EVALUATION OF NON-FERMENTED DOUGH FROM WHEAT/BARLEY/HEMP COMPOSITES*

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Basic wheat-barley flour premixes (70 : 30 and 50 : 50) were enhanced by 5 and 10% of dehulled and hulled hemp seeds wholemeal or by 2 types of hemp fine flour. Barley flour (BF) decreased both protein content and quality by approximately 1.5 and 50%, respectively. In blends, hemp fine flour containing recovered protein level back. BF lowered amylases activity by about 20–25% in maximum; hemp products had no significant effect. Farinograph water absorption was magnified by additions of both alternative flours. Considerable shortening of dough stability and decrease of resistance against over-mixing occurred for all flour tri-composites. Extensigraph dough elasticity increased and extensibility diminished. After dough resting taking 30 min, extensigraph energy of the control sample fell from 141 cm^2 to a half as barley flour portion increased. In cereal composites, hemp products demonstrated reversal tendencies. BF lowered water suspension viscosity, but hemp wholemeal H4 and especially fine hemp flour H7 caused a recovery of amylograph maxima to level comparable with wheat control. Correlation analysis confirmed analytical and rheological data agreement – the extensigraph elasticity or energy could be predicted according to the Zeleny value, or the amylograph maximum according to the Falling Number (r = 0.79, 0.90, and 0.65, respectively; P = 99.9%).

wheat-barley composite flour, cannabis, viscosity, dough rheology, correlation analysis

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INTRODUCTION

An innovation within cereal branch presents non-traditional cereals usage, with accent on nutritional benefit of bakery products. Barley and hemp milling products can serve for wheat composite flour. Both recipe components are known for a specific chemical composition with higher nutrition value compared to wheat. In spite of enhancing nutritional value and increasing bread consumer quality, the dough rheological properties of composites can be respected. The aim of rheological testing is to achieve the optimum of each dough in the production process. When bakery products are made from composite flour, their overall quality should be as similar as possible to that of products from wheat.

Barley (*Hordeum vulgare* L.), a member of the *Poaceae* family, belongs to a major for food production (malt, wort, beer, whisky). In cereal technology, barley is the fourth important cereal. Important uses include animal fodder, and a source of fermentable material for beer and certain distilled beverages. Pearl barley may be processed into a variety of barley products, including flour or flakes similar to oat, and grits. According to study published by Newman, Newman (2008), eating whole-grain barley can regulate blood sugar for up to 10 h after consumption compared to whole-grain wheat,

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which have similar glycaemic indices. In addition, barley's dietary fibre is high in beta-glucan, which helps to lower cholesterol by binding to bile acids and removing them from the body via the faeces. According to the EFSA permitted claim, fibre and barley beta-glucans were recognized to have a health benefit (Commission Regulation No. 432/2012). Grain content of protein, fat, and starch rates is known to be 10–12%, 1.5–1.8%, and approximately 75%, respectively. Hordeins as a stable protein stuff manner different behaviour in bakery technology. Starch consists of approximately 80% amylopectin and rest part forms amylose. Larger grains of elliptic shape (40 µm) participate on 90% starch content. As mentioned Chmelik et al. (2001), smaller ones (1–10 µm) tend to be deeply embedded in the protein matrix of endosperm. Due to that, they are less susceptible to enzymatic degradation as well as they gelatinize at higher temperature. Both these factors may affect standard progress of dough fermentation in bakery or mashing in brewery. Barley addition to wheat flour increased water absorption and time of dough development according to farinograph test as a positive effect but viscoelastic characteristics were changed negatively, namely with lowering of dough elasticity. Bakery profile of composite was worsening according to significant decrease of extensigraph energy. Amylograph maximum is increased twice in the case of 50% barley amount in composite with wheat (Hofmanova, 2011).

