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EFFECT OF CHIA AND TEFF SUPPLEMENT ON DIETARY FIBRE CONTENT, NON-FERMENTED DOUGH AND BREAD CHARACTERISTICS FROM WHEAT AND WHEAT-BARLEY FLOURS

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Abstract

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To elevate dietary fibre content in wheat bread, two additions of barley flour were tested (30 % and 50 %), and further 5 % or 10 % of chia or teff wholemeals. Chia elevated dietary fibre content more effectively than teff did (up to 6.41 % and 4.29 %, respectively). Non-gluten nature of proteins in non-traditional raw materials also affected farinograph, amylograph and mixolab proof results. Water absorption increased about 10 % in total, especially owing to teff presence in composite flour. All three alternative crops decelerated dough development and prolonged its stability, but dough softening degree depended on their combination. Higher water absorption was reflected in viscosity rise during amylograph testing. Using mixolab equipment, significantly more accurate differentiation of tested composites was reached, both in phase of dough kneading and registration of viscosity during heating and cooling. Contrary to this, any statistically verifiable difference was observed between chia or teff wholemeal variants from white of dark seeds. By variance analysis, some rheological parameters (dough softening degree, torque point C5, mixolab energy) together with specific bread volume were identified as principal for samples distinguishing. In terms of flour and bread quality, barley flour portion had a prevailing effect for chia tri-composites. Reversely, quality of flour blends containing teff was dependent on both barley flour and teff wholemeal portion and type.

Keywords: wheat composite flour; chia and teff wholemeal; mixolab; bread; PCA

INTRODUCTION

During last fifty years, common cereals and especially wheat underwent a great deal in agrotechnical and food quality development. At the same time, interest of consumers in nutrition aspect of daily eaten foods arose; assortment of bakery product with higher nutritional benefit has enlarged, reflecting that consumers' call for such sort of food. In this regard, earlier consumed seeds as e.g. amaranth, sunflower, quinoa, chia, hemp, teff or barley have a potential to improve nutritional value of common bread (Ohr, 2009).

As mentioned García Peris and Camblor Alvarez (1999), fibre is a concept that refers to or encompasses several carbohydrates and lignine that resist hydrolysis by human digestive enzymes and that are fermented by the microflora of the colon. From a practical point of view, fibres can be divided into soluble and insoluble. There is general acceptance of the concepts soluble fibre, fermentable, viscous and insoluble fibre, non-viscous and barely fermentable fibre. For determination of total content of dietary fibre as for its soluble and insoluble fraction (TDF, SDF and IDF, respectively), the AOAC enzymatic-gravimetric method 991.43 could be considered as the most frequently used one.

Barley (*Hordeum vulgare* L.) in form of fine flour represents easy accessible raw material with approved nutritional and healthy claims in terms of *β*-glucan polysaccharides effect on human health (EFSA, 2011). Many cereal scientists tested rheological properties of wheat-barley combination and evaluated characteristics of proper bread variants – enhancement level ranged from 10 to 60 % in case of non-fermented dough, and from 10–100 % in case of bread. An absence of gluten skeleton in pure barley dough led to depreciation of dough machinability; such dough is very 'short' during uniaxial extension and it tears easily (Sullivan *et al*., 2010; El Yamlahi *et al*., 2013). Owing to this, bread dough preparation from barley flour only is harder and quality of bread prepared from wheat-barley mixtures is finally worsened (Choi *et al*., 2011; Koletta *et al*., 2014). Unfortunately, barley flour and bakery products containing barley flour have a characteristic flavour, which could not be pleasant to common consumers. Rødbotten *et al*. (2015) collected data of wheat-barley bread preference in five European countries; consumers in the Czech Republic, Estonia and Scotland preferred the control bread containing barley flour only, while the Norwegian assessors liked the bread variant with the whole grains (i.e. product with the most intensive barley odour and flavour). Spanish consumers did not prefer any of the breads. Because of this, further alternative plant materials as chia of teff wholemeals able to mask that odour and taste could be combined with the cereal bi-composite blend.

