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FERMENTED DOUGH CHARACTERISTICS OF WHEAT-BARLEY-HEMP COMPOSITES. COMPARISON OF TWO DOSAGES OF BARLEY AND HEMP WHOLEMEAL/FLOUR

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Abstract

HRUŠKOVÁ MARIE, ŠVEC IVAN. 2016. Fermented Dough Characteristics of Wheat-barley-hemp Composites. Comparison of Two Dosages of Barley and Hemp Wholemeal/Flour. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 64(3): 803–812.

Wheat flour substitution by barley one led to shortening of fermentation and leavening times (about 14–57% and 35–83%, respectively) as well as to lessening of dough volumes (about 25–75%), based on lowered protein quality (Zeleny value). Addition of barley flour affected specific bread volume; diminishing for wheat-barley blends 70:30 and 50:50 reached 30% and 43%, respectively. Volume of bread prepared from wheat-barley blend 70:30 enhanced by dehulled hemp wholemeal was the highest within the tested tri-composites set, achieving 130% of wheat-barley control; other hemp products caused the parameter decrease (from 8 to 33%). Within a group of bakery products containing 50% of barley flour, hulled hemp wholemeal partially supressed negative effect of barley flour – specific bread volumes increased about ca 15%. Commercial fine hemp flour samples demonstrated a reversal influence – its addition resulted into lower buns size than wheat-barley control (about 3–34%). Between wheat flour and both groups of flour tri-composites, PCA confirmed differences in dough and bread technological quality. Specific bread volume could be predicted according to maturograph dough elasticity, dough or bread OTG volumes.

Keywords: wheat composite flour, barley, hemp, fermented dough, specific bread volume, principal component analysis

INTRODUCTION

Fermented dough is a complicated colloidal system built from the hydrated proteins and starch granules, fat particles and fermentation gas bubbles (Bloksma, 1990; Gujral and Singh, 1999). All dough components undergo a number of biochemical reactions, summarized as fermentation. Non-traditional crops used in cereal branch now can increase the nutritional benefit of bakery products. Barley and hemp milling products can serve for wheat flour fortification. Both recipe components are known for a specific chemical composition with higher nutrition value compared to wheat. Barley belongs to good source of pentosans, a part of soluble dietary fibre, and hemp is able to significantly enhance rates of proteins, fatty acids and dietary fibre. These nutritionally valuable components modify fermented dough properties and owing to that the wheat-barley-hemp composites could be tested with aim to predict machinery behaviour. In such case, standard rheological methods (as using farinograph and extensigraph) for the dough description and evaluation are not adequate, separation of some compound would distort its complex function due to it could be used in praxis. Empirical methods can describe state and a progress of the fermented dough system more accurately with referenced units corresponding to the technological requirements and characteristics (Autio *et al.*, 2001; Švec *et al.*, 2004). For the composite technological quality evaluation, full-formula fermented dough is mostly used. The dough properties are described separately for the each technological step by means of fermentograph, maturograph and oven rise apparatus (OTG). Baking test as a direct method for flour quality evaluation is usually performed according to internal procedure, and specific bread volume belongs to main characteristics (Hrušková *et al.*, 2006).

Barley (*Hordeum vulgare* L.), a member of the *Poaceae* family, belongs to a major cereal grain. 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 Newmans' study (2008), eating whole-grain barley can regulate blood sugar for up to 10 hours after consumption compared to whole-grain wheat, 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 FDA, barley's soluble fibre reduces the risk of coronary heart disease and can lower cholesterol. Barley also contains insoluble fibre, which reduces the risk of diabetes and colon cancer. Grain content of protein, fat and starch rates is known to be 10–12%, 1.5–1.8% and approx. 75%, respectively. Hordeins as stable protein stuff manner different behaviour in bakery technology. Starch consists of approx. 80% amylopectin and rest part forms amylose. Higher grains of elliptic shape (40 µm) participate on 90% starch content. Smaller ones (1–10 µm) are wrapping with proteins and lipids, which regulate the speed of enzymatic splitting.

Hemp (*Cannabis sativa*) is planted as two subspecies, namely ssp. *culta* a 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, also differs according to level of dehulling or defatting. Protein, fat and starch rates are known to be 30–33%, 7–13%, and approx. 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. Approx. two-thirds of hemp proteins is composed by edestin, belonging to low molecular weight globulins (Callaway, 2004). Content of 10–15% insoluble fibre (Dimić *et al.*, 2009) may be also reason for wheat flour fortification. Correspondingly to previous research (Hrušková and Švec, 2014), results of farinograph test of wheat/hemp composites show changes in dough behaviour within a stage of dough forming.

With respect to affordable references, the behaviour of cereal wheat-barley-hemp blends as fermented dough described by means of empiric rheological equipment was not published yet. Barley flour influence is tested for tens of years; recently Rieder *et al.* (2012) compared barley types and sourdough on dough rheology and quality characteristics of composite wheat bread. During manufacturing of such bread, Wang *et al.* (2013) used fine hempseed wholemeal in combination with rice flour. Radočaj *et al.* (2014) evaluated effect of hemp seed press-cake on quality of gluten-free crackers.