Hemp (*Cannabis sativa*) is planted as two subspecies, namely ssp. *culta* and ssp. *indica*. The latter is called hash hemp and belongs to forbidden raw material with respect to intoxicating substances production. Hemp flour composition depends on variety and planting locality and also differs according to the level of dehulling or defatting. Protein, fat, and starch rates are known to be 30–33%, 7–13%, approximately 40%, respectively. Seed contains a significant level of beta-carotene and vitamins B_1 and E. Considering mineral component aspect, a benefit could be found in higher portion of iron and zinc. Approximately two-thirds of hemp proteins are composed by edestin, belonging to low molecular weight globulins (Callaway, 2004). The content of 10–15% insoluble fibre (Dimic et al., 2009) may be also the reason for wheat flour fortification.

Correspondingly to previous research (Hruskova, Svec, 2014), results of farinograph test of wheat/hemp composites showed changes in dough rheological behaviour. Only the water absorption demonstrated a practical independency on hemp flour ratio, oscillating around 62.9% of added water. Compared to wheat standard, time-expressing parameters (dough development time, dough stability) were prolonged in a different extent, twice in the former and almost about 50% in both latter cases. Finally, dough softening of four hemp composites could be considered as comparable to standard – recorded degrees of softening were 40 FU for wheat sample, and 20–50 FU for fortified samples. Amylograph pasting properties of flour suspensions with hemp were determined in agreement with Falling Number (FN). The higher the hemp flour content, the lower the composites viscosity was measured (observed maximal decrease of 125 amylograph units).

With respect to literature, the behaviour of cereal wheat/barley/hemp blend described by means of rheological apparatuses has not been published yet.

The aim of the present study is to explore non-fermented dough prepared from cereal blends on the base of wheat, barley, and hemp flours, including different commonly available seed forms (wholemeal and fine) by means of Brabender rheological apparatuses. Wheat/barley composites were completely tested earlier (Hruskova et al., 2009). Within the Czech Republic, the use of hemp seed and products becomes now popular. The previous two-composite blend was modified by hemp flour with the aim to explore nutritional benefits. Statistical pattern used should reveal out relationships between single quality features and also the influence of diverse recipe composition of partial models.

MATERIAL AND METHODS

Preparation of model cereal blends

Based on commercial wheat flour (WF) produced in year 2012, cereal blends were prepared by using fine barley flour (BF) and four hemp flour samples (H4–H7). Wheat flour obtained from Czech industrial mill is characterised as bright type (ash content 0.59%) with protein content 11.98%. Hemp samples H4, H5, and H7 originated in conventional and H6 in bio-planting regime, and all named samples are of fine granulation. Furthermore, samples H4 and H5 are laboratorily prepared ones, from dehulled and hulled hemp seeds, respectively, thus both have a wholemeal character. Cereal blends were mixed in ratios wheat : barley 70 : 30 and 50 : 50 (WBF30 and WBF50, respectively). To both cereal bases, 5 and 10% of hemp flour was added.

Analytical properties of flour composites

Using factor 5.7, protein content (PRO) was determined according to the Kjeldahl's method (CSN EN ISO 1871). For protein quality description, the Zeleny test (CSN EN ISO 5529) was used, and amylolytic activity estimation as the FN was done according to CSN EN ISO 3093. Analytical features were measured in duplicate, correspondingly to the mentioned Czech norms.

Table 1. Influence of hemp addition on chemical composition of wheat-barley composites

Flour, blend	Hemp addition (%)	Proteins (%)	Zeleny test (ml)	Falling Number (s)
(a) Composites 70 : 30 (w/w)				
WF	0	11.98[b]	48[f]	379[b]
WBF30	0	11.20[a]	34[e]	294[a]
WBF30 + H4	5	11.85[ab]	29[d]	285[a]
	10	12.62[c]	24[b]	271[a]
WBF30 + H5	5	11.71[a]	29[d]	282[a]
	10	12.00[b]	24[b]	273[a]
WBF30 + H6	5	12.59[c]	27[c]	272[a]
	10	13.85[d]	20[a]	285[a]
WBF30 + H7	5	11.95[b]	30[d]	289[a]
	10	12.59[c]	25[b]	283[a]
(b) Composites 50 : 50 (w/w)				
WF	0	11.98[f]	48[g]	379[d]
WBF50	0	10.35[a]	26[f]	280[ab]
WBF50 + H4	5	11.11[bc]	20[cd]	269[a]
	10	11.78[ef]	15[a]	281[ab]
WBF50 + H5	5	11.19[c]	23[e]	292[bc]
	10	11.42[d]	19[c]	294[c]
WBF50 + H6	5	11.65[e]	21[cd]	301[c]
	10	13.04[g]	16[ab]	276[a]
WBF50 + H7	5	10.95[b]	21[d]	295[c]
	10	11.90[f]	17[b]	276[a]