Chia (*Salvia hispanica* L.) seeds are rich in minerals, about 20 % protein, 30–32 % fat, 30–40 % polysaccharide contents with the important portion of insoluble fibre (Pszczola 2012). In defatted chia seeds, total fibre content creates up to 22 % of dry matter (Verdú et al., 2015). Into final product, teff (*Eragrostis tef* Zucc.) wholemeal could introduce a great deal of minerals (mainly iron, calcium, phosphorus and copper) and B1 vitamin. Beside this, prolamins are prevailing teff proteins fraction (Adebowale *et al*., 2011), i.e. non-gluten and easy digestible source of amino acids. Compared to chia, total dietary fibre content is closely to one-fourth (4.5 %; Baye 2014).

Using the two addition levels of barley flour, changes in wheat dough rheological behaviour were described by farinograph, amylograph and mixolab tests. Within a laboratory baking trial, baking value of wheat bread and wheat-barley counterparts was evaluated. Novelty of the present article lies in wheat-barley dough formula variation by chia and teff wholemeals and testing their effect on wheat-barley dough and bread quality. As is mentioned above, all three non-traditional plant materials are good sources of dietary fibre; therefore, their contribution to nutritional value of flour composites was also quantified.

MATERIALS AND METHODS

Preparation of blends

Wheat flour (WF) was provided by the Czech industrial mill Delta Prague. WF sample, used as a standard and as a base of both wheat-barley blends, was characterised by protein content 13.0 %, ash content 0.60 % maximally (semi-bright wheat flour) and by Falling Number and Zeleny value 402 s and 47 ml, respectively. Fine barley flour (BF) was provided by the Křesín Czech mill, in which regular barley is processes; protein and total dietary fibre contents were evaluated on levels 9.26 % and 4.47 %, respectively. Blending WF and BF in ratios 70:30 and 50:50 (w/w), flour composites B30 and B50 were prepared (Tab. I).

White chia seeds (the wholemeal code CH1) were bought in a specialised food shop Country Life (Prague); according to information on packet label, the seed were produced in Paraguay and contain 21.4 % fat (of which 13.0 % of saturated), 20.0 % proteins and 17.5 % saccharides. Under trademark Raw Health, the Windmill Organics Ltd., UK, sells dark chia seeds (the wholemeal code CH2). Producer declares contents of fat 31.4 % (of which 3.8 % saturated), proteins (21.2 %), dietary fibre (31.4 %) and carbohydrates (4.5 %); their origin is not cited explicitly ('non-EU agriculture'). Tobia Teff UK Ltd. processes white and brown teff seeds, originated in Ethiopia, and produces fine white and brown teff wholegrain flours (T1 and T2, respectively). Content of carbohydrates is approximately 70 % (of which starch creates 54.0 %), fats 11.5 %, proteins 2.6 % and dietary fibre 7.6 %. Based on decision of the European Commission (258/97/ES and 2013/50/EU), for chia wholemeals replaces 5 wt. % or 10 wt. % of cereal premixes B30 or B50. Due to results comparability, the same addition levels were used for enhancement by teff wholegrain flour.

Sample coding combines cereal flour base (i.e. B30 or B50), non-traditional material type (CH1, CH2, T1 or T2) and its addition level (5 % or 10 %). Summarised, code B30CH2-5 identifies sample based on wheat-barley flour 70:30, containing dark chia seeds wholemeal added as 5 % of B30 base. Blending ratios for all flour composites tested are summarised in Tab. I.

Determination of dietary fibre content

Following the AOAC method 991.43, total, soluble and insoluble dietary fibre contents (TDF, SDF and IDF, respectively) were determined in pure plant materials WF, BF, CH1, CH1, T1 and T2. Measurement was conducted in two replications, and pair averages are presented in Tab. II. The method repeatability was evaluated earlier; for the TDF, SDF and IDF, standard deviations are 0.269, 0.230 and 0.206, respectively. The repeatability values allowed to determine IDF, SDF and TDF in one replication for the each sample. In compliance

I: *Blending ratio of flour composites tested*

Flour, flour composite	WF (g)	BF (g)	Chia wholemeal (g)*	Teff wholemeal (g)*
WF	300.0	-	-	-
BF30	270.0	30.0	-	-
B30CH1-5	199.5	85.5	15.0	-
B30CH1-10	189.0	81.0	30.0	-
B30CH2-5	199.5	85.5	15.0	-
B30CH2-10	189.0	81.0	30.0	-
B30T1-5	199.5	85.5	-	15.0
B30T1-10	189.0	81.0	-	30.0
B30T2-5	199.5	85.5	-	15.0
B30T2-10	189.0	81.0	-	30.0
BF50	150.0	150.0	-	-
B50CH1-5	142.5	142.5	15.0	-
B50CH1-10	135.0	135.0	30.0	-
B50CH2-5	142.5	142.5	15.0	-
B50CH2-10	135.0	135.0	30.0	-
B50T1-5	142.5	142.5	-	15.0
B50T1-10	135.0	135.0	-	30.0
B50T2-5	142.5	142.5	-	15.0
B50T2-10	135.0	135.0	-	30.0

