Technological quality and nutritional benefit of different flour composites

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Abstract

The aim of this article is to examine samples of wheat flour fortified with non-traditional commercial grain from a nutritional perspective. Amaranth, quinoa, lupine, teff and chia were used for wheat flour fortification in lower and higher additions. Samples with amaranth and lupine flour showed the best improvement in terms of protein content (in the range 21.1–26.0%). The highest total dietary fibre was found in lupine composites (7.1 and 9.8%). All the examined seeds could be recommended for wheat flour fortification in terms of nutritional improvement.

Keywords: *dietary fibre, flour, minerals, proteins, resistant starch*

Introduction

The application of non-traditional components in cereal technology can often extend the possibilities for producing new, alternative cereal-based products. Amaranth, quinoa, lupine, teff and chia milling products can be used for wheat flour fortification. These innovative components are known for their good chemical composition and can potentially improve the nutritional value of wheat cereal products.

Amaranth is a plant originally cultivated in South America and belongs to genus *Amaranthus* and family *Amaranthaceae*. A high protein content (15%) with a significant amount of lysine is found in its grain. The good nutritional value of amaranth is also characterized by considerable amounts of fibre, fat and minerals (Tömösközi et al., 2009; Kaur et al., 2010).

Chia is a plant categorized under the *Labiatae* family. It is native to, and cultivated in, Mexico and Guatemala. Important from a nutritional point of view is the high protein content (16–26%), with no limiting factors in amino acid composition (Ayerza and Coates, 2011). The seed also contains high amounts of fat (30–33%) and dietary fibre (37–41%) (Ciftci et al., 2012).

Lupine is a plant grown in the Mediterranean region and South America. *Lupinus albus* (white lupine) is common in Europe. Lupine belongs to the genus *Lupinus* and family *Leguminosae.* Its nutritional composition is interesting mainly due to the high protein (30–40%) and dietary fibre (up to 50%) content. In comparison with other cereals, lupine protein contains a higher amount of lysine (Písaříková and Zralý, 2010).

Quinoa is a pseudocereal initially grown in the Andean region in South America. *Chenopodium quinoa* Willd is part of the family *Chenopodiaceae* and genus *Chenopodium*. Quinoa seed contains a significant amount of protein (14–20%) with good digestibility and a considerable amount of lysine, methionin and cystine (Ruales and Nair, 1992). A high content of minerals and vitamins has been reported in quinoa seeds (Jancurová et al., 2009).

Teff is largely produced in Ethiopia and is a cereal plant of the family *Poaceae*. Great benefits can be found in its mineral composition – with high amounts of iron, calcium and magnesium (Hager et al., 2012). In seeds, a moderate content of protein with great digestibility has been found. However, low lysine in its protein content has been reported (Adebowale et al., 2011).

Non-traditional components can improve the chemical composition of wheat cereal products owing to their high protein, fibre and fat content and other elements positive to human health (vitamins, minerals, and antioxidants; Sanz-Penella et al., 2013).

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According to the literature, lupine is the best source of protein. The highest concentration of fat and fibre was found in chia seeds. Furthermore, a combination of wheat and alternative flour can provide a better overall essential amino acid balance, especially a higher lysine content. However, this procedure can also affect the technological properties of dough due to dilution of gluten, which is the main component responsible for the structure and volume of baked products (Kohajdová et al., 2011). Besides, the flavour and texture of composite cereal products can be greatly influenced by unconventional grain. Therefore, the inclusion of alternative ingredients could be significantly limited in order to maintain the quality of the final product.

Materials and Methods

As a composite base, commercial wheat flour (WF) obtained from the industrial mill Delta Praha was used. It is characterized as a bright type (ash content 0.52%) with a protein content of 10.7%.