WF = wheat flour; WBF30, WBF50 = blend from wheat and barley flour 70 : 30 and 50 : 50 (w/w), respectively; hemp products: H4 = dehulled seeds wholemeal, H5 = hulled seeds wholemeal, H6 = conventional fine flour, H7 = organic fine flour

[a–g]values in column with different letter are significantly different (*P* = 95%)

Rheological testing of dough

The rheological methods described before (Svec, Hruskova, 2009) were in a modified form applied to composites technological quality assessment in case of non-fermented dough. The Brabender farinograph (Brabender GmbH & Co KG, Germany) according to CSN EN ISO 5530-1 test procedure was used for water absorption values (WAB value; ml), development time (DDE; min), dough stability (DST; min), degree of softening (DSF; farinograph unit (FU)), and farinograph quality number (FQN; mm) determination. For extensigraph measurement, the Brabender apparatus (Brabender GmbH & Co KG) and test procedure according to CSN EN ISO 5530-2 were applied. The samples were prepared from flour, distilled water, and salt, and data for energy (E; cm^2), resistance (R; extensigraph unit (EU)), extensibility (Ex; mm), and ratio number (R/Ex) were evaluated.

Rheological testing of composites suspension

Viscous behaviour during gradual temperature rise was recorded by using the Amylograph equipment (Brabender). Following the ICC Standard No. 126/1 (2011) (CSN EN ISO 7973) procedure, the amylograph data is represented by gelatinization maximum (AMA; amylograph unit (AU)). All rheological methods for non-fermented dough are well known in cereal scientific field and for accuracy of measurement, it is necessary to follow the mentioned international norms.

Statistical analysis

By using Tukey's HSD test (analysis of variance, significance level *P* = 95%) within the STATISTICA 7.0 software (StatSoft, USA), the effects of barley or hemp flour were compared with those of additional level of the components. Correspondence of data gained

Table 2. Farinograph characteristics of wheat flour as affected by barley and hemp additions

Flour, blend	Hemp addition (%)	DDE (min)	DST (min)	DSF (FU)	FQN (min)
(a) Composites 70 : 30 (w/w)					
WF	0	2.50^{a}	8.50^{d}	40^{a}	135^{e}
WBF30	0	2.50^{a}	4.50^{b}	90^{bc}	60^{ab}
WBF30 + H4	5	2.00^{a}	4.50^{b}	80^{bc}	65^{b}
	10	2.00^{a}	4.50^{b}	80^{bc}	65^{b}
WBF30 + H5	5	2.00^{a}	5.00^{b}	70^{b}	85^{c}
	10	2.00^{a}	3.00^{a}	100^{c}	50^{a}
WBF30 + H6	5	4.50^{b}	5.00^{b}	90^{bc}	65^{b}
	10	4.50^{b}	5.00^{b}	80^{bc}	70^{b}
WBF30 + H7	5	4.50^{b}	6.50^{c}	90^{bc}	85^{c}
	10	5.50^{b}	8.00^{d}	70^{b}	110^{d}
(b) Composites 50 : 50 (w/w)					
WF	0	2.50^{ab}	8.50^{e}	40^{a}	135^{f}
WBF50	0	2.00^{ab}	4.80^{d}	100^{bc}	70^{cd}
WBF50 + H4	5	2.00^{ab}	3.00^{b}	100^{bc}	55^{b}
	10	1.80^{a}	1.50^{a}	130^{d}	40^{a}
WBF50 + H5	5	2.00^{ab}	3.50^{bc}	110^{cd}	60^{bc}
	10	2.30^{ab}	4.50^{cd}	100^{bc}	70^{cd}
WBF50 + H6	5	2.50^{ab}	4.50^{cd}	80^{b}	80^{de}
	10	2.50^{ab}	4.00^{bcd}	80^{b}	70^{cd}
WBF50 + H7	5	3.00^{b}	5.00^{d}	80^{b}	90^{e}
	10	3.00^{b}	4.80^{d}	80^{b}	90^{e}