WF, BF: wheat and barley flour, respectively; B30, B50: premixes from WF and BF (ratios 70:30 and 50:50 w/w, respectively). Non-traditional materials: CH1, CH2: white and black chia seeds wholemeal; T1, T2 – white and brown teff seeds wholemeal, respectively.
* – chia or teff wholemeal additions: 5 or 10 wt. % on base of wheat-barley premix.

with the Regulation EU 1169/2011, dietary fibre content was calculated in tested flour composites.

Rheological properties testing

Using similar procedure (Hrušková *et al.*, 2013), rheological behaviour of wheat flour, wheat-barley flour and their blends fortified by chia or teff was described by farinograph, amylograph and mixolab tests (ČSN ISO 5530-1, ISO 7973 and ICC No. 173, respectively). The mixolab tests were conducted at constant water addition (59.4 %); the amount of water corresponds to wheat dough consistency within prescribed torque range 1.05–1.15 N·m (equal to farinograph consistency 500 ± 20 Brabender units (BU). The rheological tests were conducted in one replication – for the immanent features, repeatability values are presented in the data tables.

Baking test method

Following internal procedure of the Cereal laboratory of UCT Prague, manually moulded bread was prepared in a laboratory scale (Hrušková *et al.*, 2013). Full-formula dough was prepared with the help of the farinograph; it consisted of 300 g flour or flour composite, 12 g compressed yeast, 5.1 g salt, 4.5 g sugar and distilled water amount necessary to reach the consistency 600 ± 20 BU. Dough mass fermentation took 50 min, and proofing 45 min. Bread samples baking was finished in 14 min, using laboratory oven preheated to 240 °C and steamed immediately after baking plate insertion. After 2 hours cooling at ambient temperature, bread quality was described by specific bread volume, bread shape as height-to-diameter ratio and sensory score. Bread volume was determined as usual, i.e. by rapeseed displacement method. Owing to baking trial repeatability determined before, the test was performed in one replication for the each sample; specific bread volume and shape were determined on base of three final product pieces (buns). Three trained panellists only evaluated the score, thus results represent an informative comparison to wheat and both wheat-barley bread controls. Evaluated parameters were crust parcelling, crust colour and brightness, crust thickness and hardness, crumb elasticity, crumb porosity, bread vaulting, overall aroma and taste, bread chewingness and stickiness to palate. All these hedonic attributes were scored by points 1 – 2 – 3, which mean following degrees: proper (the best) – acceptable – unacceptable. Total score is calculated as a sum of nine partial assessments, quantifying overall bread acceptability from minimum 9 points (the best quality) to maximum 27 points (unacceptable one).

Using the Penetrometer PNR-10 (Petrotest GmbH., Dahlewitz, Germany), crumb penetration rate was measured in triplicate. Samples in a form of crumb cylinders (of 35 mm in height and 30 mm in diameter) were cut-off from the bread halves centre.

II: *Content of dietary fibre and its fractions in cereal flours, non-traditional materials and flour composites*

Flour, flour composite	IDF (%)	SDF (%)	TDF (%)
WF	2.30 a	1.20 a	3.40 a
BF	2.93 ab	1.90 ab	4.47 abc
CH1	21.71 d	8.18 c	30.23 f
CH2	22.05 d	8.41 c	30.62 f
T1	4.59 c	2.52 ab	7.39 d
T2	4.76 c	2.61 b	7.48 d
B30	2.49 a	1.41 ab	3.72 a
B30CH1-5	3.45 abc	1.75 ab	5.05 bc
B30CH1-10	4.41 bc	2.09 ab	6.37 de
B30CH2-5	3.47 abc	1.76 ab	5.07 bc
B30CH2-10	4.45 bc	2.11 ab	6.41 de
B30T1-5	2.60 a	1.47 ab	3.90 ab
B30T1-10	2.70 a	1.52 ab	4.09 abc
B30T2-5	2.60 a	1.47 ab	3.91 ab
B30T2-10	2.72 a	1.53 ab	4.10 abc
B50	2.62 a	1.55 ab	3.93 ab
B50CH1-5	3.57 abc	1.88 ab	5.25 cd
B50CH1-10	4.53 c	2.21 ab	6.56 d
B50CH2-5	3.59 abc	1.89 ab	5.27 cd
B50CH2-10	4.56 c	2.24 ab	6.60 d
B50T1-5	2.72 a	1.60 ab	4.11 abc
B50T1-10	2.81 a	1.65 ab	4.28 abc
B50T2-5	2.72 a	1.60 ab	4.11 abc
B50T2-10	2.83 a	1.66 ab	4.29 abc
Repeatability	***0.269***	***0.230***	***0.206***

