OPEN ACCESS

Potravinarstvo® Scientific Journal for Food Industry

Potravinarstvo, vol. 10, 2016, no. 1, p. 287-294
doi:10.5219/594
Received: 22 February 2016. Accepted: 26 May 2016.
Available online: 14 June 2016 at www.potravinarstvo.com

ISSN 1337-0960 (online)

FLAX – EVALUATION OF COMPOSITE FLOUR AND USING IN CEREAL PRODUCTS

Marie Hrušková, Ivan Švec

ABSTRACT

Two types of yellow and brown linseed, differing in granulation, were tested in form of wheat flour composites (additions 2.5% and 5.0%) by using the Farinograph, the Extensigraph and the Rapid Visco Analyser (RVA) apparatuses. Additions of brown and yellow flax fibre significantly affected Falling Number and Zeleny test values. Curves of farinograph were differed according to flax fibre type – finer flax (better terminology) granulation meant somewhat stronger negative changes in dough stability and dough softening degree. Results of extensigraph test demonstrated changes in dough elasticity and extensibility due to lowering of gluten protein content. Appearance of the RVA profiles was verifiably different, reflecting diverse wheat and flax polysaccharides, added dietary fibre type and its granulation. Due to that, bread volume and shape was lowered up to one-half in case of golden flax composites. Similar tendencies with smaller negative influence caused the brown linseed. Fibre from flax is used for technical (textile) use, but linseed dietary fibre addition affected quality of laboratory prepared cut-off biscuits and dried pasta differently, showing a dependence on the fibre type, granulation as well as addition level. Sensory profiles of all mentioned product types were acceptable.

Keywords: brown and yellow linseed; granulation; rheology; bread; biscuits; pasta

INTRODUCTION

Flax (*Linum usitatissimum* L.) is old utility plant originated in Asia. Slim stem and light-blue flowers could distinguish the plant. Its fruit is boll containing tiny brown seeds. There exist linseed varieties (e.g. Amon, Raciol) with lighter seed, named as “yellow flax”.

Fibre flax is appraised according to flax thread characteristics, which exists into two forms for industrial processing. Between world producers belong France, Belgium and Netherlands, in the Czech Republic is not planted from the year 2010.

Linseed is planted for seeds and oil production, for both food and industrial usage. According to Catalogue of oil plant varieties (ÚKZÚZ Brno, 2015), four linseed varieties sorted in groups with low, high and usual linoleic-to-alpha-linolenic acid ratio were tested. Between varieties with medium content of these acids belongs the Czech variety Raciol, registered in year 2011.

Flax seed is, with respect to chemical composition, recommended into curative diets. Between brown and yellow coloured seeds, nutrition difference is not verifiable, but consumers prefer yellow seeds owing to somewhat intensive nutty-butter by-taste. Seed composition is typical by high oil content (40%), dietary fibre (28%) and proteins (21%). Further known constituents are minerals (4%) and non-starch polysaccharides (6%) as lignans, hemicelluloses and phenolics (**Fitzpatric, 2008; Bernacchia et al., 2014**; **Ding et al., 2014; Nitrayová et al. 2014**). Flax oil is the most favourable nutrition component, rich in omega-3 unsaturated fatty acids with short chain. Also content of alpha-linolenic acid is substantial **(Cunnane et al., 1993)**. For commercial purposes, limited stability of these oil components is discussed, which have approved health benefits in lifestyle diseases prevention (**Denmark-Wahnefriend, 2006)**. Employing of flax seed in cereal products is limited by specific structure characteristic. Owing to hard cover layers, it could be used as decorative material for spreading of special bread types. In cases of wholemeal bread, golden flax seeds are used more frequently. When it is involved into bread recipe, technological process has to be adapted in terms of so-called wort, which owing to time period and water temperature ensures sufficient water sorption and seeds softening. For such purpose, brown flax is preferred, because of difference in crumb colour profile compared to product based on wheat flour only.

Flax dietary fibre is commercial food supplement gained as by-product during oil pressing or extraction, sold in a dry powder form. Walramcom company, flax fibre producer from the New Zeeland, present mean nutritional values for the supplement from brown and golden flax: saccharides 2.4%, proteins 32.0% and total fat 16.6% (of which 13% unsaturated fatty acids). According to production method, majority mass portion presents dietary fibre (TDF 45.2%, IDF 37.9% and SDF 7.3%). Proteins have a non-gluten nature, and thus they are safe for coeliac patients. Further, flax fibre is a good source of constituents with high anti-oxidant activity, especially lignans (e.g. secoisolariciresinol diglucoside) and vitamin E. For flax lignans, a specific function in prevention cancer diseases of breast and prostate. **Budwig (2011)** presented their

