.*, 2016).

Flour mixtures were used to obtain bread (Figure 1). The results of the baking tests are presented in table 6.

It can be observed that the addition of quinoa flours determined the increase of the technological water absorption, compared to the control flours water absorption. The increase in the water absorption was higher when adding red quinoa flour (about 1.5-4.0%, depending on the used quantity) and quite modest when adding white quinoa flour (0.4-3%, depending on the amount, but also on the wheat flour type, the increase being more evident in the case of white wheat flour).

**Table 6.** Results of technological analyzes and quality parameters of bread

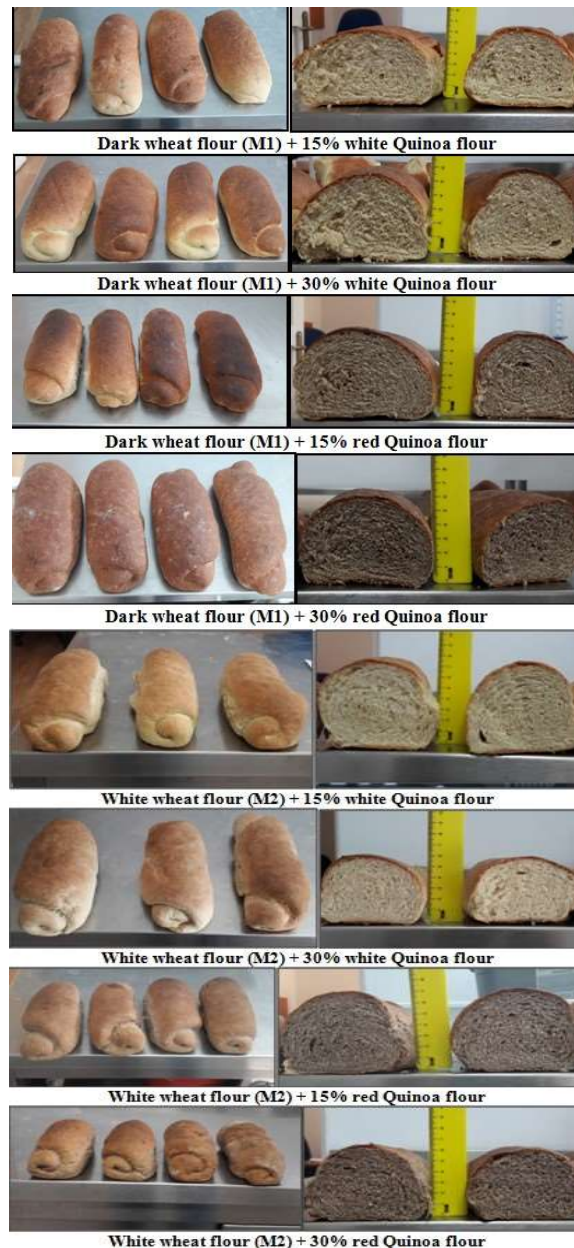
Parameter/ Flour type	Technological water absorption (%)	Dough temperature (°C)	Specific volume (ml/g)	Porosity (%)	Core moisture (%)
Dark wheat flour (M1)	60.000 ± 0.500	26.400 ± 0.100	4.686 ± 0.080	79.050 ± 1.767	44.863 ± 0.158
Type 480 Wheat flour (M2)	55.000 ± 0.200	26.400 ± 0.115	3.397 ± 0.120	80.910 ± 0.650	43.600 ± 0.112
M1-15 WQ	60.500 ± 0.158	26.800 ± 0.120	3.803 ± 0.084	79.155 ± 0.900	44.440 ± 0.158
M1-30 WQ	60.400 ± 0.220	26.400 ± 0.150	3.050 ± 0.134	72.450 ± 0.390	45.020 ± 0.160
M1-15 RQ	61.500 ± 0.342	26.600 ± 0.100	3.489 ± 0.202	78.010 ± 1.390	44.440 ± 0.180
M1-30 RQ	64.000 ± 0.750	26.100 ± 0.110	3.096 ± 0.062	74.680 ± 2.050	44.510 ± 0.120
M2-15 WQ	55.500 ± 0.222	25.400 ± 0.110	2.467 ± 0.174	74.819 ± 1.085	43.470 ± 0.150
M2-30 WQ	58.000 ± 0.350	25.600 ± 0.100	2.104 ± 0.051	70.142 ± 0.160	44.460 ± 0.100
M2-15 RQ	57.000 ± 0.500	25.200 ± 0.115	2.320 ± 0.215	75.097 ± 0.347	44.640 ± 0.150
M2-30 RQ	59.000 ± 0.250	25.600 ± 0.115	2.106 ± 0.055	71.785 ± 0.630	44.790 ± 0.118

The addition of quinoa flour significantly reduced the volume of the bakery products, in relation to the volume of control breads, both for those made out of white wheat flour, as well as for those made out of dark flour. The bakery products obtained out of dark wheat flour had a higher volume than those made out of white wheat flour, which confirms the importance of the dough extensibility for the flours bakery potential. For additions up to 15% white quinoa flour, the breads had the highest specific volumes (3.80 ml/g for dark wheat flour, respectively 2.46 ml/g for white wheat flour). For additions of 30% quinoa flours, the effects on the specific volume were similar, both for white quinoa as well as for red quinoa flour, regardless of the wheat flour type (white or dark).

