INFLUENCE OF CANAHUA AND QUINOA WHOLEMEALS ON PROPERTIES OF NON-FERMENTED WHEAT DOUGH*

I. Švec[1], M. Hrušková[1], R. Kapačinskaité[2], T. Hofmanová[1]

[1]*University of Chemistry and Technology Prague, Prague, Czech Republic*
[2]*Kaunas University of Technology, Kaunas, Lithuania*

The study compares the influence of wheat flour replacement by 10 or 20 wt% of quinoa and canahua wholemeals on wheat dough technological quality and rheological properties. The technological quality of wheat flour was affected in terms of protein quality and amylases activity, associated with a high dietary fibre content of both tested non-traditional materials. A farinograph test revealed that quinoa partially increased water absorption; a higher amount of water resulted in the shortened stability of dough consistency during mixing and its weakened cohesiveness at the end of the test. The effect of canahua was unequivocal – water absorption decreased, stability was prolonged properly, but dough softening increased. An extensigraph test confirmed a positive effect of alternative crops on dough elasticity, but in general, the composite dough with 20% of canahua or quinoa showed worsened machinability. Multivariate statistical methods proved a stronger effect when quinoa was analysed solely than when added at complete samples a set, while for canahua-wheat samples the result was opposite.

composite flour, *Chenopodium* species, rheology, extensibility

doi: 10.2478/sab-2019-0031
Received for publication on September 3, 2018
Accepted for publication on June 10, 2019

INTRODUCTION

In continuous production processes in bakery, flow properties of dough play a key role. Optimum dough development during mixing of all recipe components results into required consistency of the mass, i.e. proper viscous and elastic properties. Optimum stage allows easy splitting of leavened dough into pieces, proper forming into rolls, bread, etc. and dough maturation (volume increase in an expected extent). Before fixing the final product surface by heat in oven, dough pieces shape is assured on the base of elasticity and extensibility parameters. Among other, wheat breeding is aimed at meeting these requirements, and rheological properties of flour from industrial mills are produced for a specific usage. Wheat proteins with high molecular weight – gliadins and glutenins (known as gluten) – form the elastic skeleton of dough. The first gluten category renders to wheat dough extensibility and the second to elasticity (Shewry et al., 2000). The incorporation of non-gluten proteins disrupts cohesivity of the structure, therefore the dosage of alternative raw material must be selected carefully.

Renaissance of forgotten crops in food industry met consumers' interest in healthier nutrition. Seeds from plants as flax, chia, amaranth or soya may supplement substances missing in wheat flour. From the *Chenopodium* genus, a known and approved crop is quinoa; its botanical relative – canahua (cañihua, kañiwa) – has been recently rediscovered. Both plants originate from the South American Andes; they are very undemanding to breed, and the former is produced mainly in Bolivia, Peru and Ecuador (70 000 t produced in year 2009 – http://www. fao. org/quinoa/en/). Compared to wheat, canahua and quinoa are richer in dietary fibre (6.1% and 4.0% vs 2.5%, respectively) and in lipid and mineral contents (Rosell et al., 2009). Quinoa is a good source of lysine and histidine (Bavec, Bavec, 2007). From other phytochemicals, it contains saponins, phenolics, and flavonoids (Vega-Galvez et al., 2010; Perez et al., 2016).

---

* Supported by. the Ministry of Agriculture of the Czech Republic, Project No. QI111B053.

The present article deals with the application of quinoa and canahua wholemeals addition in terms of technological quality and rheological properties of non-fermented wheat dough. Such type of wheat flour enhancement follows the recent trend in cereal chemistry and technology as well as in bakery praxis. All non-traditional seeds as chia or just quinoa are rich in the content of unsaturated fatty acids, dietary fibre or even antioxidant compounds such as polyphenols. Addition of naturally gluten-free plant raw materials may influence wheat dough machinability, so the determination of tensile properties of composite dough takes right place. The rheological behaviour during dough development, mixing and overmixing was described using a farinograph. An extensigraph served for the quantification of changes in elasticity and extensibility of that dough type, comparing also the effect of two dough-resting times. The factors like non-traditional crop type and addition level were evaluated using multivariate statistics.