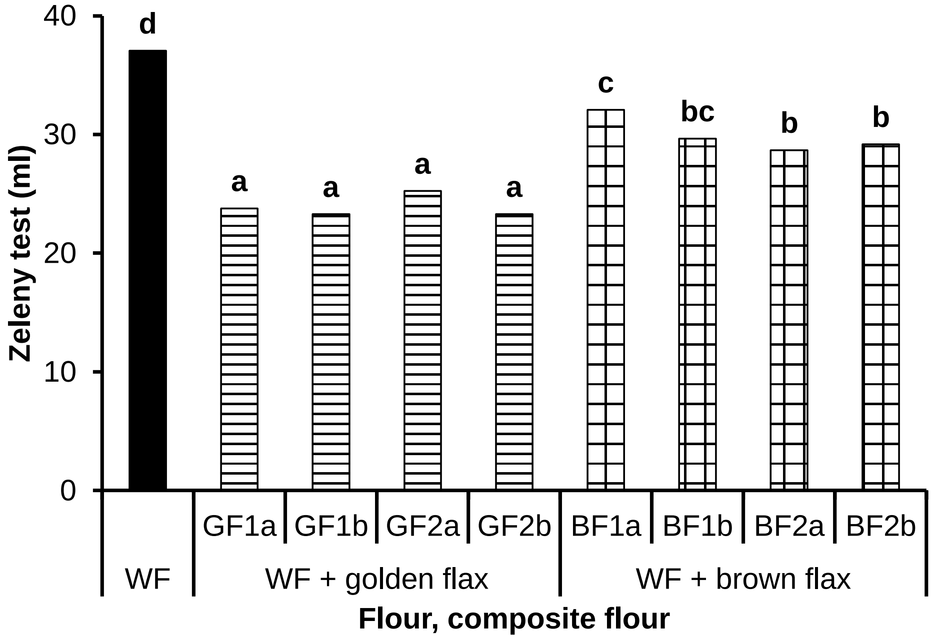

Figure 1 Zeleny test values for wheat flour (WF) and flour composites. For samples coding, see Table 1.

content 75 – 800 times higher compared to other vegetable and pulses. Owing to low presence of saccharides, flax fibre is appropriate for diabetics and sportsmen. Plant proteins may successfully enriched daily diet of vegetarians and vegans. Recommended consumption is equal to 13 g as additive into oat flakes, yogurts or soups. In terms of gluten-free material, it could serve as a base of bread, pancakes, pies etc. Flax fibre has a potential to be used as recipe component of sweet bread e.g. muffins **(Chetana et al., 2010)**, gluten-free products and pastas **(Kishk et al., 2011; Hrušková a Švec, 2013)**.

The pilot study was aimed at characteristics comparison of several commercial types of flax fibre, using them in form of composite flour during non-fermented and fermented dough properties testing. Verifying technological potential and consumer quality of these flour composites, leavened bread, cookies and pasta were manufactured in a laboratory scale.

MATERIAL AND METHODOLOGY

Preparation of flour composites

Semi-bright fine wheat flour (WF) was produced from wheat harvested in year 2015 by industrial mill Delta Prague. According to Falling number (392 s) and Zeleny sedimentation values (392 s and 37 ml, respectively), quality of the basic material is medium with lower amylases activity. The company Walramcom (New Zeeland) produced flax fibre (FF) samples, and they represent grounded flax seeds press cake after oil extraction (GF1, GF2 – golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively; BF1, BF2 – brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively). According to nutritional label, dietary fibre content is comparable in all tested ff samples. Flour composites involve 2.5% or 5.0% of ff on flour base (samples coding GF1a and GF1b, etc.).

Technological quality of flour composites

Technological features of wf and flour composites are described by Zeleny test (ČSN ISO 5529) and Falling number (ČSN ISO 3093). Non-fermented dough properties were determined by using of farinograph and extensigraph brabender (Germany), following the international norms (ČSN ISO 55 30-1, 55 30-2, respectively). Behaviour of suspension flour-water was recorded on the RVA 4500 equipment (Perten Instruments, Sweden; AACC method 76-21). According to internal procedures of the UCT Prague, rheological parameters of fermented dough was measured, using fermentograph SJA (Sweden),

Table 1 Falling number for wheat flour (WF) and flour composites.

Flour, flour composite	WF		GF1a		GF1b		GF2a		GF2b		BF1a		BF1b		BF2a		BF2b	
Falling number* (s)	392	bc	349	ab	319	a	305	a	330	ab	442	c	438	c	426	c	456	c

GF1, GF2 - golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively.
BF1, BF2 - brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively.
Example of sample coding: GF1a, GF1b - flour composites containing 2.5% or 5.0% of golden flax fibre, respectively.
* a-c: row means described by the same letter are not significantly different (p = 95%).

Table 2 Farinograph characteristics of non-fermented dough from wheat flour (WF) and flour composites.