The effect was similar in terms of the porosity parameter evolution. So, the porosity of quinoa flour products was significantly lower than the porosity of breads obtained exclusively from wheat flour. In the case of dark wheat flour, the addition of 15% quinoa flour allowed to obtain a porosity similar to those of the control flour. In the case of white wheat flour, porosity decreases from 80.9% to around 75%, both for the addition of white or red quinoa flour. The addition of 30% quinoa flours significantly worsens the value of the porosity parameter, both for dark as well as for white wheat flour.

The breads moisture with quinoa flours addition did not vary dramatically compared to the moisture of the breads obtained exclusively from wheat flours. The highest moisture had the bread made out of dark wheat flour with 30% white quinoa flour addition (45.02%). The largest moisture difference between the bread made from the control flour and the one with the addition of quinoa flour was

observed in the white flour-30% red quinoa variant (+1.19%). For certain samples, the bread moisture obtained with quinoa flour addition was even lower than the moisture of bread obtained from the control flours. This phenomenon was observed in the following variants: dark wheat flour with 15% white quinoa flour (-0.423%), dark wheat flour with 15 and 30% red quinoa flour (-0.423%, respectively -0.353%) and white wheat flour with 15% white quinoa flour (-0.13%).



**Figure 1.** General appearance and sections of breads with quinoa flours

Figure 1 presents the general aspect and the section appearance of the finished products. The general appearance of the breads with the addition of red quinoa flour was similar to those obtained from whole wheat flour (reddish color of the crust, dark-colored core, medium porosity). The breads obtained with the addition of white quinoa flour had a light color, similar to the white wheat bread, commonly consumed on the Romanian market. Their crust was crispy, with a light-colored core section and a medium porosity.

Bread produced with quinoa flour addition to wheat flour, was obtained by Chauhan *et al.* (1992) using recipes having a quinoa flour content of up to 20%. They appreciated that the optimal use of quinoa flour in making bread is max. 10%. Park and Morita (2005) obtained bakery products using up to 10% quinoa flour from germinated seeds, finding that quinoa-wheat flours doughs are significantly improved by the addition of enzymes such as lipases. Kovács (2003) showed the favorable effect of transglutaminase on the quality of products obtained with quinoa flours. Salazar *et al.* (2017) concluded that the maximum utilization of quinoa flour added to wheat flour in bread recipes is 15%, beyond this value the products being accompanied by a gradual loss of acceptability, due to the worsening of sensory attributes, like the appearance of a bitter taste.

## Conclusions

The obtained results suggest that the optimum baking potential of wheat flours mixtures with quinoa flours was reached at a high value of extensibility and a low value of resistance.

Compared to white quinoa flour, red quinoa flour had worsened the values of mechanical alveographic work (probably due to its higher fibers content).

The addition of quinoa flours had the effect of increasing the technological water absorption of flour mixtures, especially with the addition of red quinoa mixed with white wheat flour.

The addition of quinoa flours significantly reduced the volume of breads compared to the control breads. The breads in mixtures with dark wheat flour had higher volumes than those with white wheat flours (the fact confirmed the importance of dough extensibility in realizing the flours baking potential). For additions up to 15% white quinoa the breads had the highest specific volumes (3.8 ml/g for dark wheat flour and 2.5 ml/g for white wheat flour). For the additions of 30% quinoa flour, white or red, the effects on the bread volumes were similar, regardless of the type of wheat flour (white or dark).

The breads porosity with quinoa flours addition was significantly lower than the porosity of wheat flour products. In dark wheat flour bread, the addition of 15% quinoa flour has formed pores similar to those from bread obtained exclusively from wheat flour. In white flour bread, the porosity decreased from 80.9% to 75% both in addition of white or red quinoa flour. The addition of 30% quinoa flour, to dark or white flour, significantly worsened the bread porosity.

The moisture content of flours mixtures did not significantly depend on the amount of quinoa flour added, but rather of specific technological conditions, like the amount of water used in doughs preparation (technological water absorption), which determined 58.3% of the breads moisture.

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