DDE = development time, DST = dough stability, DSF = degree of softening, FQN = farinograph quality number, WF = wheat flour; B30, B50 = blend of wheat and barley flour 70 : 30 and 50 : 50 (w/w), respectively; hemp flour: H4 = dehulled wholemeal, H5 = hulled wholemeal, H6 = conventional fine, H7 = organic fine

$^{a–f}$column means signed by the same letter are not statistically different (P = 95%)

by analytical and rheological methods was verified by correlation analysis (P = 95%).

RESULTS

Analytical properties of flour composites

Basic component WF is characterised by proteins (PRO) and Zeleny test (ZT) (11.98% and 48 ml; Table 1) satisfying quality for the purpose of addition of alternative plant materials containing non-gluten proteins such as barley and hemp. The FN (317 s) corresponds to harvest year weather course and with respect to final usage for bakery product manufacturing, it is softly above the technological optimum of 250 s.

For composites WBF30 and WBF50, statistically verifiable diminishing of PRO correspondingly to the BF addition level was evaluated (Table 1a, b). A higher portion of BF also caused a broader interval of PRO measured, interacting with hemp flour recover-

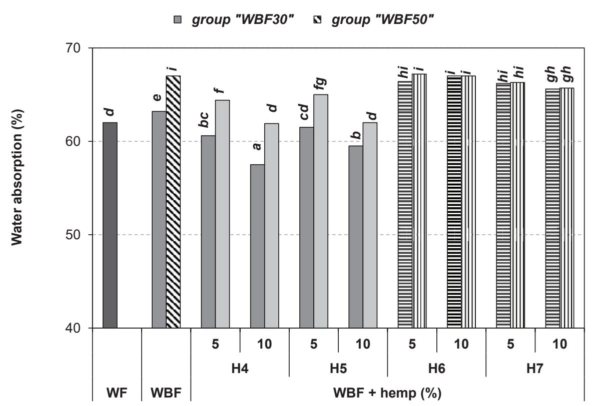

Fig. 1. Influence of barley and hemp flour on farinograph water absorption of wheat dough. WF = wheat flour, WBF30, WBF50 = wheat-barley flour composite 70:30 and 50:50, respectively; H4, H5 = hemp wholemeal from dehulled and hulled seeds, H6, H7 = commercial fine hemp flour.

Table 3. Extensigraph characteristic of wheat dough as changed by barley and hemp flour additions