Flour, flour composite	Water absorption* (%)		Dough development time* (min)		Dough softening degree* (FU)	
WF	67.8	a	3.15	bc	50	b
GF1a	70.3	b	2.00	a	30	ab
GF1b	72.5	d	2.50	ab	30	ab
GF2a	70.0	b	2.50	ab	20	a
GF2b	72.0	cd	4.00	cd	10	a
BF1a	71.0	bc	3.00	abc	30	ab
BF1b	71.9	cd	3.50	bcd	10	a
BF2a	70.3	b	3.50	bcd	15	a
BF2b	72.3	d	4.50	d	10	a

GF1, GF2 - golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively.
BF1, BF2 - brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively.
Example of sample coding: GF1a, GF1b - flour composites containing 2.5% or 5.0% of golden flax fibre, respectively.
FU – farinograph unit.
* a-d: column means described by the same letter are not significantly different (p = 95%).

maturograph and oven rise recorder (OTG) Brabender (Germany). From prepared wheat-flax fibre composites, bread, cut-off biscuits and pasta were manufactured, following further internal methods ended by quality evaluation.

Statistical evaluation of ff effect

Influence of FF type and dosage level was evaluated it terms of variation of selected dough rheological features and final products (Tukey test, p = 95%). Aimed on determination of quality features dominant for bread, biscuits and pasta, Principal Components Analysis (PCA) was used. In cases PCA of bread, biscuits and pasta, the datasets were analogous to ensure the comparability of the analysis findings – two analytical features, three farinograph and two extensigraph ones, a pair of the pasting characteristics and foursome of the product quality attributes immanent to the product type.

RESULTS AND DISCUSSION

Evaluation of technological quality of flour composites

According to Zeleny test values, bakery quality of proteins could be considered as lower compared to WF (Figure 1). Addition of GF caused a decrease in a higher extent (about 30%) in relation to BF influence (-18%) and WF control. As could be noticed in Figure 1, neither addition level nor FF granulation did not trigger significant differences.

In wheat flour sample, amylases activity as the Falling number was estimated about ca 25% lower than optimum for standard bakery processing is (250 s). With respect to variability in the FF type (GF vs. BF), granulation (2 types) as well as addition level (2.5% vs. 5.0%), flax fibre contributed to Falling number change softly. An insignificant lowering and increase was observed for GF and BF, respectively, with weak impact of addition level.

Evaluation of non-fermented dough features

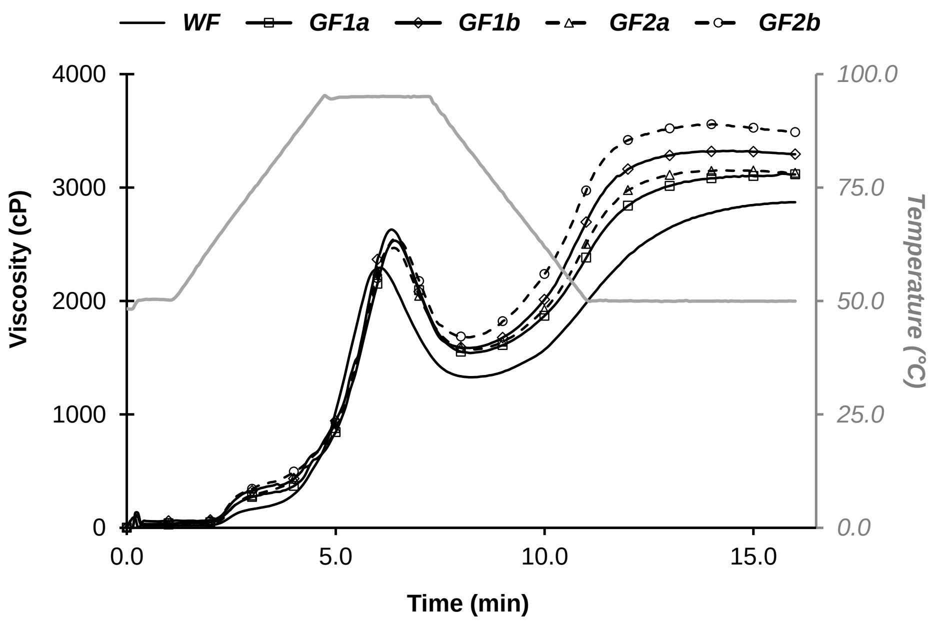

Figure 2 RVA profiles of wheat flour and selected flour composites. For samples coding, see Table 1.