WF: wheat flour, BF: barley flour; B30, B50: premixes from WF and BF, prepared in ratios 70:30 and 50:50 (w/w), respectively.
Non-traditional materials: CH1, CH2: white and black chia seeds wholemeal;
T1, T2 - white and brown teff seeds wholemeal, respectively.
IDF, SDF, TDF – insoluble, soluble and total dietary fibre content, respectively.
a:f - values in partial columns marked by different letter differ statistically (P = 95 %).

Statistical analysis

Using software Statistica 7.1 (StatSoft Inc., Tulsa, USA), variance in recorded analytical and qualitative parameters was described by HSD Tukey's test (P = 95 %). Observed factors were composite flour type (constitution of composite flour) and addition level of non-traditional material.

RESULTS

Dietary fibre content in flour, wholemeals and flour composites

Tab. II presents dietary fibre contents in wheat and barley flour, chia and teff wholemeals. As could be noticed, all three alternative plant materials have a potential to improve a nutritional value of cereal products. Barley flour demonstrated higher dietary fibre content than wheat one, and TDF content was significantly increased in B50 premix (Tab. II). Within the teff wholemeals, level of dietary fibre is approximately twofold without effect of white/brown seeds type. In this regard, chia contributed to dietary fibre content in the largest extent (5.05 %–6.60 %). In other flour composites, portions of IDF and SDF fractions were comparable to ones in WF and BF controls, reflecting low additions of chia and teff wholemeals.

Farinograph characteristics of wheat flour, wheat and wheat-barley composites

Control sample WF demonstrated sufficient water absorption (61.6 %), somewhat longer dough development time (6:45 min) and medium dough stability (5:30 min, Tab. III). Dough resistance to overmixing (the softening degree) of wheat dough was also satisfying (55 BU). Behaviour of barley dough during the farinograph test had a non-standard course, thus only water absorption 63.0 % was determined. Mainly for B50 premix, incorporation of barley flour increased water absorption, and shortened development time and stability about 22 %–70 %. Composite dough prepared from B50 premix was also less resistant

III: *Influence of barley on farinograph, amylograph and mixolab behaviour on wheat flour*

Flour, flour composite	Farinograph				
	Water absorption (%)	Dough development (min:s)	Dough stability (min:s)	Degree of softening (BU)	Farinograph quality number (mm)
WF	61.6 a	6:45 c	5:30 c	55 a	85 c
BF	63.0 b	*n.e.*	*n.e.*	*n.e.*	*n.e.*
B30	65.5 c	3:30 b	4:00 a	60 a	65 b
B50	67.1 d	2:00 a	4:15 b	130 b	45 a
Repeatability	***0.2***	***0:12***	***0:12***	***8***	***0.4***

Flour, flour composite	Amylograph		
	Temperature of gelatinization beginning (°C)	Temperature of gelatinization maximum (°C)	Amylograph maximum (BU)
WF	61.0. *n.e.*	91.0 *n.e.*	680 a
BF	58.0 *n.e.*	65.5 *n.e.*	1000 c
B30	61.0 *n.e.*	91.7 *n.e.*	790 b
B50	60.3 *n.e.*	91.0 *n.e.*	820 b
Repeatability	-	-	***4.2***

Flour, flour composite	Mixolab				
	C1* (N·m)	C2 (N·m)	C3 (N·m)	C4 (N·m)	C5 (N·m)
WF	1.07 *n.e.*	0.60 b	2.12 b	1.92 c	2.99 d
BF	1.29 *n.e.*	0.00 a	0.10 a	0.01 a	0.00 a
B30	1.17 *n.e.*	0.51 b	2.24 b	1.69 b	2.56 b
B50	1.23 *n.e.*	0.54 b	2.34 b	1.71 b	2.60 c
Repeatability	-	***0.03***	***0.05***	***0.03***	***0.00***

WF: wheat flour, BF: barley flour, B30, B50: premixes from WF and BF in ratios 70:30 and 50:50 (w/w), respectively.
BU: Brabender unit.
* - constant water addition (59.4 %)
a:c - values in partial columns marked by different letter differ statistically (P = 95 %); n.e. - not evaluatable.

to overmixing, dough softening was approx. twice than for WF dough (130 BU vs. 55 BU, respectively).