Composite	Hemp addition (%)	R 30’ (EU)	Ex 30’ (mm)	R 60’ (EU)	Ex 60’ (mm)
(a) Composites 70:30 (w/w)					
WF	0	355^{abc}	189^{i}	450^{ab}	177^{g}
WBF30	0	340^{abc}	135g^{h}	470^{abc}	120^{ef}
WBF30 + H4	5	330^{ab}	149^{h}	470^{abc}	123^{f}
	10	300^{a}	125^{fg}	430^{a}	124^{f}
WBF30 + H5	5	373^{abcd}	124^{fg}	500^{abc}	108^{def}
	10	395^{abcd}	104^{cdef}	490^{abc}	120^{ef}
WBF30 + H6	5	433^{bcd}	121^{efg}	545^{bc}	103^{def}
	10	335^{abc}	101^{cde}	400^{a}	116^{ef}
WBF30 + H7	5	453^{cd}	107^{def}	570^{c}	99^{cde}
	10	490^{d}	136^{gh}	698^{d}	93^{cd}
(b) Composites 50:50 (w/w)					
WBF50	0	455^{cd}	93^{bcd}	545^{bc}	77^{abc}
WBF50 + H4	5	368^{abc}	90^{bcd}	458^{ab}	77^{abc}
	10	373^{abcd}	75^{ab}	413^{a}	90^{bcd}
WBF50 + H5	5	405^{abcd}	76^{ab}	573^{c}	70^{ab}
	10	445^{bcd}	76^{ab}	558^{bc}	69^{ab}
WBF50 + H6	5	398^{abcd}	72^{ab}	470^{abc}	66^{a}
	10	360^{abc}	65^{a}	390^{a}	63^{a}
WBF50 + H7	5	423^{bcd}	63^{a}	455^{ab}	62^{a}
	10	445^{bcd}	82^{abc}	485^{abc}	59^{a}

Extensigraph features: R = dough resistance, Ex = extensibility, 30’, 60’ = dough resting time in minutes, WF = wheat flour, WBF30, WBF50 = blend from wheat and barley flour 70 : 30 and 50 : 50 (w/w), respectively; hemp products: H4 = dehulled seeds wholemeal, H5 =hulled seeds wholemeal, H6 = conventional fine flour, H7 = organic fine flour

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

ing effect. In the cases of WBF30 and WBF50 blends, the ZT values were lessened to 71 and 54%, respectively. Further negative change was not dependent on hemp wholemeal, but as expected, on the portion of hemp flour included. Trends observed in the FN were unequivocally positive, barley flour fortification significantly magnified amyloses activity – both for WBF30 and WBF50, a decrease in order of 90 s was recorded (Table 1a, b). Variation caused by hemp items was insignificant with respect to measurement accuracy (± 25 s; CSN EN ISO 3093).

Farinograph properties of flour composites

During the farinograph test, wheat control showed a high WAB value, which was further increased by barley flour portions; significantly for the WBF50 only (Fig. 1). Addition of hemp wholemeals H4 or H5 had no significant impact on the WAB in comparison to the WF standard, and their higher dosage levelled the WAB determined for WBF30 (i.e. it increased softly). In contrast to this, fine hemp flour samples H6 and H7 had a uniform impact independently on portion in

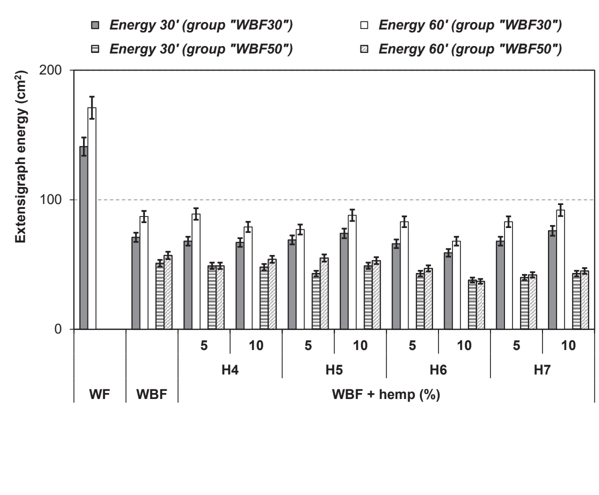

Fig. 2. Influence of barley and hemp flour on extensigraph energy of wheat dough. WF = wheat flour, WBF30, WBF50 = wheat-barley flour composite 70:30 and 50:50, respectively; H4, H5 = hemp wholemeal from dehulled and hulled seeds, H6, H7 = commercial fine hemp flour.

the composite; all WAB values were as higher to the ones recorded for composites with hemp wholemeal, so similar to the WAB of the blend WBF50.