MATERIAL AND METHODS

Preparation of flour composites

Two standard wheat flour samples (WF1 and WF2) were produced by the Czech industrial mill Jaroslav Chochole – Delta Praha in years 2015 and 2017, respectively. WF1 and WF2 were used as the basis for flour composites containing quinoa and canahua wholemeal, respectively. Basic technological quality parameters of WF1 and WF2 (protein content 12.7% and 13.1%, Zeleny value 40 and 55 ml, and Falling number 421 and 317 s, respectively) corresponded to long-term average within the Czech agriculture production. The alternative crops quinoa and canahua were bought in the form of hulled whole seeds in specialised retail shops. In the study by Steffolanni et al. (2013), the protein contents of three quinoa varieties were 13.64–14.51% and of four canahua ecotypes 12.02–17.55% and crude fibre contents were 1.95–2.00% and 3.42–5.71%, respectively. To produce quinoa (Q) and canahua (CA) wholemeals of fine granulation comparable to WF, a laboratory grinder Concept KM 5001 (Elko Valenta, Czech Republic) was used. Seeds were treated stepwise with raw material dosage around 25 g and operation time 3.0 min.

In the tested flour composites, the non-traditional materials replaced 10 or 20 wt% of wheat flour (sample codes WF1+10Q, WF1+20Q, WF2+10CA, WF2+20CA).

Analytical parameters of flour composites technological quality

Following the standards CSN EN ISO 3039 and CSN EN ISO 5529, the amylases activity and proteins quality were estimated as the Falling number and the Zeleny sedimentation value, respectively. The parameters were determined in two repetitions, and the determination errors were ± 25 s and ± 1 ml, respectively.

Rheological testing of wheat and composite dough

The rheological properties and behaviour of wheat controls and flour composites were determined using a Farinograph® (model DM 17) and an Extensigraph® (model EXEK 17; both apparatuses Brabender GmbH & Co KG), according to CSN EN ISO 5530-1 and CSN EN ISO 5530-2 standards, respectively. For the former test, parameters of water absorption and dough stability were selected as principal. The extensigraph test was carried out in a shortened version (dough resting 30 and 60 min). The elasticity-to-extensibility ratio as well as extensigraph energy are discussed further. For cluster analysis, all five farinograph and all five extensigraph characteristics (in pairs for resting times 30 and 60 min, i.e. 10 parameters in total) were included into a data matrix.

Statistical analysis

Gained data were subjected to two-way analysis of variance (ANOVA, $P = 95\%$) by STATISTICA 13.0 software to explore the combined effects of non-traditional flour and the addition level on wheat flour analytical and rheological properties (identification of the statistically different arithmetic means, signed by different letters). Further, a complex influence of both factors, including their interactions, was described by principal component and hierarchical cluster analyses. Both statistical routines are based on data transformation into latent variables in the first case and in inter-distances in the second; the transformation uses a linear combination of the measured features. The latter method employs the Euclidean metrics (distances calculated according to multidimensional Pythagoras theorem), using the Complete linkage (Furthest neighbour) clustering algorithm (Hruskova, Svec, 2015). The mentioned attitude makes it possible to precisely calculate statistical similarities among tested samples as well as clearly identify the members in the clusters built. In the present study, data matrix for clustering involved totally 17 observed parameters – two analytical (Zeleny test, Falling number), five farinograph plus five extensigraph ones (2 × 5 due to dough resting times 30 and 60 min). In the first step, clustering included two wheat controls and four flour bi-composites (i.e. all samples tested) to compare the combined effects of wheat flour base, non-traditional material type and addition level. In further two steps, samples were separated into WF1 and WF2 triads; such a splitting targeted to compare the effect of the addition level between quinoa and canahua wholemeals.

RESULTS

Analytical properties of flour composites

With respect to ANOVA results, the quality of proteins in controls WF1 and WF2 was evaluated as statistically different (unequal variance letters 'cd' and 'e', respectively). Both Q and CA affected the sedimentation value similarly, values of 43 ml were comparable to WF1 control (variance 'd', 'd' and 'cd', respectively) (Fig. 1). Both quinoa and canahua wholemeals are naturally gluten-free – high sediment volumes could be attributed to thickening of suspension by the action of dietary fibre, resulting in the deceleration of sedimentation velocity. For blends containing 10 or 20% of the alternative materials, the effect of non-traditional material type (Q or CA) could be considered improvable, but the addition level one was significant. Compared to proper wheat controls, these two dosages decreased protein quality about one-fourth at least.