The samples of amaranth and quinoa (A, Q) were originally produced in India and Ecuador, respectively. Both grains were bought in Country Life CZ (Czech Republic). Conventionally produced white and dark chia seeds were used for the preparation of wholemeal flour samples CH1 and CH2 (Aida Organic and Country Life CZ, respectively). The chia grain was produced in Mexico. The blade grinder Concept type KM5001 was used to transform all the above-mentioned samples into a fine flour. The lupine sample (L) was grown in Austria and purchased in a form of a commercial fine flour milled by the company Natural Jihlava (Czech Republic). Two teff flour samples T1 and T2 were commercially milled fine flours from white and brown botanical types of teff, respectively (Tobia Teff UK Ltd.). All samples of grains, as well as commercial flours, were bought solely for purpose of this research.

Amaranth, quinoa and lupine were mixed with wheat flour in the ratio 10:90 and 20:80 (w/w). Due to different contents of dietary fibre, where enhancement was required these levels were changed using teff and chia. Teff flour of 20 and 30% was used for fortification. Amounts of 2.5 and 5% were added in the case of chia samples. Moreover, fortification using chia flour was restricted due to limits imposed by the European Commission.

Ash was measured by combustion of a sample at 900 °C according to the Czech standard method (ČSN 56 0512-8). Kjeldahl's method (ČSN 56 0512-12) with factor 6.25 was used for determination of protein content. Total dietary fibre (TDF), soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) were examined by using the enzymatic-gravimetric method with a Megazyme assay kit (AOAC 985.29). A different Megazyme kit was used for measuring amounts of resistant starch (RS, AOAC 2002.02).

The baking test was performed according to the internal method of UCT Prague. Laboratory prepared bread was evaluated by specific bread volume and shape (height-to-diameter ratio; Hrušková et al., 2006).

The collected data were subjected to correlation analysis in order to explore relationships among the observed nutritional components (P = 95 and 99%). Since wheat samples were enhanced by several non-traditional plant materials at two clearly different fortification levels, the impact of the mentioned factors, together with their reciprocal interactions, was compared by *F*-test (P = 95, 99 and 99.9%). In both statistical approaches, Statistica software v. 10.0 from the Dell Company (USA) was employed.

Results and Discussion

The aim of this article was to describe the chemical composition of wheat flour composites with non-traditional grains. The results for the determination of ash, protein and resistant starch content are summarized in Table 1. Amaranth and lupine flours were evaluated as the best source of proteins. (Plate XIII., Fig. 1a and 1b) graphically illustrate the content of all types of dietary fibre detected in the examined WF mixtures. Wheat flour with 20% lupine has the highest content of total dietary fibre. The results showed that all studied composite samples had better nutritional composition compared to fine wheat flour.

Table 1. Approximate composition for tested non-traditional seeds

	Protein (%)	Carbohydrates (%)	Fat (%)	Fibre (%)
Amaranth[1]	17	66	6	21
Quinoa[2]	17	69	6	4
Lupin[3]	39	35	7	15
Teff[4]	10	73	2	3
Chia[5]	20	34	32	24

[1] Alvarez-Jubete, et al. 2010; [2, 3] Jancurová et al., 2009; [4] Bultosa, 2007; [5] Mohd et al., 2012

Content of proteins

Due to its nutritional significance and its contribution to texture, the amount of protein was measured in all samples. Data are summarized in Table 2. The incorporation of non-traditional flours caused an increase in protein content, regardless of the percentage or type of alternative component was used. The lowest amount of protein was observed in teff and chia samples (results in the range 11–13%). The results regarding protein content in their seeds correspond to that reported in the other studies, where it was found to be the same or slightly higher in comparison to wheat (Ayerza and Coates 2011; Hager et al. 2012; Mohd et al. 2012). Amaranth largely improves our composites' nutritional value in the case of protein content (21.1 and 21.6%). The best results were obtained for lupine samples (22.8 and 26.0%), which is in agreement with the lupine chemical composition published by other researchers (Erbas et al. 2005).