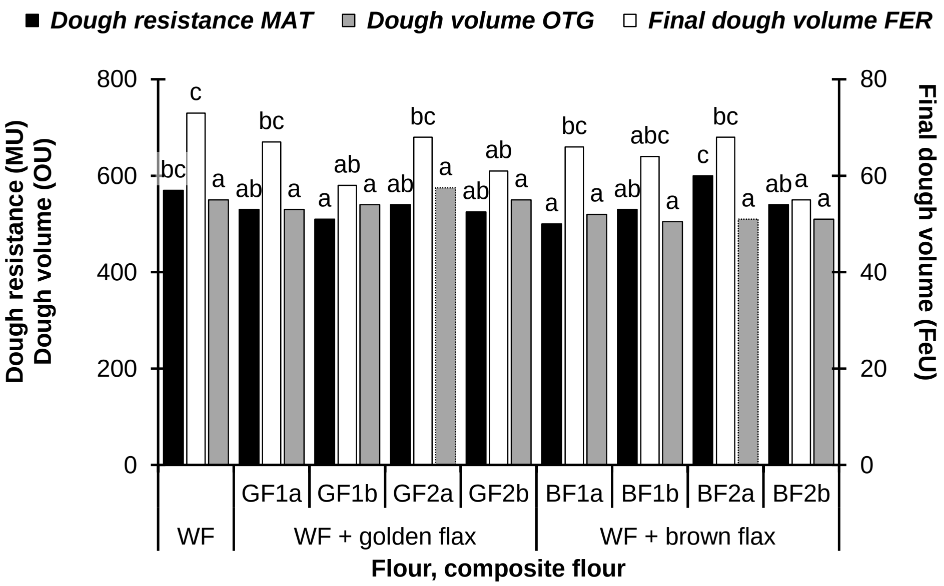

Figure 3 Characteristics of fermented dough from wheat flour and flour composites. For samples coding, see Table 1.

In case of standard farinograph proof, rheological properties of non-fermented dough prepared from flour composites are characterised by water absorption increase about 3% – 7%. Higher values were determined for 5% addition and BF of coarser granulation. Dough development time was shortened by the GF effect (from 3 min to 2 min), and reversal trend was observed for the BF (prolongation about 25%). Preparation of composite dough variants did not leave the line of standard process, and the values of dough softening degree point to higher resistance to overmixing (Table 2); on the farinograms, the second maxima were identified for more enhanced samples, which discussed **Xu et al. (2014)**.

According to extensigraph characteristics, change in dough viscoelastic properties implies the elasticity-to-extensibility ratio determined after 60 min of dough resting, which simulates II. phase of fermentation process during wheat bread manufacturing. The ratio increased from 2.18 (WF control) about 10% – 70% reflecting FF type and granulation of GF and BF (data not shown). In composite dough, diluted gluten protein contributed to lowering of bakery quality of tested dough samples; extensigraph energy decreased seriously by incorporation of finer GF (about 15%), while impact of coarser GF addition was softer (decrease ca 10%).

Both BF counterparts rather increased dough bakery quality, and effect of granulation was indefinite. RVA profile course describing viscous behaviour of wheat suspension could be designated as standard, values of the Peak Viscosity and Final Viscosity corresponds to presumed using for bread manufacturing. As illustrates Figure 2, suspensions of flour composites differed from the control in earlier gelatinisation beginning, reflecting the FF type and granulation. Between golden and brown flax, measured differences correspond to diverse representation of polysaccharide fractions, and they

Table 3 Features of bread prepared from wheat flour and flour composites.

Flour, flour composite	Specific bread volume** (ml/100g)	Bread shape*, ** (-)	Crumb penetration** (mm)
WF	334 d	0.61 a	14.3 f
GF1a	285 cd	0.54 ab	9.5 d
GF1b	242 abc	0.41 a	5.8 a
GF2a	283 cd	0.53 ab	10.4 e
GF2b	182 a	0.42 a	6.2 b
BF1a	205 ab	0.51 ab	6.2 ab
BF1b	268 bcd	0.55 ab	8.0 c
BF2a	197 ab	0.44 ab	6.6 b
BF2b	246 abc	0.56 ab	9.1 d

GF1, GF2 - golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively.
BF1, BF2 - brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively.
Example of sample coding: GF1a, GF1b - flour composites containing 2.5% or 5.0% of golden flax fibre, respectively.
* Height-to-diameter ratio.
** a-d: column means described by the same letter are not significantly different (p = 95%).

Table 4 Features of biscuits prepared from wheat flour and flour composites

Flour, flour composite	Specific biscuit volume** (ml/100 g)	Spread ratio*, ** (-)	Sensory profile** (-)
WF	165 ab	4.35 b	12.0 ab
GF1a	172 b	4.41 b	11.5 ab
GF1b	134 a	4.81 b	12.5 b
GF2a	167 ab	4.53 b	11.0 a
GF2b	147 ab	4.13 b	11.0 a
BF1a	143 ab	1.98 a	11.5 ab
BF1b	145 ab	1.73 a	11.5 ab
BF2a	149 ab	2.07 a	11.5 ab
BF2b	155 ab	2.05 a	11.5 ab

GF1, GF2 - golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively.
BF1, BF2 - brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively.
Example of sample coding: GF1a, GF1b - flour composites containing 2.5% or 5.0% of golden flax fibre, respectively.
* Diameter-to-height ratio.
** a-d: column means described by the same letter are not significantly different (p = 95%).

demonstrated a reversal tendency than published **Mueller et al. (2010)**. Influence of three factors on RVA features are discussed by **Švec and Hrušková (2016)**.