In terms of fermentation ability estimation by Falling number, both wheat controls showed lower amylases activity than empirical optimum 250 ± 25 s. With regard to the method accuracy, values 421 and 317 s were statistically different (signed by letters 'B' and 'A', respectively). The finding reflects different climate conditions in 2015 and 2017 during harvest. As mentioned above, non-starch polysaccharides in Q and CA wholemeals demonstrate high water absorption capacity – the premise is supported just by Falling number measurement. For pure Q and CA samples, the parameter overcame the value 900 s, i.e., it was unevaluable (variance letters 'D' for both). During flash pasting of composite suspensions, dietary fibre fixed available distilled water completely and restricted amylases activity to zero. For the tested flour bi-composites, the Falling number level increased from usual 300–400 s up to 569 s (sample WF1+20Q; Fig. 2). ANOVA conjoined composite sample pairs WF1+10Q – WF1+20Q and WF2+10CA – WF2+20CA together with control WF1 (variance 'B', 'BC', and

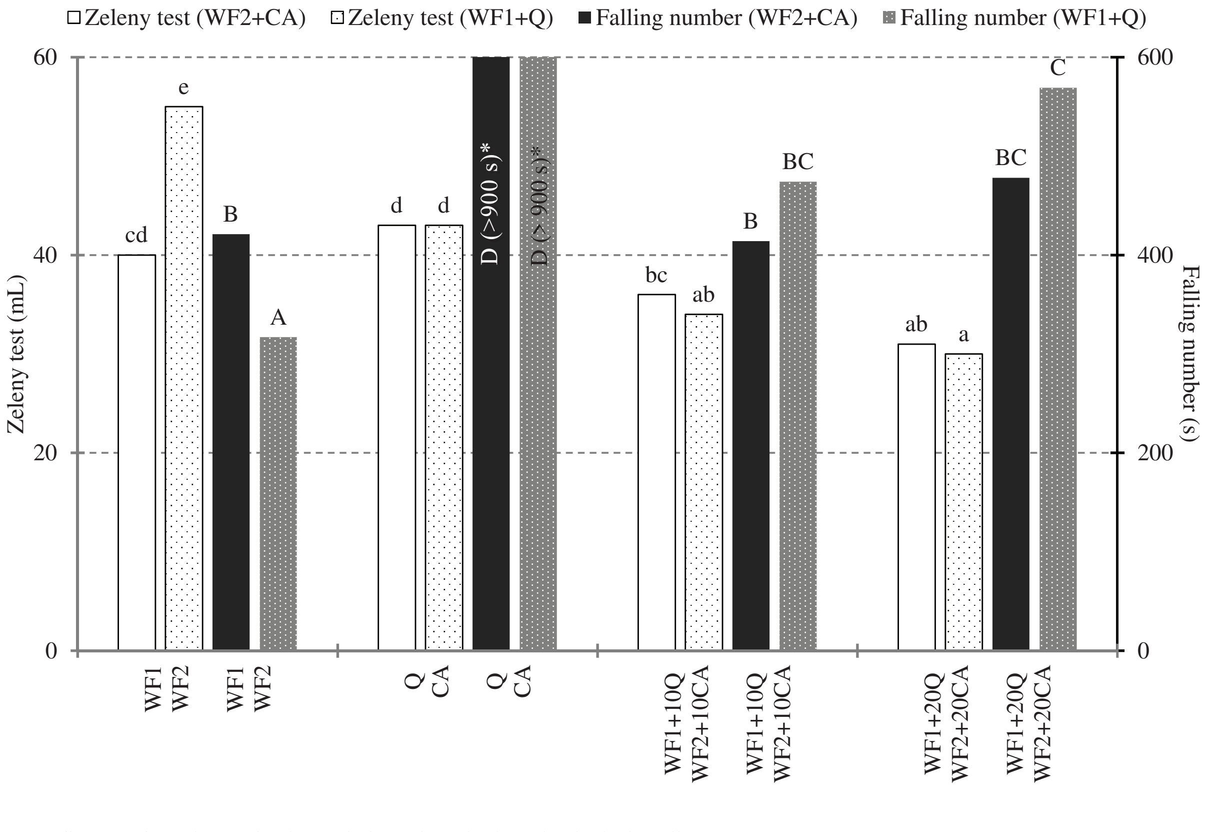

Fig. 1. Influence of canahua and quinoa wholemeals on basic technological quality

WF1, WF2 = control wheat flour samples; CA, Q = canahua and quinoa wholemeals, respectively; WF2+10CA = composite flour containing 90% of WF2 and 10 wt% of CA

a–e values of Zeleny test signed by different letter are significantly different (P = 95%)

A–D values of Falling number signed by different letter are significantly different (P = 95%)

*Falling numbers of pure Q and CA wholemeals were unevaluable (> 900 s

'C'). Within this group, the values determined for WF1 and WF2+20CA significantly differed (421 and 569 s).