During dough kneading, behaviour of tri-composite blends depended mainly on addition level of chia or teff. Dosage of 5 % those wholemeals did not change a course farinograph curves obviously (Fig. 1a, 1c). The effect of 10 % addition varied mainly water absorption (rise up to 74.9 %), dough stability (shortening to 2:00 min) and dough softening degree (increase up to 130 BU; Fig. 1b, 1d).

Pasting characteristics of wheat flour, wheat and wheat-barley composites

Viscosity of WF sample suspension 680 BU was close to empirical optimum (400–600 BU), indicating prosperous progress of dough fermentation and sufficient bread volume. For barley flour, gelatinization begun at lower temperature and viscosity maximum occurred earlier (58.0 °C and 65.5 °C, respectively). Maximal viscosity of BF was significantly higher than for WF control and it reach technical limit 1000 BU. Higher water absorption ability of BF was reflected in amylograph curves course during premixes B30 and B50 testing – increase to viscosity maximum 790 BU for the former sample was significant, while to 820 BU for the latter did not (Tab. III).

The amylograph maxima of 16 flour tri-composites were determined in a narrow range (820–1020 BU), and partial differences could be noticed in thermal properties of wheat–barley–chia and wheat–barley–teff combinations. Non-starch nature of both non-traditional materials accelerated gelatinisation. Based on B50 premix, effect of chia and teff wholemeals differed in a broader extent. Composites containing chia became to gelatinise at lower temperatures (i.e. earlier), but viscosity maximum was recorded at higher temperatures (later) than for BF50 control (Fig. 1g, 1h).

Mixolab characteristics of wheat, wheat flour, wheat and wheat-barley composites

According to recorded mixolab profiles, WF and BF samples differed clearly in all observed torque points – dough prepared from the latter sample demonstrated very short development time (shorter than 1 min), sharp consistency maximum and very short stability (close to zero, data not shown).

Thereafter, registered torque slowly decreased to zero, reaching it firstly in 29^{th} min of the test and persisting until the end of the test (45 min in total). Data in Tab. III shows, that torque points C2–C5 were therefore identical to zero. In correspondence to the farinograph and amylograph proofs, barley flour portions in BF30 and BF50 dough induced higher initial consistency (C1) as well as hot gel stability (C4; Tab. III). Both wheat-barley blends were characterised by lower rate of polysaccharides retrogradation (C5 parameter), indicating a slower staling of bakery products.

Chia or teff varied a course of the test of wheat-barley samples, both mixing and pasting phases. Teff composite dough was somewhat more resistant to kneading, based on insufficient amount of water added in dough (farinograph water absorption higher about 2 %–3 % that for chia composites; data not shown). Teff wholemeal also accelerated dough development and fasten decrease in its consistence. The main differences between both alternative plant materials are evident in final stage of the mixolab profiles, i.e. during phases of constant temperature (90 °C) followed by stepwise cooling to 50 °C. Mixolab profiles for pairs wheat-barley-chia and wheat-barley-teff blends (i.e. white and dark seeds wholemeals) laid over themselves, with torque points C5 higher for chia tri-composites (Fig. 1i-1l).

Baking test results

In agreement with changed rheological properties of wheat-barley dough, both BF dosages (30 % or 50 %) lowered high specific volume and worsened satisfying vaulting of wheat control. Organoleptic properties of wheat-barley bread variants were partially worsened by typical barley flour flavour (e.g. soft bitter aftertaste) as well as by higher mouthful stickiness (Tab. IV); that finding corresponds to higher recipe addition of water. On the other hand, crumb of wheat-barley bread was evaluated as tougher than the control; penetration rate fell to approx. 25 % for bread from both premixes (Tab. IV).

