Effects of Flour and Protein Preparations from Amaranth and Quinoa Seeds on the Rheological Properties of Wheat-Flour Dough and Bread Crumb

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Abstract

Tömösközi S., Gyenge L., Pelcéder A., Abonyi T., Lásztity R. (2011): **The effects of flour and protein preparations from amaranth and quinoa seeds on the rheological properties of wheat-flour dough and bread crumb**. Czech J. Food Sci., **29**: 109–116.

The effects of amaranth and quinoa flours and protein isolates prepared from amaranth and quinoa seeds on the rheological properties of wheat flour dough and bread were studied using new recording instruments, the micro Z-arm mixer (for dough) and the SMS-Texture analyser (for bread crumb). The addition of 10% amaranth or quinoa flours did not cause significant changes in rheological properties. However, higher additions (20% and 30%) resulted in significant changes in stability, the degree of softening and elasticity. Substitution of wheat flour by amaranth or quinoa flours resulted in an increase of water absorption capacity. A significant reduction of specific volume and an increase of resistance to deformation (firmness) of the crumb of breads prepared from flour mixtures containing high percentages of amaranth or quinoa flours was observed. The addition of protein isolates did not significantly influence the main rheological parameters of dough, and bread crumb.

Keywords: pseudocereals; baked goods; microvalorigraph; quality

Different species of the amaranth plant were grown and consumed both as green vegetable and as cereal grains by ancient civilisations of Aztecs, Mayas and Incas. During the Mayan and Aztec periods in Central America, amaranth was the staple food for the population. After the colonisation of America, amaranth as food fell into disuse and its consumption decreased to a negligible level. This crop was used only in some parts of the world as traditional food specialties such as popped amaranth seeds and their combinations with molasses, honey or syrup, or chapatti like pancakes.

In the last decades, a resurgence of interest in amaranth may be observed. Amaranths are noted for high tolerance to arid conditions and poor soils, where cereals cannot grow with ease (Saunders & Becker 1984). It produces good yields of grain that contains relatively high levels of proteins and starch and a considerable (higher than any of the cereals) content of lipids. The protein has a high lysine content, higher than those of the other cereal proteins which are deficient in this amino acid. Thus, from the point of view of the nutritional value, amaranth grain is more advantageous than the cereal grains.

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A considerable amount of scientific literature is available on the amaranth and good review papers (Saunders & Becker 1984; Breene 1991) and books (Belton & Taylor 1993) were published. Several reports were published (Saunders & Becker 1984; Bressani *et al*. 1987; Prakash & Pal 1992; Parades-Lopez 1994) on the chemical composition of amaranth grain. Based on the results published, it may be stated that considerable differences exist depending on the species and conditions of growing. Consequently, the values reported for the seed components should be viewed as rather representative than exhaustive. The selection of a variety most suitable from the nutritional point of view needs a study of the composition of varieties grown under known conditions. The results of such studies may be helpful in the determination of the aims of further breeding programs.

Food uses of amaranth grain were also studied and a lot of potential products or amaranth-containing foods are mentioned in the literature such as popped grain, amaranth-containing baked goods, cakes, extruded products etc. (Saunders & Becker 1984; Breene 1991; Kovacs *et al.* 2001; Escudero *et al*. 2004). From the point of view of food production, the technological properties and quality of amaranth seeds may be of interest and should be investigated. The production of high quality products needs the selection of raw materials maximally corresponding to the technological needs of the producers. Except popped grains (Lara & Ruales 2002), no detailed studies were realised concerning the particular characteristics – and methods of their determination – of amaranth grain serving for different food purposes.

The other pseudocereal studied, the quinoa, cultivated since ancient times in South America (major producing countries are Bolivia, Peru and Ecuador), is also noted – similarly to amaranth for high tolerance to arid conditions and a relatively high protein content of good nutritive value (Taylor & Parker 2002). Possible food uses (in addition to the traditional use, common in South America) of quinoa were recently studied by several researchers including its use in the production of bread and cakes (Been & Fellers 1982; Lorenz & Coulter 1991; Chauhan 1992) and pasta (Caperuto *et al*. 2001).