Evaluation of fermented dough features

With the help of three laboratory apparatuses, fermentograph, maturograph and OTG, three phases called fermentation, proofing and first stage of baking are simulated, allowing to describe fermented dough behaviour and estimation of technological potential of flour composites for operational application. Gained readings allow to evaluate 12 parameters, from which three are substantial for comparison with wheat dough – final dough volume (fermentograph), dough resistance (maturograph) and dough volume (OTG test). As shown Figure 3, type, granulation as well as FF type affected these features, but measurement accuracy did not allow distinguishing composite dough items from wheat control.

There could be noticed, that final dough volume depends more on FF addition level than its type. With exception of BF2a composite dough, dough resistance of other samples reached comparable level to wheat one. Bread volume in the third phase of fermentation predicts specific bread volume, and soft increase as result of GF enhancement was observed. Our results agree with effect of FF addition (6%) described by **Xu et al., (2014)**.

Evaluation of wheat bread features

Simulating a straight-dough process in a bakery, a baking trial was conducted according to the internal method (Babiaková, 2015). Quality assessment of laboratory prepared bread demonstrated a negative relationship between GF dosage and specific bread volume. For 5% addition of GF1 and GF2, a decrease reached almost one-third compared to control (242 ml.100 g^{-1} and 182 ml.100 g^{-1}, respectively, against 334 ml.100 g^{-1}). Buns vaulting became lower as FF portion in bread recipe increased; height-to-diameter ratio decrease was significant in cases of higher enhancement. Quantifying sensorial score, the change was confirmed, too – crumb of fortified bread samples were tougher and thus less tasty. By BF addition, consumer quality lowering of wheat bread

Table 5 Features of cooked pasta prepared from wheat flour and flour composites

Flour, flour composite	Absorption* (%)	Swelling index* (-)	Sediment* (ml)
WF	159.2 c	1.45 a	120 abcd
GF1a	134.0 ab	1.52 a	96 ab
GF1b	131.6 ab	1.58 a	96 ab
GF2a	147.2 bc	1.56 a	104 abc
GF2b	135.6 ab	1.58 a	80 a
BF1a	126.0 a	1.32 a	160 d
BF1b	135.2 ab	1.35 a	126 bcd
BF2a	136.8 ab	1.40 a	144 cd
BF2b	132.8 ab	1.50 a	80 a

GF1, GF2 - golden flax fibre with granulation 0-300 μm and 500-700 μm, respectively.
BF1, BF2 - brown flax fibre with granulation 300-500 μm and 500-700 μm, respectively.
Example of sample coding: GF1a, GF1b - flour composites containing 2.5% or 5.0% of golden flax fibre, respectively.
* a-b: column means described by the same letter are not significantly different (p = 95%).

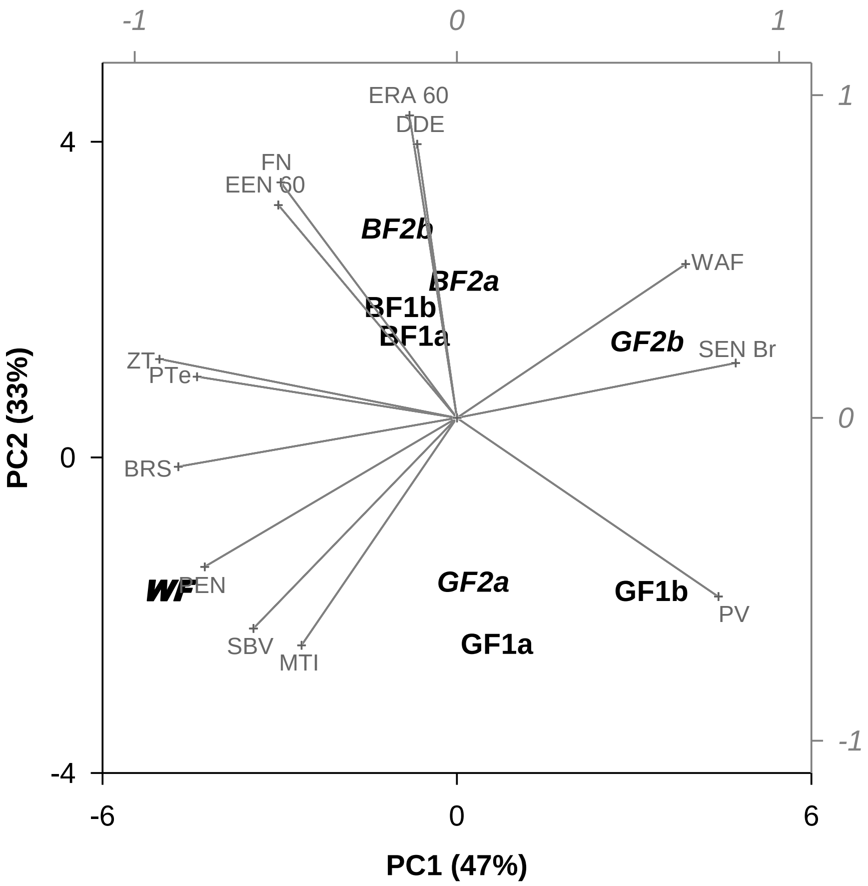

Figure 4 Principal component (PC) analysis of flax fibre effect on dough and bread technological quality. FN – Falling number, ZT – Zeleny test; WAB – water absorption, DDE – dough development time, MTI – mixing tolerance index (dough softening degree); ERA 60, EEN 60 – extensigraph elasticity-to-extensibility ratio and energy, respectively (dough resting 60 min); PTe – pasting temperature, PV – peak viscosity; SBV – specific bread volume, BRS – bread shape (height-to- diameter ratio, PEN – crumb penetration, SEN Br – bread sensory profile. For samples coding, see Table 1.