Wheat-barley bread enhancement by both wholemeal types was reflected in further decrease of buns volumes. Breads shape was worsened by teff incorporation, while chia wholemeals had a reversal influence. Overall sensory profile of such tri-composite bread types were improved by masking of barley flavour (especially within the B30 subset). Higher chia dosage altered appearance of bread surface by roughness, caused by visually noticeable dark dots in crust (particles of outer shells of seeds). These semi-hard particles also lowered consumer quality during sample mastication. Between tested chia types, no significant difference was observed (Tab. IV). During mastication, crumb pieces were resistant fairly to chewing in correspondence to penetration close to 5 mm.

Both teff wholemeal variants had a soft impact on specific volume of wheat-barley bread, but their additions verifiably lowered buns height and enlarged buns diameter. Consumer quality of all teff breads prepared according to eight recipe modifications was comparable together, with soft negative shifts in flavour (with participation of BF, too), perception during mastication and mouthful stickiness (higher recipe water addition). Crumb penetration of wheat-barley-teff bread was comparable to chia counterparts, lower values reflected higher barley flour dosage in bread formula.

DISCUSSION

Dietary fibre content in flour, wholemeals and flour composites

Content of dietary fibre in WF and BF correspond to regular type of both cereals. In case of wheat flour, Hager *et al.* (2012) published comparable TDF content (3.44 %). For barley, higher dietary fibre content is known to be higher in hulless and waxy varieties. Nowadays, breeding lines of barley, which have an increased content of beta-glucans belonging to soluble fibre, are intended for health food use. In such materials, TDF is ranged between 18.7–20.8 % (Šterna *et al.*, 2015) and even higher (21.9–24.1 %, Noworolnik *et al.*, 2014), depending on tested variety and hulled or hulless grain type. Total dietary fibre content in tested variants of chia (approximately 22 %) represent a bottom limit – Reyes-Caudillo *et al.* (2008) mentioned that TDF range in chia seeds may oscillated between 18 % and 60 %. In teff flour, TDF level is significantly lower; Hager *et al.* (2012) presented a content 4.54 %, which is approximately half in contrast to our data (7.39 % for T1 and 7.48 % for T2; Tab. II).

Rheological behaviour of wheat composite flour

Testing three wheat-barley flour blends, Choi *et al.* (2011) confirmed a significant changes in farinograph water absorption, dough development time as results of wheat flour substitution by barley one at levels 10, 20 and 30 %. Ahmed (2015) attributed these changes to barley β-glucans, exploring their concentrate effect on rheological properties. Reversely, Sullivan *et al.* (2010) stated, that neither 70 % wheat flour replacement by pearled BF rather lowered the water absorption, but other farinograph characteristics were not changed. In correspondence to gained results, 30 % replacement of wheat flour by teff one resulted in provably higher water absorption and in lower resistance to overmixing of composite dough about 3 % and 33 %, respectively (Alaunyte *et al.*, 2012). Hydrocolloids in chia flour also support water absorption during dough kneading, prolong dough development time but reversely shorten dough stability (Steffolani *et al.*, 2015).

IV: *Influence of barley, chia and teff flour on baking test results*

Bread variant (flour composite)	Specific bread volume (ml/100 g)	Bread shape (-)	Crumb penetration (mm)	Sensory profile (points)
WF	374 d	0.59 abcd	13.3 d	8.5 a
B30	233 c	0.57 abcd	4.2 abc	14.5 bcd
B30CH1-5	176 abc	0.59 abcd	4.0 abc	10.0 ab
B30CH1-10	184 abc	0.63 bcd	5.4 c	12.0 abc
B30CH2-5	154 ab	0.59 abcd	6.7 abc	13.0 abcd
B30CH2-10	169 abc	0.68 d	4.5 abc	18.0 d
B30T1-5	211 abc	0.42 a	4.3 abc	12.5 abc
B30T1-10	226 bc	0.40 a	5.5 abc	13.0 abcd
B30T2-5	179 abc	0.46 abc	6.1 a	13.0 abcd
B30T2-10	199 abc	0.42 a	5.6 abc	14.0 bcd
B50	199 abc	0.42 a	5.7 abc	14.0 bcd
B50CH1-5	148 a	0.68 d	4.9 abc	14.5 bcd
B50CH1-10	180 abc	0.65 cd	3.2 bc	16.5 cd
B50CH2-5	165 abc	0.64 bcd	4.4 abc	15.0 bcd
B50CH2-10	167 abc	0.64 bcd	3.8 abc	15.0 bcd
B50T1-5	203 abc	0.41 a	4.1 abc	13.0 abcd
B50T1-10	201 abc	0.43 a	3.5 ab	12.5 abc
B50T2-5	196 abc	0.45 ab	3.8 ab	12.0 abc
B50T2-10	185 abc	0.46 abc	3.7 ab	15.0 bcd
Repeatability	***13.00***	***0.03***	***1.23***	***0.89***