Recipe modification was also reflected in the DDE parameter – it was changed improvably by barley flour as by additions of H4 or H5 (Table 2). Fine hemp flours prolonged that interval twice in the case of 5% of hemp in composite, and up to about 50% for 10% incorporated. The DST was reversely shortened, mainly by barley flour presence (about 50–60%). Lower amount of H4 and H5 had no verifiable effect, but their higher dosage shortened the DST again. Both tested levels of fine hemp flour varied the DST clearly; for 10% in composite, changes were unverifiable compared to wheat-barley blends, but still about 50% shorter than for the control sample.

Overmixing of wheat dough revealed out its good quality (bakery strong flour) owing to the DSF equal to 25 FU. A crucial role on dough consistency decrease was attributed to barley flour added – lower gluten net cohesiveness was recorded as 4-times higher DSF. Hemp flour did not affect the characteristic significantly; recorded oscillations were ± 10 FU against the wheat-barley composites. As could be noticed, neither hemp type nor addition level played a substantial role. Similar tendencies were found in the FQN trait – changes were comparable to wheat-barley premixes; somewhat higher was the oscillation for composites with H6 and H7 (Table 2).

Extensigraph properties of flour composites

Extensigraph test describes a machinability of the dough, comparing its resistance (elasticity) and extensibility. Both main physico-mechanical properties are dependent on dough resting time, during which dough comes relaxed by water sorption into inner structures of proteins and polysaccharides. That fact is documented well in case of the WF standard, whose R increased about 100 EU after resting for 60 min (while the Ex was varied improvably). Addition of 30% of barley flour led to the R 60′ increase comparably to WF and to diminishing of the Ex 60′ about 20%. An increase of the R to the highest value within the tested set was caused by higher proportion of barley flour in wheat composite; as well as a reduction of the Ex in the largest extent was found (Table 3).

Hemp flour combination with wheat-barley premixes had a significant impact on extensigraph elasticity (R) – its increase was dependent on hemp type and fortification level applied. Also dough resting time played a significant role as is clearly demonstrated for WBF30 composite with 10% of H7 – during 60 min of resting, recorded positive increment of resistance was about one-third, and a negative one of the E value almost to one-half (compared to 30 min resting).

Influences of four tested hemp flours on properties within WBF50 group showed a similar course as for the WBF30 ones. After 30 min of resting, the R values oscillation was attributed to hemp flour types; twofold dough relaxation time brought a higher data variation, the strongest effect was evaluated for the H5 sample. In terms of dough extensibility, its level fell verifiably affected by resting time; included hemp flour type caused an oscillation of the Ex again. As could be noticed, dough from WBF50 and H7 was shortened in the highest extent when it was rested for 60 min (Table 3).

Changes in recorded curves shape (in height and length) were also reflected in the values of E – value of the control sample increased about 20% at longer resting time (Fig. 2). Barley flour supplement lessened the E level approximately about 50% at both portions used. That destroying effect was not corrected by longer resting time neither; further fall about 20% was contrariwise determined. In correspondence to data in Table 3, samples H4–H7 did not brought about any provable change in extensigraph energy, independently on used wheat-barley premix.

Amylograph properties of flour composites

Viscosity of WF water suspension reached an optimal value, i.e. the flour sample contained common proportion of damaged starch and sufficiently active amylases as well. Supplement by BF led to the AMA decrease about 20%, and no significant impact of the substitution level was observed. Suspensions that are more viscous were determined during tri-composites testing; between the hemp wholemeals, mainly 5% of H4 one added to WBF30 had such effect. The AMA level of blends containing the H6 was comparable to

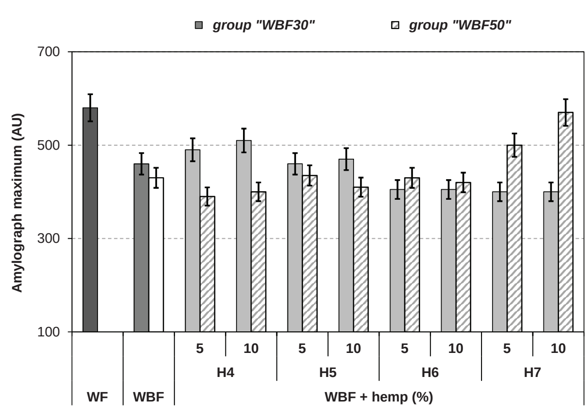

Fig. 3. Influence of barley and hemp flour on amylograph viscosity maximum of wheat flour (WF). WBF30, WBF50 = wheat-barley flour composite 70:30 and 50:50, respectively; H4, H5 = hemp wholemeal from dehulled and hulled seeds, H6, H7 = commercial fine hemp flour.