Table 1. Effect of canahua and quinoa wholemeals on the basic farinograph parameters

Composite flour	Water absorption (%)	Dough stability (min)
WF1	62.5^{ab}	10.50^{d}
WF1+10Q	63.4^{b}	8.75^{c}
WF2+20Q	63.4^{b}	6.25^{b}
WF2	65.0^{c}	3.50^{a}
WF1+10CA	65.0^{c}	4.50^{a}
WF2+20CA	62.0^{a}	10.00^{d}

WF1, WF2 = control wheat flour samples; CA, Q = canahua and quinoa wholemeal, respectively; WF1+10CA, WF2+20Q, WF1+10CA, WF2+20CA = flour composites containing 10 (20) wt% of CA or Q

$^{a–d}$values in column with different letter are significantly different (*P* = 95%)

Farinograph properties of flour composites

Farinograph testing confirmed two practical experiences – non-traditional gluten-free crops have usually hydrophilic character and thus they may increase water absorption during non-fermented dough preparation, but at the same time, they are able to prolong dough development and weaken dough stability. This trend was observed for wheat-quinoa composites, although samples WF1+10Q and WF1+20Q absorbed the same volume of water. In the case of 20% canahua incorporation, water absorption unexpectedly decreased about 3 percent points, resulting into double prolongation of dough stability (the less the water, the harder the dough and perhaps the longer the stability). Within the tested flour composites set, dough softening partially rose in comparable extent (e.g. from 50 to 80 Brabender units (BU) for WF-Q composites; Table 1). From empirical point of view, values lower than 100 BU are considered as still acceptable.

Extensigraph properties of flour composites

With respect to protein quality estimation by the Zeleny sedimentation test, extensigraph proof showed reversal results – WF1 was evaluated as a raw material of higher technological quality than WF2. After 30 min of dough resting, viscoelastic properties (i.e. machinability) of both controls were mutually comparable (elasticity-to-extensibility ratios 1.60 and 1.77, respectively), but energy as a complex quality descriptor demonstrated a better breadmaking potential for WF1 specimen (values 116.0 and 83.0 cm^2, respectively). A double prolongation of dough maturation supported the elasticity of WF1 and lessened the difference in energy to a half (130.0 and 104.9 cm^2, respectively; Table 2).

After a shorter dough resting, quinoa improved viscoelastic properties of wheat flour to optimum, but extensigraph energy level dropped to about 40%. After 60 min, wheat-quinoa dough exhibited similar elasticity but worse extensibility, indicated by the ratio rise (Table 2). Although 10% of canahua wholemeal had rather insignificant effect on both elasticity and

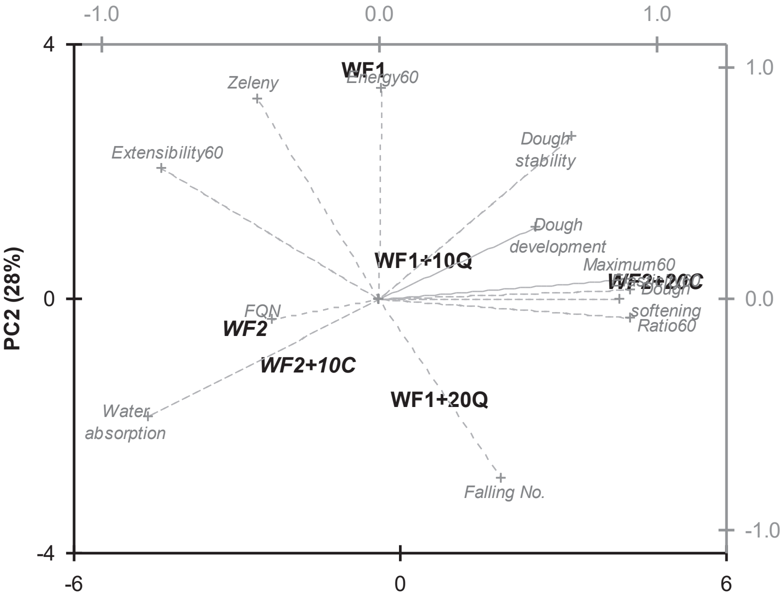

Fig. 2. Principal components (PC) biplot WF1, WF2 = control wheat flour samples; CA, Q = canahua and quinoa wholemeals, respectively; WF1+10CA = composite flour containing 10 wt% of CA; Energy 30, Energy 60 = extensigraph energy determined after two different resting times of non-fermented dough (similarly for other extensigraph parameters)