Table 2. Chemical composition of non-traditional seed composites

Flour, composite flour	Fortification (%)	Ash (%)	Protein (%)	Resistant starch (%)
WF	-	0.52	10.7	0.4
WF + A	10	0.71	21.1	0.4
	20	0.92	21.6	0.4
WF + Q	10	0.74	19.9	0.2
	20	0.96	19.9	0.2
WF + L	10	0.76	22.8	0.5
	20	1.00	26.0	0.5
WF + T1	20	0.96	12.6	0.4
	30	1.15	12.6	0.5
WF + T2	20	0.94	13.1	0.7
	30	1.11	13.1	0.6
WF + CH1	2.5	0.59	11.0	0.6
	5.0	0.69	11.2	0.5
WF + CH2	2.5	0.59	11.0	0.3
	5.0	0.69	11.2	0.4
Repeatability		*0.05*	*0.10*	*0.04*

WF – wheat flour; A, Q, L, T1, T2, CH1, CH2 – flour from amaranth, quinoa, lupine, and light and dark teff and chia seeds, respectively

Content of minerals

In terms of the amount of minerals, a moderate improvement was determined for all examined samples. This corresponds with the chemical composition of the non-traditional components, as published by other authors (Ando et al. 2002; Kaur et al. 2010; Hager et al. 2012; Mohd et al. 2012). Better results were found for higher levels of flour fortification.

Content of resistant starch

Resistant starch (RS) has similar properties and biological functions as soluble dietary fibre. In fine wheat flour, 0.4% of RS was determined. Only small differences were observed between the studied composite flours and the control sample – the results could be considered statistically different, but similar in terms of consumer quality. Bouzová (2011) measured RS content in amaranth and quinoa, and these results correspond with the small differences in the case of our composite flours. With regard to the small amount of RS detected, the addition of non-traditional grain did not have any high nutritional importance.

Content of dietary fibre

Dietary fibre is one of the most nutritionally important components in cereal products. In comparison to the control wheat sample, all studied composites showed a positive effect on dietary fibre levels (Plate XY, Fig. 1a and 1b). Despite being only a small addition to wheat flour, chia proved a good source of TDF (equally 4.6% for both 5% CH1 and 5% CH2). The results correspond with the high dietary fibre content in chia seeds published by other researchers (Segura-Campos et al. 2013; Reyes-Caudillo et al., 2008). A good amount of dietary fibre was found in amaranth samples (5.1 and 6.2%); however, lupine demonstrated the most potential as an ingredient for wheat flour fortification (9.8% TDF for 20% dosage of lupine flour). Other published data indicate that TDF content in both grains can vary greatly due to different environmental conditions. Nevertheless, dietary fibre in amaranth and lupine was reported to be up to 20.6 and 50.4%, respectively, and therefore corresponds with a great improvement in the composite samples (Tömösközi et al., 2009; Alvarez-Jubete et al., 2010; Písaříková and Zralý, 2010; Erbas et al., 2005). Besides the amount of TDF, the nutritional potential of dietary fibre was examined in terms of the content and their ratio of IDF and SDF fractions (usually 3:1 is recommended; Reyes-Caudillo et al., 2008). All samples had a slightly lower IDF content in comparison to SDF, and their ratio was ranged from 1.2:1 to 2.3:1 (data not shown). For all types of dietary fibre, only a small increase was detected in the case of a higher fortification level.

Statistical analysis

Correlation analysis was used for calculating the linear inter-relation between the quantities of the various chemical components in the examined samples. According to Table 3, positive correlation was confirmed for all types of dietary fibre (r between 0.92–0.98, P = 99%). A high positive relationship was found for proteins and all types of fibre, which corresponds with their location in outer layer of seeds. To summarise, proteins could partially represent both the IDF and the SDF fractions (r = 0.77 and 0.86, respectively; P = 99%).