Protein preparations (concentrates, isolates, hydrolysates) are widely used in the food production. The aim of their use is on one hand the protein enrichment and, consequently, the increase of the nutritive value of food and/or, on the other hand, the improvement of the texture of food (Tomoskozi *et al*. 1994, 1996; Bajkai *et al*. 1996). The rapidly increasing demand for food-grade proteins has sent up the cost of the traditionally used animal protein sources such as proteins of milk, egg, meat, and fish. However, the requirements and the regulations concerning the quality of animal proteins have become more strict, most likely due to the food safety problems connected to BSE, dioxine crisis, avian influenza, etc. Therefore, it is understandable that the interest in the potential use of alternative protein sources of plant origin is growing, although problems relating to the questionable acceptance of GMOs by consumers exist. Among potential sources of food-grade protein preparations, the seeds of amaranth and partly quinoa may achieve a significant role.

The amaranth proteins have a good digestibility, a majority of proteins belonging to the group of water-soluble albumins and salt-soluble globulins (Saunders & Becker 1984; Seguranieto *et al*. 1992; Sanfeng & Parades-Lopez 1997; Gorinstein *et al*. 2002). Another ancient crop, the quinoa with a similar chemical composition (except for the considerable amount of saponins in the hull of the seed) is also treated as pseudocereal.

Although the properties of amaranth proteins have been studied by several researchers, only few data are available in the literature on the functional properties of different protein fractions of this crop (Bejosano & Corke 1998; Marcone & Kakuda 1999; Silva-Sanchez *et al*. 2004). In addition, different methods have been used under different conditions which makes the comparison and evaluation of the research data difficult. Bakeries belong to the group of food producers interested in the use of protein preparations with the aim to increase the nutritive value of breads and introduce new specialty breads. However, this enrichment should not negatively influence the other quality parameters of the baked goods. The aim of the research presented in this paper was: on one hand, to study the rheological properties of doughs prepared from mixtures of wheat and amaranth flours or wheat and quinoa flours and, on the other hand, to study the effects of the additions of protein isolates from amaranth and quinoa seeds on the dough properties. In addition, the quality parameters of experimental breads, as influenced by pseudocereal flours and protein isolates, were also studied.

Table 1. Chemical composition of the materials used (% w/w)

Sample	Moisture	Protein	Fat	Ash	Fiber
Amaranth PO22	8.42[a]	14.13[a]	6.98[a]	2.32[a]	5.29[a]
Amaranth EDIT	10.88[b]	15.76[b]	6.61[a]	2.73[a]	4.41[b]
Amaranth AMAR	8.55[a]	14.89[a]	7.06[a]	2.32[a]	4.73[b]
Quinoa	11.23[b]	12.05[c]	5.76[a]	1.97[a]	3.19[c]
Isolate PO22	6.75[a]	79.59[b]	9.70[b]	1.86[a]	–
Isolate EDIT	7.03[a]	80.31[a]	8.72[a]	1.92[a]	–
Isolate AMAR	6.94[a]	80.12[a]	8.91[a]	1.97[a]	–
Isolate Quinoa	7.48[a]	81.05[a]	6.67[c]	1.73[a]	–
Wheat flour	11.54	10.46	0.98	0.55	0.87

Different upper letters mean: significant difference ($P < 0.05$)

MATERIALS AND METHODS

Flours. Three amaranth cultivars – the *Amaranthus hypochondriacus* cultivar (PO22), produced by Klorofil Ltd, Kecskemét (Hungary), and two *Amaranthus cruentus* cultivars (EDIT and AMAR), purchased from the Botanical Garden Vácrátót (Hungary), were used for the production of flours and protein isolates. A commercial quinoa seed sample (a variety of Mexican origin) was also used in the experiments.

Whole seeds were ground in a laboratory mill (Chemotec, LabMill, Tecator AB, Sweden) (granularity: 95% of particles smaller than 1 mm).

Wheat flour. Flour (ash content 0.55% d.w.b.) from HRW (hard red winter) cultivar grown in Hungary was used.

Preparation of protein isolates. The flours were defatted by shaking with hexane (solvent/flour ratio 3:1). The extraction was repeated three times and hexane was then evaporated under vacuum. The defatted flour (containing 0.7–0.9% fat) was suspended in distilled water (water/flour ratio 8:1) and pH of the suspension was adjusted to 9.5 by adding 1M sodium hydroxide. The suspension was stirred for 60 min and centrifuged for 20 min (rpm 3500). The supernatant was decanted and the procedure was repeated. The two supernatants were pooled and pH was adjusted to 4.5 in order to precipitate the proteins. After centrifugation (30 min), the precipitate was separated and freeze-dried.