Table 2. Canahua and quinoa wholemeal effect on the basic extensigraph parameters

Composite flour	Ratio ela-ext 30′ (-)*	Energy 30′ (cm^2)*	Ratio ela-ext 60′ (-)**	Energy 60′ (cm^2)**, ***
WF1	1.60^{a}	116.0^{b}	1.90^{a}	130.0^{b}
WF1+10Q	2.20^{b}	97.0^{ab}	2.70^{b}	117.0^{ab}
WF2+20Q	2.20^{b}	69.0^{a}	2.90^{b}	84.0^{a}
WF2	1.77^{a}	83.0^{ab}	1.78^{a}	104.9^{ab}
WF1+10CA	1.85^{a}	72.0^{ab}	1.74^{a}	81.3^{a}
WF2+20CA	5.62^{c}	85.6^{ab}	9.21^{c}	102.1^{ab}

WF1, WF2 = control wheat flour samples; CA, Q = canahua and quinoa wholemeal, respectively; WF1+10CA, WF2+20Q, WF1+10CA, WF2+20CA = flour composites containing 10 (20) wt% of CA or Q; ela-ext = elasticity-to-extensibility

*, **dough resting time 30 and 60 min, respectively

***energy evaluated as the area under the curve in (cm^2)

$^{a–c}$ values in column with different letter are significantly different (P = 95%)

extensibility of wheat dough, energy levels dropped especially after 60 min of dough resting (about 25%; Table 2). A twofold portion of CA changed dough machinability to unacceptable state, dough elasticity increased twice at least and thus the ratio was multiplied. Nevertheless, energy of WF2+20CA sample (as the area under the curve) was comparable to that of wheat control WF2.

Statistical analysis – Principal Component Analysis

Using a data matrix containing two analytical, five farinograph and ten extensigraph parameters, the effects of quinoa and/or canahua and their addition levels were explored by Principal Component Analysis. A biplot of variables and samples explained 81% of data scatter by the first two principal components (PC), 53% by PC1 and 28% by PC2 (Fig. 2). Among extensigraph features, a tight relationship was confirmed between parameter fivesomes as determined at two different times of dough resting. Within the tested composites group, extensigraph energy could be predicted according to the Zeleny value, and the extensigraph ratio was dependent mainly on dough elasticity. The position of single composite samples reflected the differences in rheological properties and behaviour described supra.

Statistical analysis – hierarchical clustering

Generally, the cluster analysis is targeted at finding similar objects (samples) within a multidimensional cloud of the quality parameters measured. The simplest

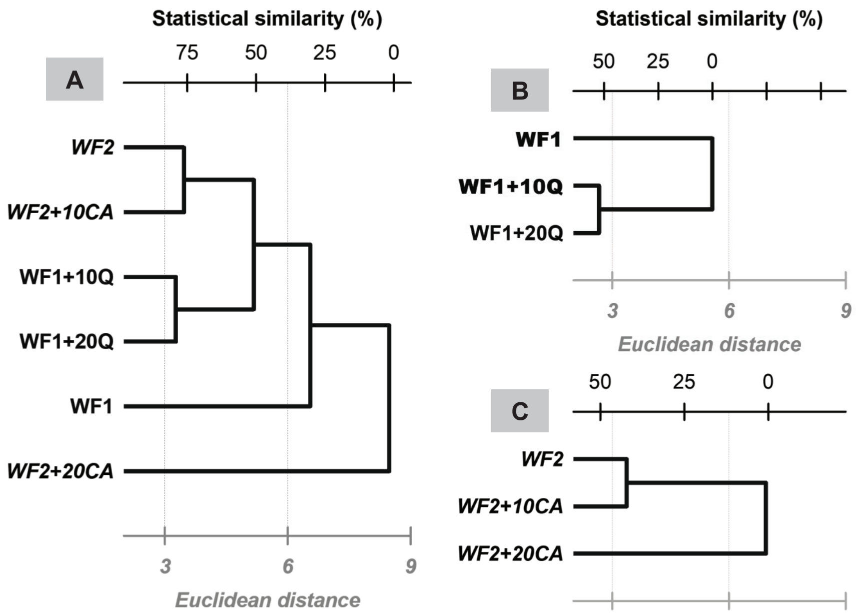

Fig. 3. Comparison of statistical similarity between samples of wheat-canahua and wheat-quinoa flour composites

method to calculate distances within that cloud is linear Euclidean metrics as mentioned supra. The distances could be easily converted to relative statistical similarity, expressing the percentage of similar properties between all sample pairs (plus the identification of the dissimilar pair of samples).