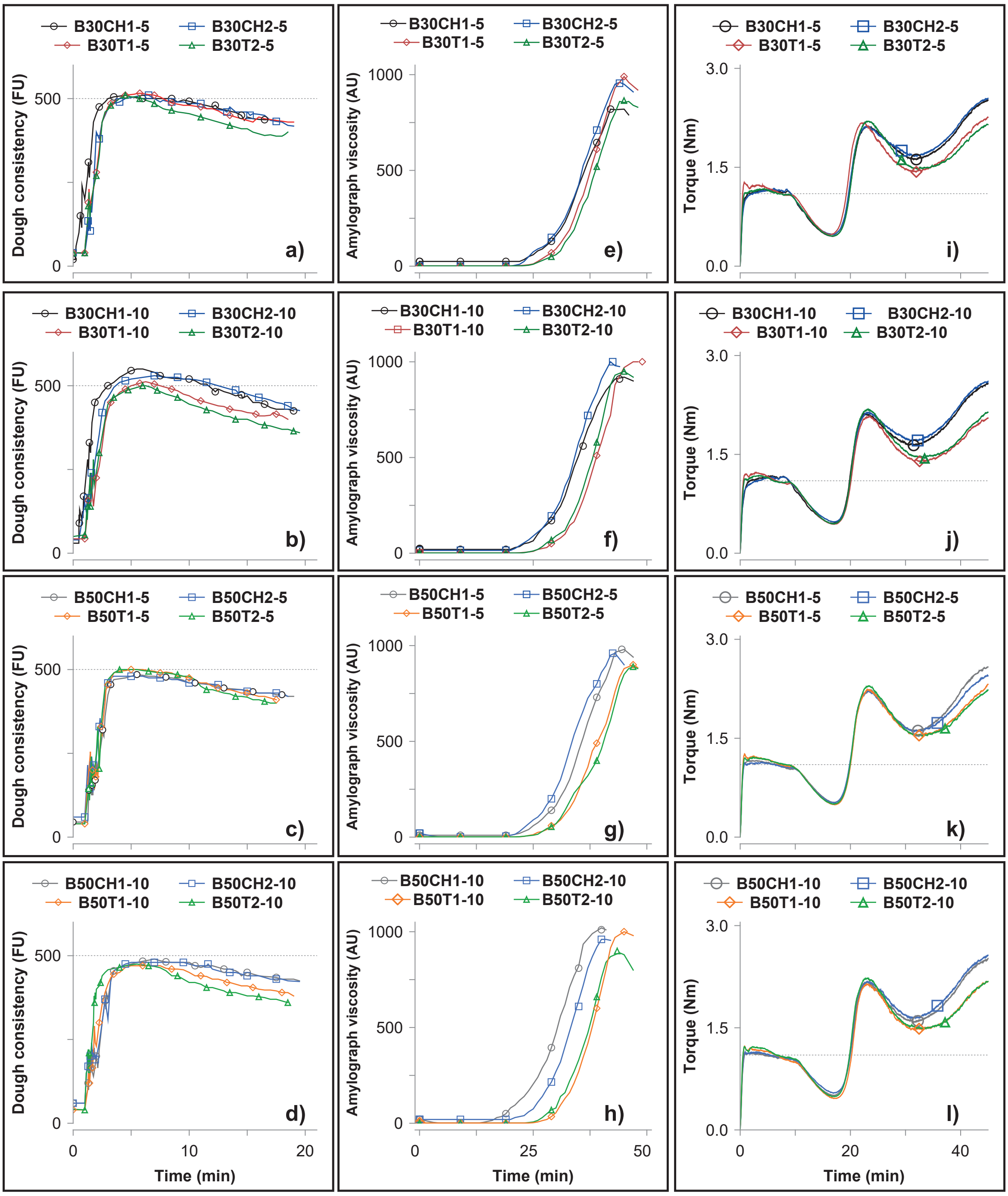
WF: wheat flour; B30, B50: premixes from WF and BF, prepared in ratios 70:30 and 50:50 (w/w), respectively.
Non-traditional materials: CH1, CH2: white and black chia seeds wholemeal; T1, T2 - white and brown teff seeds wholemeal, respectively.
a:d - values in partial columns marked by different letter differ statistically (P = 95 %).