Table 4. Correlation analysis between the analytical and the rheological data

Feature	Zeleny test
R 30’	–0.15
R 60’	0.14
Ex 30’	0.78***
Ex 60’	0.79***
E 30’	0.88***
E 60’	0.90***
	Falling number
AMA	0.65**

Extensigraph features: R = dough resistance, Ex = extensibility, E = energy; 30‘, 60‘ = dough resting time in minutes; amylograph feature: AMA = amylograph maximum

**, ***relationships significant at P = 99% and 99.9%, respectively

the one recorded for wheat-barley premixes, while 10% of H7 levelled the suspension viscosity up to the control one (Fig. 3).

Correlation analysis

Evaluation of technological quality of multi-composite blends using rheological methods as the farinograph, the extensigraph, and the amylograph belongs to the precise ones, but such procedures are time-consuming besides the apparatuses price. An alternation represents a sufficiently robust and statistically verified prediction based on the quality traits measured analytically. Within tested composites set, data of the ZT and the extensigraph curve (gluten complex properties) as well as the FN vs the amylograph ones (starch properties and amylose activity) could be contrasted together. As is summarised in Table 4, correlation coefficient verifiable on P = 99.9% was calculated between the ZT and the Ex; with the same significance, a tighter relation was found between the ZT and the E parameters. In both cases, different dough resting time did not influence the relationships. Correlation coefficient between the ZT and the extensigraph energy r = 0.43 was provable on P = 99.9%.

Starch complex properties as the AMA could be sufficiently predicted according to the FN measurement (r = 0.65, P = 99.9%) (Table 4).

DISCUSSION

In terms of change in protein content, Hruskova, Svec (2014) confirmed corresponding tendencies within a set of five wheat-hemp composites – e.g. for composite containing 10% of K1 fine hemp flour, PRO increased up to about 7% and protein quality (ZT) was lowered to 80%. Addition of 5% or 10% of other non-traditional plant materials as chia or teff usually do not bring a verifiable rise in PRO (Hruskova et al., 2013), although they may contain proteins in a multiple higher level than wheat flour.

Varied protein constitution and its total content influence rheological properties of flour–water system, during the first phase of dough development at least. Combined with the presence of non-starch polysaccharides as barley beta-glucan, absorption capacity increases – during farinograph test, Hussein et al. (2013) mentioned provable rise in water absorption from 55.5 to 61.5% for wheat flour sample and its blend with 30% of wholegrain barley flour. On the other hand, identical dosage of gelatinized corn flour had a reversal effect. The authors used bakery weaker wheat flour (dough softening degree 110 FU), thus incorporation of BF had not significant effect (100 FBU). This barley flour effect was verified also by Maiya et al. (2015). Babiakova (2015) demonstrated a positive effect of chia and teff wholemeal flours on water absorption of wheat-barley blend with 30% of the latter flour as well as a reversal effect on dough softening. Non-starch polysaccharides have a great absorption capacity and they are able to compete for water with other constituents in the dough system. Nowadays, the farinograph method could be simulated by using of the Mixolab apparatus (ICC Standard No. 173 (2011). Contrasted to pure wheat flour, Apostol et al. (2015) evaluated rheological properties of five wheat-hemp bi-composites containing 5–20% of the alternative material. Due to increasing fat content, a gradual decrease in water absorption (from 61.0 to 56.0%) as well as in dough stability (from 8.97 min to 7.77 min) was recorded. At the same time, dietary fibre content increased almost ten times (1.90 vs 10.59%); according to this, rather water absorption could be presumed.