The samples grouping in the PC biplot was quantified by a hierarchical cluster analysis. The presumed differentiating of the observed samples on the basis of WF1 and WF2 was not confirmed – in Fig. 3A, WF1 and WF2+20CA could be marked as outliers (statistical similarities e.g. to WF2 33% and 0%, respectively; data not shown). As the samples WF1+10Q and WF1+20Q were joined together, the influence of Q could be considered stronger than that of the addition level (Fig. 3B). For canahua counterparts, the replacement ratio played a significant role because of clustering of the WF2 control together with composite WF2+10CA (Fig. 3C).

DISCUSSION

Analytical properties of flour composites

Non-traditional crops as quinoa or canahua usually do not contain gluten or gluten-like proteins (Stikic et al., 2012), an exception are seeds of African grasses fonio and teff. At the end of Zeleny test, the sediment volume is built most likely on the base of hydrophilic polysaccharides. In this regard, Hruskova et al. (2012) compared hemp and teff flour as non-gluten vs cereal raw material – 10% of the former raw material lowered the volume of the control from 41 to 27 ml (–40%), the latter from 41 to 32 ml (–22%).

Non-starch polysaccharides, known as dietary fibre, stand behind high viscosity of water-flour suspensions when heated – comparably to Q and CA, also pure nopal powder exhibited Falling number over 900 s (Hruskova et al., 2016) – during minute pasting, the present water was very quickly absorbed by fibre and within such viscous (dense) starch gel, amylases had no chance to act. Mucilage in chia was also able to elevate viscosity during a 25-minute testing on a rotational viscosimeter Rapid Visco Analyser (Inglett et al., 2013). Rosell et al. (2009) compared the thermomechanical behaviour of quinoa and canahua by using a mixolab device combining the farinograph and amylograph testing. Starch, the main component both quinoa and canahua, is responsible for dough consistency – according to Rosell et al. (2009) quinoa needs a higher temperature than wheat flour to gelatinise (72°C). Canahua flour did not demonstrate any starch gelatinisation, although temperature was set to rise from 55 to 90°C. For quinoa-wheat and canahua-wheat blends, the maximum torque during pasting was lower than for wheat control in both cases. According to Steffolani et al. (2013), amylose and crude fibre contents in three quinoa varieties were significantly lower than in four canahua ecotypes. In food industry, amylose could be used as a thickener. In this regard, the conclusions of Rosell et al. (2009) about zero viscosity of canahua flour at temperature over 50°C are unexpected.

Farinograph properties of flour composites

In line with our findings, cahanua as well as quinoa shortened dough stability during the mixolab test, which was performed at constant water addition (Rosell et al., 2009). Overall, wheat-canahua doughs only were very fragile with minimum resistance to overmixing. Buresova, Kubinek (2016) tested viscoelastic properties of a set of non-gluten plant materials by a shear oscillatory test, and found identical behaviour for quinoa and millet dough variants.

Enriquez et al. (2003) also stated that 15% of quinoa produced composite dough with short stability and a high softening degree (consistency decrease), while composites with lower dosages exhibited good breadmaking properties. In the form of peeled seeds, quinoa replacing 10 or 15% of wheat flour did not substantially affect rheological behaviour (Stikic et al., 2012). Reversely, 20% replacement brought a softer lowering of dough softening degree (90 BU for wheat standard and 75 BU for blend wheat-quinoa seeds 80 : 20 wt%). Lowering of baking value could be attributed to dietary fibre, which disrupts gluten skeleton of wheat dough as well as it competes about added water. In quinoa wholemeal, its ratio is close to 6% (ca. 13% in defatted wholemeal form) (Moscoso-Mujica et al., 2017). The effect of fenugreek fibre (added as 3, 6, 9 and 12%) on farinograph behaviour of wheat flour was rather positive. A substantial increase of water absorption (from 63.4% up to 87.0%) and a weak impact on dough softening degree (22 BU for the control vs average value 29 BU) were considered beneficial. A double prolongation of dough stability was positive as well. The only one disadvantage of such enhancement was the extension of dough development time from 3.5 to 22.6 min (Huang et al., 2016); this fact should likely lead to modification of the manufacturing process in bakery.