Aim of the presented study is to explore fermented dough prepared from cereal blends on base of wheat, barley and hemp flours, including different commonly available seed forms (wholemeal and fine) by means of empirical rheological apparatuses (fermentograf, maturograph and oven rise) and internal baking test. Statistical pattern used should reveal out relationships between single quality features and also influence of different recipe composition of partial models.

MATERIALS AND METHODS

Preparation of blends: based on commercial wheat flour produced in year 2012 (signed as WF), cereal blends were prepared by using barley fine flour and four hemp flour samples (singed as BF and H4 – H7 respectively). Two wheat flour samples WF1 and WF2 were obtained from Czech industrial mill; both were characterised as bright type (ash content max. 0.60%) with comparable protein contents 11.98% and 11.93%, respectively. Hemp fine wholemeal H4 and H5 were prepared in laboratory scale by disintegration of dehulled and hulled seeds, respectively, both bred under conventional planting regime (company Hemp Production, Chraštice, Czech Republic). Commercial hemp flour specimens H6 and H7 were of fine granulation, and the latter one was H7 of organic quality. Based on WF1 and WF2, cereal blends were mixed in ratios wheat-barley 70:30 and 50:50 (WBF30 and WBF50, respectively). To both cereal blends, 5% or 10% of the each hemp flour was added separately. In tables, codes of samples combined cereal premix with hemp type and its addition level (e.g. 'WBF30 + H6.10'); for principal components biplot, the abbreviation of wheat-barley blend WBF50 was replaced by an asterisk (e.g. H5.10 vs. H5.10*, respectively).

Analytical proofs: using factor 5.7, protein content (PRO) was determined according to the Kjeldahl's method (ČSN ISO 1871). For protein quality determination, the Zeleny test (ZT, ČSN ISO 5529) was used; amylolytic activity estimation as the Falling Number (FN) was evaluated according to ČSN ISO 3039. Analytical features were measured in duplicate, correspondingly to the mentioned Czech norms. By using of the Megazyme Assay kit, contents of soluble, insoluble and total dietary fibre were determined in wheat flour, bi- and tri-composite ones (AOAC method 991.43, abbreviations SDF, IDF and TDF, respectively). Average contents were calculated from duplicate values determined. Influence of non-traditional materials on amounts of damaged starch and mainly nutritionally important pentosans (arabinoxylans) was evaluated within the Solvent retention capacity test (AACC method 56-11, abbreviation SRC), using the sucrose and the sodium carbonate SRC (SUSRC and SCSRC, respectively).

Behaviour of fermented dough: fermented dough parameters were acquired following internal methods with the help of empirical apparatuses fermentograph (SJA, Sweden; Švec and Hrušková, 2004), maturograph and OTG (oven rise apparatus) (Brabender, Germany; Kučerová, 2002), characterising its behaviour during fermentation, leavening and the first stage of baking, respectively. The fermentograph test is represented by fermentation time T_{FER} in minutes, and final dough V_D and gases volumes V_G in fermentograph units (FeU). The dough level (also called resistance) and its elasticity (R_D and E_D in maturograph unit [MU], respectively) describe dough behaviour during the maturograph test. From the OTG record, volumes of sample at the beginning, in the 11th minute and at the end of the proof (i.e. in 22nd minute) were read out (V_0 – initial dough volume, V_{11} – sample volume, V_{22} – OTG bread volume, respectively, in OTG unit [OU]). Additionally, OTG volume rise as V_{22}–V_0 was calculated, too. Possibility of usage these apparatuses was described in our previous papers (Kučerová, 2002; Švec and Hrušková, 2004).

Baking test: baking test was performed according to the internal method of the Cereal laboratory of the UCT Prague, and laboratory prepared bread was evaluated by specific bread volume (SBV) (Hrušková *et al.*, 2006).

Statistical evaluation: by using Statistica 7.0 software (Statsoft, Tulsa, USA), multivariable dataset was processed by principal component analysis (PCA) to find the main structures in the data. To maintain clarity of variables and samples biplot built, abbreviations and codes mentioned above were applied. The scores from PCA were subjected to Tukey HSD test ($p < 0.05$) to determine significant differences among the WF and flour composites when considering all characteristics of fermented dough and specific bread volume simultaneously.

RESULTS

Analytical properties of composite: basic components WF1 and WF2, characterised by PRO and ZT (11.98% and 44 ml vs. 11.93% and 48 ml, respectively; Tab. I), have a satisfying quality for purpose of addition of alternative plant materials containing non-gluten proteins such as barley and hemp. Both FN values (317 s or 379 s, respectively) correspond to harvest year weather course; with respect to final usage for bakery product manufacturing, they are softly above the technological optimum of 250 s.