Quinoa seeds were treated in the same way as amaranth seeds to obtain flour and protein isolates.

Chemical composition. The determination of macro-composition (moisture, protein, oil, ash content) was realised according to the methods of AOAC. Tecator AB Fibertec instrument was used

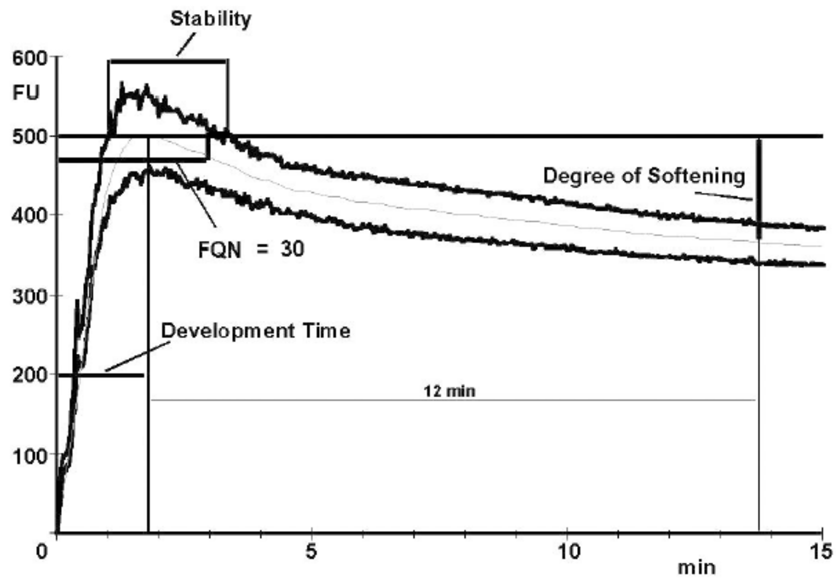

Figure 1. Evaluation of standard Farinographic curve (source:www.brabender.com)

for the determination of the fiber content. The chemical composition is shown in Table 1.

Preparation of breads. The conventional sponge and dough technology was used. 300 g of flour (s) were used for the preparation of test breads with water quantity determined by valorigraf, and 3% yeast and 1% salt. The baking was performed in a tinplate iron form of 16 × 5 × 8 cm. The volume of the test breads was determined by the method of mustard seeds displacement.

Study of the rheological properties of dough. A recording Z-arm micromixer (microvalorigraph) was used for the study of the rheological properties of dough (Tomoskozi *et al*. 2002; Haraszi *et al*. 2004). This instrument – similarly to the widely used farinograph – measures and records the changes in the resistance to mixing in the time dependence. The mixing curve is characterised by an ascending part that indicates the changes during the dough development process, while the subsequent decline in the resistance is taken as a sign of a steady breakdown of the dough structure upon mixing beyond the point of optimum development. Optimum development from the standpoint of bread quality may occur slightly past the "mixing peak". The following parameters (usually applied in the baking industry) (Dappolonia & Kunerth 1984; Lasztity & Torley 1987) were determined:

Water absorption. Defined as the amount of water required to centre the highest part of the mixing curve on the arbitrary 500 VU (valorigraph units) line.

Mixing time (Dough development time). Time interval (in min) from the first addition of water until the curve reaches its maximum height (Figure 1).

Stability. Time in minutes for which the top of the curve remains over 500 line (Figure 1).

Degree of softening in VU. The distance between the centre of the mixing curve and the 500 line after 15 min mixing (Figure 1).

Elasticity in VU. Defined as the width of the recorded curve after 15 min mixing in VU.

Study of the rheological properties of breads. A SMS Texture Analyser (Stable Micro Systems Ltd, Godalming, UK) was used. The crust and the parts in near proximity to it were cut from a crumb-piece of 4 × 4 × 3.5 cm and tested in the instrument. The resistance to compression and the viscous and elastic deformations were measured (Figure 2), and the relative elasticity (ratio of viscous to elastic deformation) was calculated. Total deformation of the crumb under constant stress was also determined using the method of Lasztity (1980).