Extensigraph properties of flour composites

From texturometer recordings, Buresova, Kubinek (2016) confirmed approximately twice higher elasticity of quinoa, rice and millet doughs than showed other three gluten-free doughs, however the elasticity was still significantly lower if compared to wheat dough (for quinoa approximately 60% of wheat control). They stated that dough elongation depends on the length of molecular structures that form the dough skeleton. In the case of quinoa, such a function have arabinoxylans the molecular weight of which is

10–100 times lower than that of wheat gluten. Also in the case of gluten-free dough, quinoa wholemeal improved dough structure and supported dough elasticity, replacing the function of gluten (Turkut et al., 2016). A relatively huge portion of quinoa proteins with higher molecular weight also contributes to such tensile properties. In two canahua varieties with an average total protein content 17.5% dry matter (for wheat sample control 13.7%), prolamins and glutelins represented 10 + 22% of proteins, while in defatted quinoa wholemeals albumins and globulins represented 16 + 26%, respectively (Moscoso-Mujica et al., 2017). By the same electrophoresis procedure, the wheat control contained 20 + 28% and 12 + 10% of the protein fractions in defatted wholemeal, respectively.

During simulation of the extensigraph test using a texture analyser TA.XTPlus (TTC; Hamilton, USA), Buresova et al. (2014) determined approximately 50% resistance to extension for quinoa and rice dough variants compared to wheat dough. A 5% addition of quinoa flour into wheat-rye based dough (50 : 50 wt%) did not significantly modify viscoelastic properties of this dough – storage modulus (elasticity) decreased from 4004 ± 95 Pa to 3647 ± 65 Pa, and loss modulus (viscosity) from 2384 ± 63 to 2235 ± 96 Pa (Collar, Angioloni, 2014). Koca, Anil (2007) tested the influence of flaxseed flour, and concluded that broader stepwise shift in wheat-flaxseed dough machinability occurred in elasticity than in extensibility. By 10 or 20% additions, the ratios have risen from 2.78 to 3.15 and 3.33, respectively. As the area under the curve, the energy necessary for such deformation also fell from 107 cm^2 to 98 and 85 cm^2, respectively.

CONCLUSION

Currently, wheat flour as a basic bakery raw material is commonly partially replaced both in cereal research and bakery praxis. The usage of non-traditional crops characterised as non-gluten ones brings about a risk of technological complication during continuous manufacturing of bakery products. A proven limit of such fortification is 10%, generating a partially improved nutrition score of the final product. To reach that level, some raw materials must be debittered, and their final form (dried or macerated whole seeds, milled seeds, etc.) substantially contribute to the sensory profile. Both for quinoa and canahua flour, 10% was confirmed as acceptable from the technological point of view. When using a weaker wheat flour in bakery, both alternative crops are able to improve viscoelastic properties and behaviour to optimum.

REFERENCES

Bavec F, Bavec M (2007): Organic production and use of alternative crops. Taylor Francis Group, New York.

Buresova I, Kubinek R (2016): The behaviour of amaranth, chickpea, millet, corn, quinoa, buckwheat and rice doughs under shear oscillatory and uniaxial elongational tests simulating proving and baking. Journal of Texture Studies, 47, 423-431. doi: 10.1111/jtxs.12176.

Buresova I, Kracmar S, Dvorakova P, Streda T (2014): The relationship between rheological characteristics of gluten-free dough and the quality of biologically leavened bread. Journal of Cereal Science, 60, 271-275. doi: 10.1016/j.jcs.2014.07.001.

Collar C, Angioloni A (2014): Pseudocereals and teff in complex breadmaking matrices: Impact on lipid dynamics. Journal of Cereal Science, 59, 145-154. doi: 10.1016/j.jcs.2013.12.008.

CSN EN ISO 3093 (2011): Wheat, rye and their flours, durum wheat and durum wheat semolina – Determination of the falling number according to Hagberg-Perten. Czech Office for Standards, Metrology and Testing, Prague.

CSN EN ISO 5529 (2011): Wheat – Determination of the sedimentation index – Zeleny test. Czech Office for Standards, Metrology and Testing, Prague.