Table 3. Correlation analysis among contents of nutritive compounds

Component	Ash	Protein	Resistant starch	IDF	SDF
TDF	0.35	0.84**	0.03	0.98**	0.96**
SDF	0.37	0.86**	-0.01	0.92**	
IDF	0.31	0.77**	0.10		
RS	0.23	-0.24			
Protein	0.27				

N = 15; ** – pair correlations provable at P = 95% and 99%, respectively.

The statistical strength of the factors *Blend composition* and *Fortification level* of the non-traditional material, together with their interaction on the nutritional composition of the studied composites, was compared by F-test. According to Table 4, the former factor (i.e. the type of non-traditional flour used) had a greater influence on the chemical composition of WF composites. Although interactions between *Blend composition* and *Addition level* were provable in all cases, the calculated F-values were lower when compared to those determined for single factors. In the case of resistant starch, the F-value of over 25,000 was the highest.

Results of the laboratory baking test

The quality of laboratory prepared bread was evaluated in terms of bread volume and shape, because both parameters are preferentially perceived by consumers. The control wheat bread

Table 4. Comparison of factors' strength on the nutritional composition of wheat flour blends

Factor	Ash	Protein	IDF	SDF	TDF	RS
Blend type	145,474**	1,192,932***	174,202**	73,923**	406,905**	2,947*
Fortification level	216,129**	24,014**	160,514**	52,117**	275,221**	0
Blend × Fortification	3,162*	13,614**	19,614**	6,347**	25,846**	267*

IDF, SDF, TDF – insoluble, soluble and total dietary fibre, respectively; RS – resistant starch
*, **, *** – F-values significant at P = 95%, 99% and 99.9%, respectively

volume reached 313 ml/100 g, and its shape was standard (recommended height-to-diameter ratio 0.63). Within the alternative grain group, the addition of amaranth, quinoa as well as lupine lessened the specific bread volume. This negative effect of all three non-traditional flours corresponded to their dosage in the recipe. The strongest such impact was observed for wheat-lupine bread (decrease about 40%; Table 5). Wheat flour replacement by teff also affected bread size, and both tested types caused approximately the same diminishing rate. Compared to the control, the volume of bread containing 30% teff fell by up to about half. Correspondingly, the shape of the bread became flatter, depending on the amount added. An improvement in consumer bread quality was determined for both chia types tested (light CH1, dark CH2). Specific bread volume increased by approximately one-quarter, and baking test results were similar for both fortification rates. The bun-shape of the wheat/chia bread variant was at least comparable to the control (range 0.60–0.76; Table 5).

Table 5. Baking trial results for wheat flour as affected by additions of non-traditional flours

Bread sample	Fortification (%)	Specific bread volume (ml/100 g)	Bread shape h/d (1)
WF	-	313	0.53
WF + A	10	284	0.48
	20	258	0.59
WF + Q	10	224	0.52
	20	235	0.47
WF + L	10	218	0.53
	20	200	0.55
WF + T1	20	257	0.43
	30	135	0.23
WF + T2	20	277	0.45
	30	186	0.37
WF + CH1	2.5	396	0.60
	5.0	388	0.76
WF + CH2	2.5	391	0.60
	5.0	392	0.61
Repeatability		*13.5*	*0.04*

WF – wheat flour; A, Q, L, T1, T2, CH1, CH2 – flour from amaranth, quinoa, lupine, and light and dark teff and chia seeds, respectively

Conclusion

This survey showed that non-traditional grains make good ingredients for fortifying wheat flour. All the examined samples of composite flour had a better nutritional composition than the wheat control sample in terms of proteins, minerals and dietary fibre fractions. Amaranth and lupine flours were evaluated as the best source for fortification by protein. Since the amounts of dietary fibre in the two tested chia samples were multiple times higher than in the wheat control, small additions in both cases ensured sufficient health benefits. The amount of alternative grain used for fortification could be limited with respect to standard bakery technology. The effect of adding non-traditional flours changed the consumer features of laboratory prepared bread, depending on the type and amount of additions. Although the nutritional benefit of the tested non-traditional grains could not be doubted, their incorporation into the bread recipe was not, for the most part, reflected in the sensorial quality of the bread.