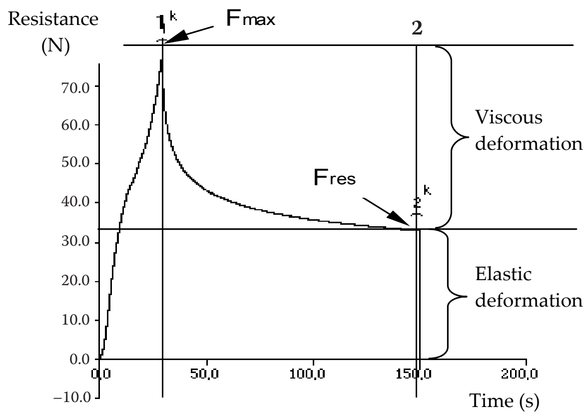

Figure 2. Resistance-time diagram of measurement of bread crumb rheological properties by Texture Analyser

Statistics. The average of three parallel measurements was calculated in every case. Probability level (P values at 0.05 level) was considered to determine the degree of significance between the results.

RESULTS

Composition of seeds, flours and protein isolates

The data on the chemical composition of the materials used in the experiments are collected in Table 1. The isolates had, as expected, high protein-, low mineral matter- and moderate fat (oil) content. Only small, but in some cases significant differences ($P < 0.05$) were found between the cultivars.

Effect of amaranth and quinoa seed flours on the rheological properties of dough

Water absorption. Mixes of wheat and amaranth flours and of wheat and quinoa flours were prepared by substitution of wheat flour by 10%, 20%, and 30% (w/w) of amaranth or quinoa flours. The rheological properties of the doughs produced from these flour mixes were studied by micro Z-arm mixer. An increase of water absorption capacity (quantity of water required for the preparation of dough expressed as g × water/g × flour) of mixes – in comparison to wheat flour – was observed. The increase depended on the proportion of amaranth/quinoa flour (Figure 3). Significant differences ($P < 0.05$) were found between the cultivars. E.g. in the case of a mix containing 30% amaranth

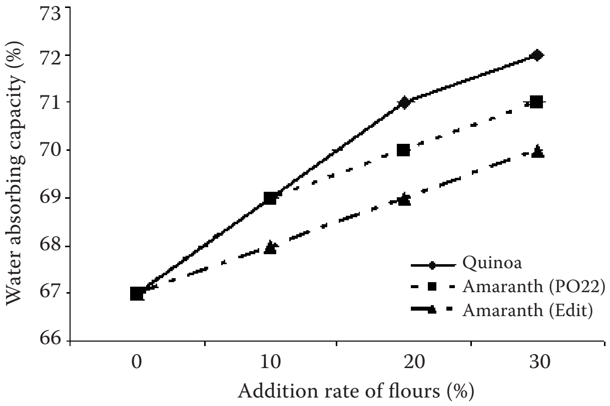

Figure 3. Effects of addition of different pseudo cereal flours on water absorption capacity

flour of cultivar PO22, the increase (in comparison to wheat flour) was 5%, however, it was only 3.5% in the case of a mix with 30% of the flour of cultivar EDIT (Figure 3). The correlation between the increase of water absorption and the proportion of amaranth or quinoa flour was practically linear (R^2 = 0.81).

Rheological properties of doughs made from wheat amaranth and wheat quinoa flours mixes. The values of the parameters determined by micro-Z-arm mixer for control wheat flour and flour mixes containing 10%, 20%, and 30% of amaranth or quinoa flour are given in Table 2. As seen, the addition of 10% of amaranth flour caused only small but significant changes of the rheological parameters of the recorded curve (valorigram) (Table 2). Similar conclusions were reported by other researchers (Teutonico & Knorr 1985; Brummer & Morgenstern 1992; Kuhn & Goetz 1999). A higher change is observable in the case of 20% amaranth flour addition. The addition of 30% of amaranth flour caused important significant changes in all parameters measured, and consequently negatively affected the quality of the end product.

Typical mixograms (valorigrams) obtained in the study of quinoa-wheat flours mixes are shown in Figure 4. The substitution of wheat flour by 10% quinoa flour resulted in a slight decrease of elasticity (Figure 4). The substitution at 30% level caused a significant decrease of all parameters studied (Figure 4).

Effects of the protein isolates from amaranth and quinoa seeds on the rheological properties of dough

Flour mixes containing wheat flour and added protein isolates from different amaranth and quinoa seeds were prepared and studied by micro Z-arm mixer. The amounts of the isolates were 1%, 3%, and 5%. No significant changes were observed in rheological parameters when 1% or 3% of isolate was added (Figure 5).