was not so dramatic, higher dosage of BF1 and BF2 (i.e. 5.0%) lowered bread volume to 268 ml.100 g^{-1} and 246 ml.100 g^{-1}, respectively; that finding correspond to conclusion in paper of **Marpalle et al. (2014)**. Samples containing 5.0% of both BF reached significantly higher volumes than their less enhanced counterparts did. Besides, shape and crumb texture of buns with BF obtained a score closer to the WF standard (Table 3).

Multivariate statistics explained 80% of data variability; 47% was covered by principal component PC1 and 33% by PC2 (Figure 4). Within PC1 x PC2 area, conjoining of observed dough and bread features as well as tested samples has a relation to their dependence rate on the FF effect. As was discussed, impact of GF and BF addition was verifiably different – golden flax fibre additions influenced bread quality less negatively. Within PC1 x PC2 area, position of GF1a, GF1b and GF2a samples are obviously closer to WF one, confirming lower level of the dough softening degree (MTI) and reversely higher values of the specific bread volume and crumb penetration. Within the biplot, there could be noticed a significant role of bread sensory score in bread recipe discrimination (explored from 75% by PC1, and from 3% by PC2).

Evaluation of cut-off biscuit features

Cut-off biscuits are characteristic by manufacturing technique, i.e. by cutting-off from dough plate of calibrated thickness, and within the Czech assortment of long-life confectionery, they represent ca 20%. The mentioned internal method (Hrušková and Švec, 2015) operates with seven quality characteristics, of which three (specific volume of baked biscuits, shape as spread ratio (diameter-to-height ratio) and sensory profile allow to compare different recipe variants. For biscuits containing GF, 2.5% such fibre had a positive influence on the evaluated features; the impact of GF granulation was less provable. Brown flax fibre caused a soft specific volume decrease (about approx. 10%), and biscuits shape spread into approx. a half scale (Table 4). Sensorial profiles of GF and BF biscuits did not deviate from the wheat control one. Yellow linseed contributed to attractive yellow shade of biscuit surface, and brownish one in case of BF. Coarser flax dietary fibre (granulation over 500 μm) was visually detectable as darker dots in biscuit crust, especially in case of biscuits containing brown seeds FF.

PCA results of biscuits quality, based on the analogous data set for composite flour and dough behaviour as in case of bread, shown comparable dependences as illustrated in Figure 4 (biplot not shown). The first two PC explored also 80% of data variability, and the dominant features for biscuits recipe distinguishing maintained the Zeleny test, the extensigraph energy, both RVA pasting features and the specific volume together with the biscuit shape (spread ratio). The product sensory score depended mainly on the PC3 (80%), PC1-PC2 pair explained 18% of the scatter only.

Evaluation of dried pasta features

Employing a laboratory pasta line, dried (elbow shape) pasta was prepared, following the internal method of Vítová (2009). The link compose of pasta press Korgold TR 70 (Korngold, Austria), pre-drier Sun P+ and drying kiln Sun 405/2 (Mezos, Czech Republic), simulating process in factory. Prepared pasta is evaluated during pressing and in raw – dried – cooked forms by 12 characteristics in total. According to selected three ones (absorption, swelling index, sediment height), basic comparison of different pasta types could be carried out. Pressing of FF-fortified pasta passed off in standard way, pasta surface temperature did not overcome recommendedlevel 40 °C. Neither raw nor dried elbow pasta did not demonstrate an excessive shape deformation. After drying, pasta colour corresponded with FF type and addition level – GF contributed to lighter and BF to pleasant darker shade in surface colour of basic product. For all pasta variants, optimal cooking time reached a standard duration (8.00 min), but decrease in absorption, about 7.5% to 20.0% was evaluated. Swelling index, which characterises ability to absorb boiling water, was higher for samples enrichen by GF without impact of granulation and addition level. For pasta involving finer BF (300-500 μm), a lowering of the feature was observed. Sediment volume express a mass extracted during cooking into salt water, determined as a height of turbidity after 1 hour of standing. The feature has a relation to polysaccharides components in recipe, and measured values indicate a dependence on the FF addition level and its granulation.