Pasting characteristics of wheat composite flour

Similarly to results of fundamental rheology tests, also pasting behaviour of composite wheat flour shows similar tendencies – RVA peak viscosity significantly increased up to 20 % for mixture containing 30 % tef (Alaunyte *et al.*, 2012). Also mixtures supplemented by 5 %, 10 % or 15 % chia flour demonstrated a stepwise increase of viscosity (Verdú *et al.*, 2015). For barley-chia blend 90:10, Inglett *et al.* (2013) recorded a similar pattern of the RVA curve as for barley flour control, i.e. chia addition has not significant effect.

Baking test results

In non-traditional materials, proteins have structures depending on plant species – non-gluten proteins in barley or chia have a negative impact on bread volume, while teff gluten-like ones could even improve the loaf size. Sullivan *et al.* (2010) stated that 30–100 % pearled barley addition of barley changed wheat flour formulation slightly. In teff flour, Adebowale *et al.* (2011) classified prevailing protein fraction as prolamins, which could be embedded in wheat dough gluten net. Due to that, Alaunyte *et al.* (2012) determined softly lower specific volume of wheat-teff bread than control one. Wheat flour substitution by 10 % teff lowered bread volume improvably (from 354 mL/100 g for control to 346 mL/100 g for wheat-teff bread). Organoleptic properties of such composite bread were softly affected in sweet flavour decrease and in bitterness detection; overall acceptability dropped to 92 %. In case of gluten-free bread, addition of 20 % teff flour induced also a decrease in the loaf area (Campo *et al.*, 2015). Wheat flour replacement by 10 % chia seeds produced a decrease in bread volume and an increase in crumb firmness, but total sensory score was similar to control (Steffolani *et al.*, 2015). Texture of three wheat-chia bread variants (95:5, 90:10, 85:15, respectively) was described by larger pores and their similar counts per square unit (Verdú *et al.*, 2015). At the same time, bread volumes at least comparable to the control one could be presumed.



1: *Comparison of farinograph [a)-d)], amylograph [e)-h)] and mixolab curves [i)-l)] of wheat-barley dough as affected by additions of two types of chia and two teff wholemeal. For coding of composite flour samples, see Tab. I.*

CONCLUSION

Among tested plant materials type, barley, chia as well as teff have higher dietary fibre content than wheat. Beside this, proteins of all three non-traditional plants are characterised as non-gluten ones. These two facts influenced pasting behaviour of flour suspensions and viscoelastic properties of non-fermented dough, determined during amylograph, farinograph and mixolab tests. Influence of barley flour, introduced in tens of percent into wheat flour composites, levelled to ones of chia and barley added into lower ratios. Composite flours were able to absorb provably higher amount of water, but prepared dough variants were poorer in stability and cohesiveness. Pasting behaviour of tested flour composites differed softly in amylograph viscosity maxima; the main change occurred in times of pasting beginning (or temperature), which shown a partial dependence on botanical specie. Mixolab profiles confirmed a greater data scatter during pasting phase of the test than during the mixing one; a significant variance was observed in hot gel stability and its retrogradation rate. Wheat-barley bread quality was affected by lessening of bun volumes as well as by typical barley flavour; bread crumb was more humid and sticky than the wheat one. Specific volumes of bread prepared from teff flour composites were comparable to both wheat-barley controls, while addition of chia magnified worsening of consumer's quality. On the other hand, teff wholemeal verifiably contributed to spread of dough pieces during baking – buns were lower in height and larger in diameter. Dietary fibre in chia, representing 4–6 % of bun weight, restricted that process and supported buns arching (better-vaulted shape). Crumb penetration as a rate of crumb softness/firmness corresponded to specific bread volume clearly – the broader bread recipe modification, the denser crumb (lower depth of penetration). Chia and teff partially masked barley flavour, especially in case of 30 % proportion of barley flour in recipe. With respect to demanded higher rate of dietary fibre in final bakery products, recommended constitution of flour composites is 30 % of barley flour and 10 % of chia or teff wholemeal.

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