Effects of amaranth and quinoa flour additions on the rheological properties of bread crumb

The resistance to deformation (the firmness), and the relative elasticity together with the specific volumes of loaves are summarised in Table 3. Even the addition of 10% of pseudocereal flour caused a small but statistically significant change (P < 0.05) in the quality parameters. However only the addition of 30% caused important changes and consequently, a lower quality.

DISCUSSION

The main purpose of the production of mixed wheat- amaranth wheat-quinoa breads and other

Table 2. Rheological parameters of dough as affected by addition of amaranth or quinoa flour to wheat flours

Parameter	Control	Amaranth flour added (%)			Quinoa flour added (%)		
		10	20	30	10	20	30
Dough development time (min)	3[a]	7[b]	8[b]	8[b]	3[a]	6[c]	6[c]
Stability (min)	8[a]	5[b]	3[c]	3[c]	6[b]	4[c]	4[c]
Degree of softening (VU)	50[a]	70[b]	80[c]	85[c]	80[c]	85[c]	100[d]
Elasticity (VU)	105[a]	66[b]	50[c]	50[c]	60[b]	50[c]	40[d]

Different upper letters mean significant difference (P < 0.05)

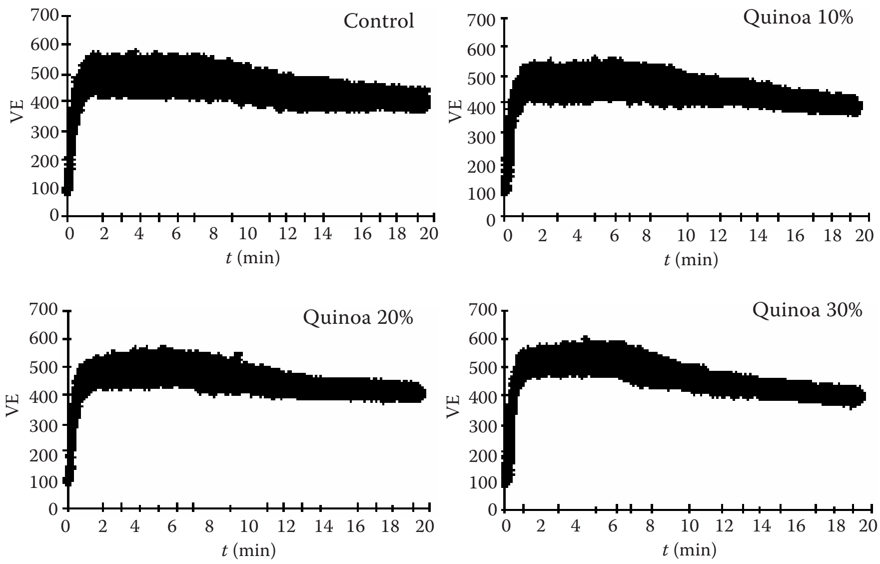

Figure 4. Effect of quinoa flour addition on the mixing properties of wheat dough

cereal based products – in addition to the efforts to increase the sortiment by introducing new foods – is the improvement of the nutritive value of the end product. However, any addition of new ingredients or replacement of traditional ingredients may influence not only the nutritive properties of the new food product but also the texture and physical- and sensory properties. It was reported that the replacement of wheat flour with amaranth flour lowered the loaf volume and resulted in a darker coloured bread (Lorenz 1981). The effect of amaranth flour addition on the quality of other baked goods such as corn bread, cakes, muffins, donughts etc. was also studied.

To avoid or minimise the negative effects of the substitution of part of wheat flour by amaranth or quinoa flour, better knowledge of the rheological properties of dough and other steps of processing is needed.

An increased water absorption capacity was observed in our studies. This observation is in agreement with earlier results (Lorenz 1981) and other researchers reports (Saunders & Becker 1984; Breene 1991; Brummer & Morgenstern 1992). It has been proposed to calculate with 1% increase at 5% amaranth flour addition. However – as our results show – significant differences ($P <$ 0.05) may exist between amaranth varieties.