Pasta quality features appointed to the dough one did not changed the data variation seriously – the PC1 explained 47% and the PC2 32% of the data scatter (Figure 5). Absorption of cooked pasta corresponds strongly with mechanical properties of proteins and polysaccharides in non-fermented dough, and swelling index with Peak viscosity on the RVA curve. Pasta samples containing either GF or BF were statistically different similarly to bread and biscuit items; within the biplot, pasta consumer quality belonged to the dominant quality features (57% and 29% of variation covered under PC1 and PC2, respectively).

CONCLUSION

Owing to chemical composition, flax seed and dietary fibre have a potential to be used in food industry. Dietary fibre gained from seeds of common flax is declared as

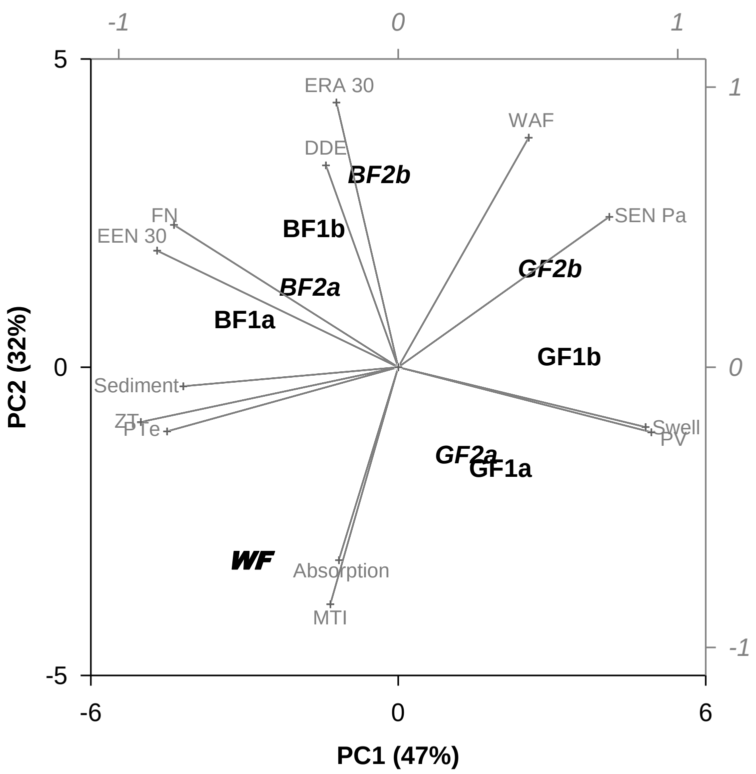

Figure 5 Principal component (PC) analysis of flax fibre effect on dough and pasta technological quality. FN – Falling number, ZT – Zeleny test; WAB – water absorption, DDE – dough development time, MTI – mixing tolerance index (dough softening degree); ERA 30, EEN 30 – extensigraph elasticity-to-extensibility ratio and energy, respectively (dough resting 30 min); PTe – pasting temperature, PV – peak viscosity; Absorption – amount of water absorbed by pasta, Swell – Swelling ratio, Sediment – height of sediment after pasta cooking, SEN Pa – pasta sensory profile. For samples coding, see Table 1.

source of plant proteins, lipids of valuable constitution and non-starch polysaccharides. Added into wheat flour, flax dietary fibre changed its technological and rheological behaviour in correspondence with flax fibre type (yellow/brown flax), fibre granulation as well as addition level. Compared to wheat flour, Zeleny test values demonstrated a lowering of protein quality and of Falling number soft increase, although the changes extent was significantly different between neither the fibre types nor both granulations. Wheat flour enrichment was verifiably reflected in water absorption rise and in the RVA features scatter; the recorded viscosity parameters differentiated flour composites containing yellow and brown flax dietary fibre. Rheological characteristics of fermented composite dough variants were less affected compared to wheat control as well as in relation to flax dietary fibre types, because observed differences were close to measurement accuracy of the internal methods. Bread buns containing flax dietary fibre was characterised by lower specific volume and less vaulted shape. According to objective quality features, shape and crumb of bread prepared from flour composite with fibre from yellow flax seeds were closer to wheat bread control characteristics. Towards to cut-off biscuit attributes, flax fibre from yellow seeds had stronger positive effect than the brown one. Enrichment of dried wheat pasta recipe did not affect its standard shape, both in raw and dried stage; after cooking, golden flax counterparts scored better. During sensory tests, all cereal product enhanced by flax fibre were described as acceptable for common consumers. In relation to tested recipe composition, a higher technological potential was observed for commercial fibre gained from yellow flax seeds, produced by the company Walramcom, the New Zeeland.

REFERENCES

Babiaková, B. 2015. *Characteristics of composite mixture containing non-traditional seeds*: master thesis. [In Czech]. Prague, Czech Republic: University of Chemistry and Technology Prague. 99 p.

Bernacchia, R., Preti, R., Vinci, G. 2014. Chemical composition and health benefits of flaxseed. *Austin Journal of Nutrition and Food Science*, vol. 2, no. 8, id 1045, 9 p.