Machinability of composite dough also reflects actual dough composition, and in dependence on non-traditional plant tested, both variants (dough elasticity support – extensibility decrease vs elasticity diminishing – extensibility increase) may occur. Although the elasticity-to-extensibility ratio could not change eventually, a usual drop in total area under the extensigraph curve (i.e. in the extensigraph energy) means a worsening of baking potential of such blend. For barley flour additions up to 40%, Maiya et al. (2015) recorded increase in elasticity, and decreases in extensibility and strength of the dough in agreement with our conclusions. That effect was confirmed for croissant dough, containing 60 g fat per 100 g of wheat (or wheat-barley) flour – extensigraph parameters decreased about up to 30% as barley flour proportion increased to 30% in maximum (Shouk, El-Faham, 2005).

As BF dosage in wheat-barley premix increased, maximum of amylograph viscosity decreased from 580 AU to 460 and 430 AU for premixes WBF30 and

WBF50; the drop represents 20% and 25%, respectively. Maiya et al. (2015) observed a reversal trend, incorporation of 10–40% barley flour into wheat flour thickened the suspension by about 4–16% (from 921 to 960–1064 AU). Rise in amylograph viscosity is attributed to amylose release into solution (Symons, Brennan, 2004). For wheat-barley-hemp flour composites, a narrow range of amylograph maximum was determined (390–510 AU). An exception perhaps represents WBF50 composites including H7 specimen – recorded values are 500 and 570 AU for 5 and 10% dosages, respectively. Recently, a Rapid Visco Analyser (RVA) designed for pasting characteristics determination became to be commonly used within the European region. The RVA method renders description of pasting behaviour in detail, and corresponding curve parameters are pasting temperature and peak viscosity (viscosity maximum). As declared Ragaee, Abdel-Aal (2006), there is a possibility to distinguish wheat-barley blend prepared from hard and soft wheat flour according this method. In the former case, 15% addition of BF caused a soft peak viscosity increase (from 1335 to 1426 mPa·s), and reversely in the latter (from 2599 to 2073 mPa·s). By the RVA method, a huge spectrum of bi-composites was explored, but literature data on wheat-hemp pasting behaviour are scant. Blends were prepared both on the basis of cereal flour (e.g. wheat-chia or barley-chia, wheat-teff, wheat-chestnut flour) as well as gluten-free ones (e.g. oat-chia, brown rice-corn) with evaluation of technological potential for bread, cookies or pasta manufacturing. Yadav et al. (2014) tested wheat-chestnut blend (75 : 25 w/w, respectively), and measured values of the peak viscosity as well as six other RVA parameters, and they were comparable to the wheat flour ones. Besides pleasant sweetish taste, chestnut flour characterised by low fat content (6.0–7.0%), high percentage of MUFA and PUFA in amino-acid score (both around 40%), and high antioxidant capacity (Morrone et al., 2015) is precious food with broad technological potential.

CONCLUSION

Technological behaviour of starch and gluten proteins, the main constituents of wheat flour, was significantly modified by the addition of both barley and hemp flour, reflecting the dosage levels of the alternative raw materials (30 or 50%, and 5 or 10%, respectively). Evaluated by analytical and rheological methods, the protein quality was better from nutrition and worse from bread-making. Negative changes were related mainly to a substantial proportion of barley flour in the composites prepared. Hemp wholemeal or fine hemp flour varied quality parameters softly, but the influence of the mentioned types differed significantly. Viscous behaviour of wheat starch complex as the amylograph maximum was optimal. Viscosity was partially lowered by barley flour incorporation, but it was recovered by 10% of hemp fine flour H7. Data gained during time-consuming rheological proofs could be sufficiently predicted according to analytical features of tested composites – gluten characteristics as the extensigraph elasticity or energy according to the Zeleny test, as well as the amylograph viscosity according to the FN.

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