Concerning the changes in rheological properties measured by micro Z-arm mixer, first the great increase of the dough development time needs explanation. Based on the research connected with starch of amaranth and quinoa seeds (Ahamed *et al*. 1996; Qian & Kuhn 1999; Resio *et al*. 1999),

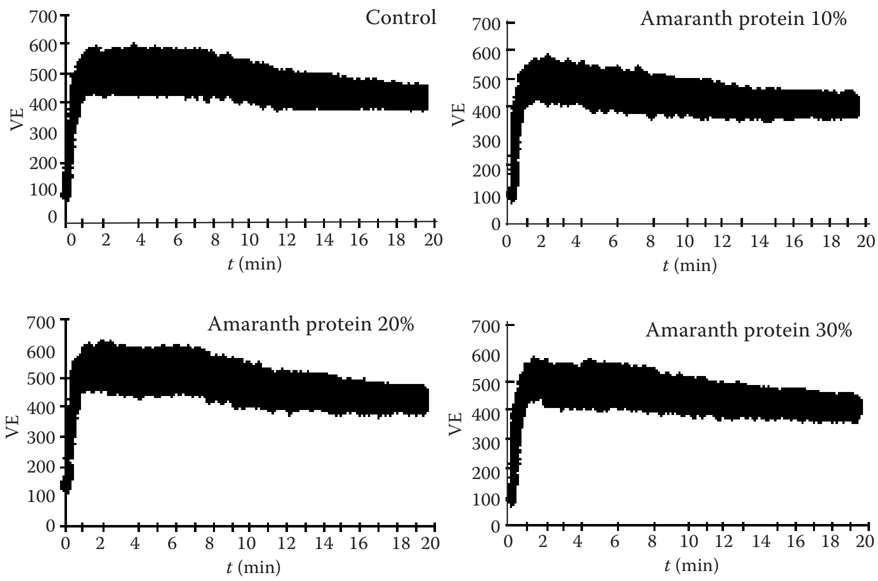

Figure 5. Effect of addition of amaranth protein isolate on the mixing properties of wheat dough (the addition were calculated on the base of protein content)

Table 3. Specific volume, resistance to deformation (firmness), relative lasticity and total deformation of experimental breads

Parameter	Control	Amaranth flour added (%)			Quinoa flour added (%)		
		10	20	30	10	20	30
Specific volume (cm^3/100g)	573^a	502^b	480^c	420^d	510^b	470^c	447^d
Resistance to compression (N)	15^a	21^b	25^b	37^c	18^a	25^b	32^c
Relative elasticity (%)	55^a	52^b	51^b	48^b	50^b	57^a	61^a
Total deformation (arbitrary units)	10.5^a	9.3^b	8.5^b	7.8^b	9.5^b	7.9^b	7.5^c

Different upper letters mean significant difference ($P < 0.05$)

it may be suggested that the starch constituents of pseudo cereals play the most important role in the longer time of the dough development. The low amylose and high amylopectin contents and the starch morphology result in a higher water sorption in comparison to wheat starch. In addition, we suggest that the longer development time is also caused by the difference in the rate of water absorption by wheat and amaranth flours, due to higher amounts of soluble proteins in amaranth flour and maybe also due to water absorption characteristics of amaranth starch and nonstarch polysaccharides. This may cause a delayed formation of the gluten network in the dough.

The enrichment of wheat flour with added protein isolate from amaranth seed had a small effect on rheological properties as shown by the results of our investigations.

A significant decrease of the volume of breads prepared from flours with higher (20–30%) contents of amaranth or quinoa flour was observed. This is connected with the weakening of the gluten network in dough and reduced gas retention of dough (predictable from the higher degree of dough softening and lower elasticity determined by Z-arm mixer). The higher resistance to constant deformation of bread crumb on one hand and, on the other hand, the lower degree of total deformation under constant stress is the consequence of a lower volume and lower porosity, causing thicker walls of pores in bread crumb (Lasztity 1980).

CONCLUSION

The substitution of wheat flour by amaranth and/or quinoa seeds flours results in the changes in rheological properties of dough and test bread quality parameters (volume, crumb firmness). The addition of 30% and above causes important quality deterioration in comparison to wheat bread.

From the practical point of view, the results suggest that – if the purpose of amaranth and/or quinoa use in bread making is primarily the increase of the protein nutritive value – the use of protein isolate may be preferred in order to avoid quality deterioration of the end product in comparison to baked goods from wheat.

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