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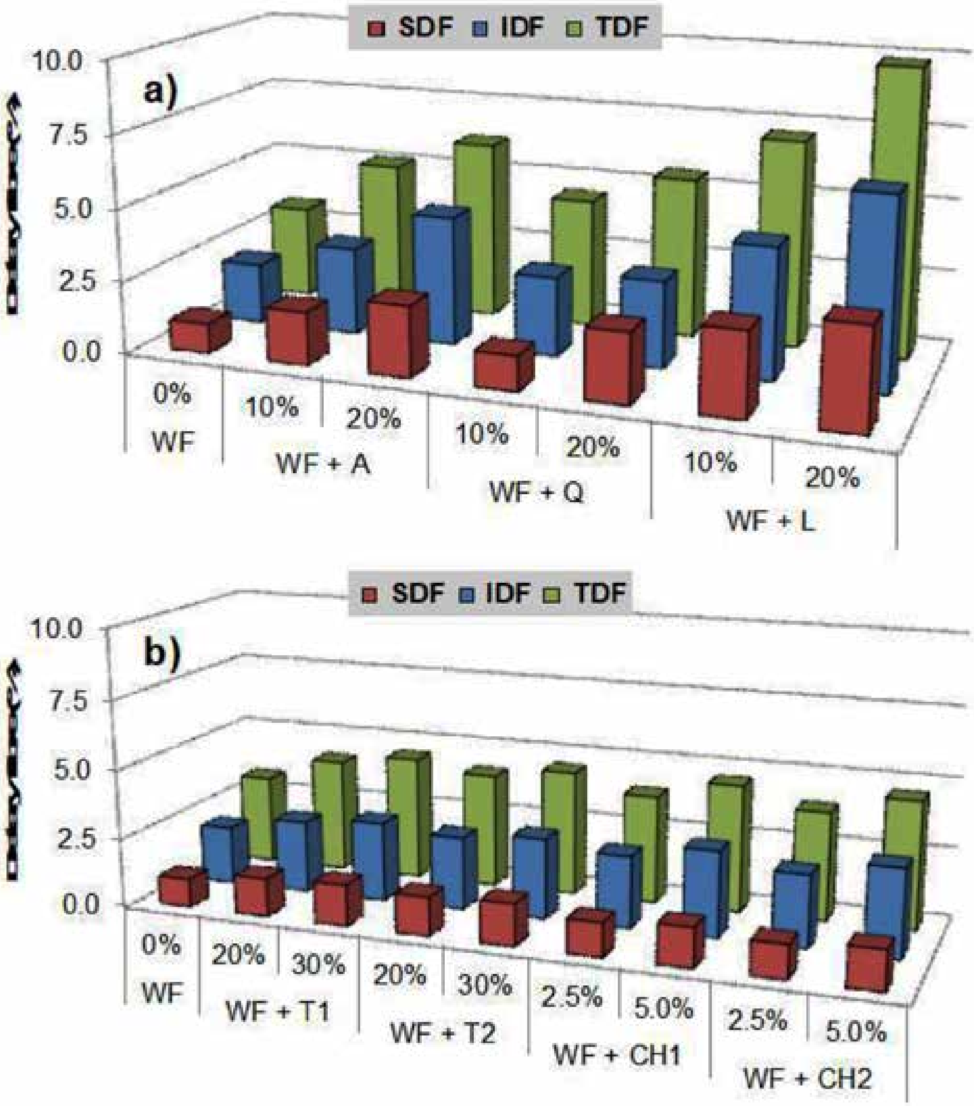

Fig. 1. Dietary fibre content in tested wheat flour (WF) composites. a) Blends with amaranth, quinoa, and lupine (A, Q and L, respectively); b) blends with white and dark teff and chia (T1 and T2, CH1 and CH2, respectively). SDF, IDF, TDF – soluble, insoluble and total dietary fibre, respectively