Budwig, J. 2011. *The Budwig cancer and coronary hearth disease prevention diet*. 1st ed., LOS ANGELES, USA: Freedom Press, 215 p.

Chetana, Sudha, M. L., Begum, K., Ramasarma, P. R. 2010. Nutritional characteristics of linseed/flaxseed (*Linum usitatissimum*) and its application in muffin making. *Journal of Texture Studies*, vol. 41, no. 4, p. 563-578. http://dx.doi.org/10.1111/j.1745-4603.2010.00242.x

Cunnane, S. C., Ganuli, S., Menard, C., Wolever, T. M., Jenkins, D. J. 1993. High alfa-linolenic acid flaxseed: Some nutritional properties in humans. *British Journal of Nutrition*, vol. 69, no. 2, p. 443-453.

Denmark-Wahnefriend, W. 2006. Flaxseed and prostate cancer: demon seed or seed of salvation? *Seminars in Preventive and Alternative Medicine*, vol. 2, no. 4, p. 205-207.

Ding, H. H., Cui, S. W., Goff, H. D., Wang, Q., Chen, J., Han, N. F. 2014. Soluble polysaccharides from flaxseed kernel as a new source of dietary fibres: Extraction and physicochemical characterization. *Food Research International*, vol. 56, p. 166-173. http://dx.doi.org/10.1016/j.foodres.2013.12.005

Fitzpatric, C. K. 2008. Stabilizing flax for food application. *Cereal Food World*, vol. 53, no. 5, p. 280-282. http://dx.doi.org/10.1094/CFW-53-5-0280

Fitzpatric M., Švec I. 2015. Cookie making potential of composite flour containing wheat, barley and hemp. *Czech Journal of Food Science*, vol. 33, no. 6, 2015, p. 545-555. http://dx.doi.org/10.17221/9/2015-CJFS

Hrušková, M., Švec, I., Jurinová, I. 2013. Flax fibre – additions influence Lněná vláknina – vliv přídavků na kvalitu pšeničné mouky, *Pekař a cukrář*, vol. 2, p. 82-87.

Kishk, Y. F. M., Elsheshetawy, H. E., Mahmoud, E. A. M. 2011. Influence of isolated flaxseed mucilage as a non-starch polysaccharide on noodle quality. *International Journal of Food Science and Technology*, vol. 46, no. 3, p. 661-668. http://dx.doi.org/10.1111/j.1365-2621.2010.02547.x

Marpalle, P., Sonawane, S. K, Shalini Subhash Arya 2014. Effect of flaxseed flour addition on physicochemical and sensory properties of functional bread. *LWT – Food Science and Technology*, vol. 58, no. 2, p. 614.619. http://dx.doi.org/10.1016/j.lwt.2014.04.003

Mueller, K., Eisner, P., Yoshie-Stark, Y., Nakada, R., Kirchhoff, E. 2010. Functional properties and chemical composition of fractionated brown and yellow linseed meal (*Linum usitatissimum* L.). *Journal of Food Engineering*, vol. 98, no. 4, p. 453-460. http://dx.doi.org/10.1016/j.jfoodeng.2010.01.028

Nitrayová, S., Brestenský, M., Heger, J., Patráš, P., Rafay, J., Sirotkin, A. 2014. Amino acids and fatty acids profile of chia (*Salvia hispanica* L.) and flax (*Linum usitatissimum* L.) seed. *Potravinarstvo*, vol. 8, no. 1, p. 72-76. http://dx.doi.org/10.5219/332

Švec, I., Hrušková, M. 2016. Statistical description of RVA profiles of composite blends with flax fibre, In Proceedings of the Ingrovy dny 2016, MU Brno, 7 p.

UKZUZ Brno, 2015. *Seznam doporučených odrůd – Olejniny (Catalogue of oil plant varieties)*. 1st ed., Brno, Česká republika: Vydavatelství ÚKZÚZ Brno, 132 p.

Vítová, M. 2007. *Pasta laboratory test*: bachelor thesis [In Czech]. Prague, Czech Republic: University of Chemistry and Technology Prague, 74 p.

Xu, Y., Hall III, C. A., Manthey, F. A. 2014. Effect of flaxseed flour on rheologial properties of wheat flour dough and on bread characteristics. *Journal of Food Research*, vol. 3, no. 6, p. 83-91. http://dx.doi.org/10.5539/jfr.v3n6p83

Acknowledgments:

This work was supported by grant NAZV OI 151 027.

Contact address:

Marie Hrušková, University of Chemistry and Technology Prague, Faculty of Food and Biochemical Technology, Department of Carbohydrates and Cereals, Technická 5, 166 28 Praha 6, Czech Republic, E-mail: Marie.Hruskova@vscht.cz.

Ivan Švec, University of Chemistry and Technology Prague, Faculty of Food and Biochemical Technology, Department of Carbohydrates ad Cereals, Technická 5, 166 28 Praha 6, Czech Republic, E-mail: Ivan.Svec@vscht.cz.