CSN EN ISO 5530-1 (2011): Wheat flour: Physical characteristics of doughs. Part 1: Determination of water absorption and rheological properties using a farinograph. Czech Office for Standards, Metrology and Testing, Prague.

CSN EN ISO 5530-2 (2011): Wheat flour: Physical characteristics of doughs. Part 2: Determination of water absorption and rheological properties using an extensigraph. Czech Office for Standards, Metrology and Testing, Prague.

Enriquez N, Peltzer M, Raimundi A, Tosi V, Pollio ML (2003): Characterization of the wheat and quinoa flour blends in relation to their bread making quality. Journal of the Argentine Chemical Society, 91, 47-54.

Hruskova M, Svec I (2015): Cookie making potential of composite flour containing wheat, barley and hemp. Czech Journal of Food Sciences, 33, 545-555. doi: 10.17221/9/2015-CJFS.

Hruskova M, Svec I, Jurinova I (2012): Composite flours – characteristics of wheat/hemp and wheat/teff models. Food and Nutrition Sciences, 3, 1484-1490. doi: 10.4236/fns.2012.311193.

Hruskova M, Svec I, Mrvikova L, Capova V (2016): Nopal flour – application in composite flours and bakery products. Ročenka Pekaře a cukráře, 1, 14-18. (in Czech)

Huang G, Huo Q, Wanf C, Ding HH, Cui SW (2016): LWT – Food Science and Technology, 71, 274-280. doi: 10.1016/j.lwt.2016.03.040.

Inglett GE, Chen D, Xu J, Lee S (2013): Pasting and rheological properties of chia composites containing barley flour. International Journal of Food Science and Technology, 48, 2564-2570. doi: 10.1111/ijfs.12250.

Koca AF, Munir A (2007): Effect of flaxseed and wheat flour blends on dough rheology and bread quality. Journal of the Science of Food and Agriculture, 87, 1172-1175. doi: 10.1002/jsfa.2739.

Moscoso-Mujica1 G, Zavaleta A, Mujica Á, Santos M, Calixto R (2017): Fraccionamiento y caracterización electroforética de las proteínas de la semilla de kañihua (*Chenopodium pallidicaule* Aellen). Revista Chilena de Nutrición, 44, 144-152. doi: 10.4067/S0717-75182017000200005. (in Spanish)

Perez GT, Steffolani ME, Leon AE (2016): Canahua: An ancient grain for new foods. In: Kristbergsson K, Otles S (eds): Functional properties of traditional foods. Springer US, Boston.

Rosell CM, Cortez G, Repo-Carrasco R (2009): Breadmaking use of Andean crops quinoa, kañiwa, kiwicha, and tarwi. Cereal Chemistry, 86, 386-392. doi: 10.1094/CCHEM-86-4-0386.

Shewry PR, Popineau Y, Lafiandra D, Belton P (2000): Wheat glutenin subunits and dough elasticity: Findings of the EUROWHEAT project. Trends in Food Science and Technology, 11, 433-441. doi: 10.1016/S0924-2244(01)00035-8.

Steffolani ME, Leon AE, Perez GT (2013): Study of the physicochemical and functional characterization of quinoa and kañiwa starches. Starch, 65, 976-983. doi: 10.1002/star.201200286.

Stikic R, Glamoclija D, Demin M, Vucelic-Radovic B, Jovanovic Z, Milojkovic-Opsenica D, Jacobsen S-E, Milovanovic M (2012): Agronomical and nutritional evaluation of quinoa seeds (*Chenopodium quinoa* Willd.) as an ingredient in bread formulations. Journal of Cereal Science, 55, 132-138. doi: 10.1016/j.jcs.2011.10.010.

Turkut GM, Cakmak H, Kumcuoglu S, Tavman S (2016): Effect of quinoa flour on gluten-free bread batter rheology and bread quality. Journal of Cereal Science, 69, 174-181. doi: 10.1016/j.jcs.2016.03.005.

Vega-Galvez A, Miranda M, Vergara J, Uribe E, Puente L, Martinez EA (2010): Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain: A review. Journal of the Science of Food and Agriculture, 90, 2541-2547. doi: 10.1002/jsfa.4158.

Corresponding Author:

Ing. Ivan Švec, Ph.D., University of Chemistry and Technology Prague, Department of Carbohydrates and Cereals, Technická 5, 166 28 Prague 6, Czech Republic, phone: +420 220 443 206, e-mail: Ivan.Svec@vscht.cz