I: *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)				
WF1	0	11.98	44	317
WBF30	0	11.20	34	294
WBF30 + H4	5	11.85	29	285
	10	12.62	24	271
WBF30 + H5	5	11.71	29	282
	10	12.00	24	273
WBF30 + H6	5	12.59	27	272
	10	13.85	20	285
WBF30 + H7	5	11.95	30	289
	10	12.59	25	283
b) Composites 50:50 (w/w)				
WF2	0	11.93	48	379
WBF50	0	10.35	26	280
WBF50 + H4	5	11.11	20	269
	10	11.78	15	281
WBF50 + H5	5	11.19	23	292
	10	11.42	19	294
WBF50 + H6	5	11.65	21	301
	10	13.04	16	276
WBF50 + H7	5	10.95	21	295
	10	11.90	17	276
	Repeatability	*0.20*	*2*	*25*

WF – wheat flour; WBF30, WBF50 – blend of wheat and barley flour 70:30 and 50:50 (w/w) based on WF1 and WF2, respectively.
Hemp flour: H4 – dehulled wholemeal, H5 – hulled wholemeal, H6 – conventional fine, H7 – organic fine.

For composites WBF30 and WBF50, statistically verifiable decrease of PRO corresponding to BF addition level was evaluated. Higher portion of BF also caused broader interval of PRO measured, interacted with hemp flour recovering effect. In cases of WBF30 and WBF50 blends, the ZT values were lessened to 77% and 54%, respectively. Further negative change was not dependent on hemp wholemeal, but as expected, on portion of hemp flour included. Trends observed in the FN were unequivocally positive, WF fortification significantly magnified amyloses activity; both for WBF30 and WBF50, a decrease in order of 90 s was recorded (Tab. I). Variation caused by hemp items was insignificant with respect to measurement accuracy (±25 s, ČSN ISO 3039).

In terms of dietary fibre content, nutritional benefit of barley and hemp products was confirmed – with respect to proportion of barley flour, levels of IDF, SDF and TDF in flour composites were multiplied twice and nearly three-times (Tab. II). Compared to this, hemp products caused a minor change reflecting hemp fortification level only – tested hemp wholemeal and commercial flour types could not be distinguished one from each other. Compared to levels of SDF and TDF in WF30 composites, which have risen about 4% and 8% units for lower and higher hemp amount incorporated, a benefit in SDF reached approx. two-thirds of the mentioned values (3% and 6%, respectively). In case of blends richer in barley flour, enhancement by four hemp samples contributed mainly to increase of SDF content (approx. about 4% and 8%, respectively). The TDF level has risen in a softer extent, about 1.5 and 3.5% in case of blend with 5% or 10% of hemp.

Recorded SRC profiles revealed out rather negative impact of H4 and H5 addition, which could distinguish these tri-composites reciprocally. In terms of damaged starch content, barley flour addition as 50% of cereal premix interacted with H6 and H7 enhancement, causing the SUSRC increase about one-fifth related to WF control. The effect intensified in case of the SCSRC determination, according which subsets of WBF30 and WBF50 base could be differentiated (medians 88.0% and 100.3%, respectively).

Technological properties of composite: as is mentioned above, a fermentation process was studied in three phases corresponding to bakery

II: *Influence of hemp addition on dietary fibre content and SRC profile of wheat-barley composites*

Flour, blend	Hemp addition (%)	IDF (%)	SDF (%)	TDF (%)	SUSRC (%)	SCSRC (%)
a) Composites 70:30 (w/w)						
WF1	0	2.26	1.66	3.27	116.3	88.6
WBF30	0	4.36	2.48	6.21	111.8	95.4
WBF30 + H4	5	4.57	2.56	6.46	99.2	86.8
	10	5.00	2.63	6.72	88.4	82.1
WBF30 + H5	5	4.54	2.57	6.53	103.5	89.2
	10	4.72	2.66	6.85	91.5	83.0
WBF30 + H6	5	4.52	2.56	6.46	109.7	93.9
	10	4.68	2.64	6.72	108.5	91.2
WBF30 + H7	5	4.54	2.54	6.45	109.1	89.3
	10	4.72	2.60	6.70	106.3	86.4
b) Composites 50:50 (w/w)						
WF2	0	2.26	1.66	3.27	90.9	74.8
WBF50	0	6.35	2.59	8.52	121.1	104.0
WBF50 + H4	5	6.38	2.71	8.68	109.0	97.4
	10	6.44	2.83	8.83	92.9	91.7
WBF50 + H5	5	6.41	2.69	8.69	108.6	99.9
	10	6.48	2.78	8.87	98.8	104.6
WBF50 + H6	5	6.38	2.68	8.65	119.3	101.1
	10	6.42	2.84	8.77	119.1	100.1
WBF50 + H7	5	6.44	2.64	8.64	119.1	100.5
	10	6.51	2.68	8.77	117.1	106.1
	Repeatability	-	-	-	*0.73*	*0.67*

WF – wheat flour; WBF30, WBF50 – blend of wheat and barley flour 70:30 and 50:50 (w/w) based on WF1 and WF2, respectively.
Hemp flour: H4 – dehulled wholemeal, H5 – hulled wholemeal, H6 – conventional fine, H7 – organic fine.
IDF, SDF, TDF – insoluble, soluble and total dietary fibre content, respectively.
SUSRC, SCSRC – sucrose and sodium carbonate solvent retention capacity, respectively.

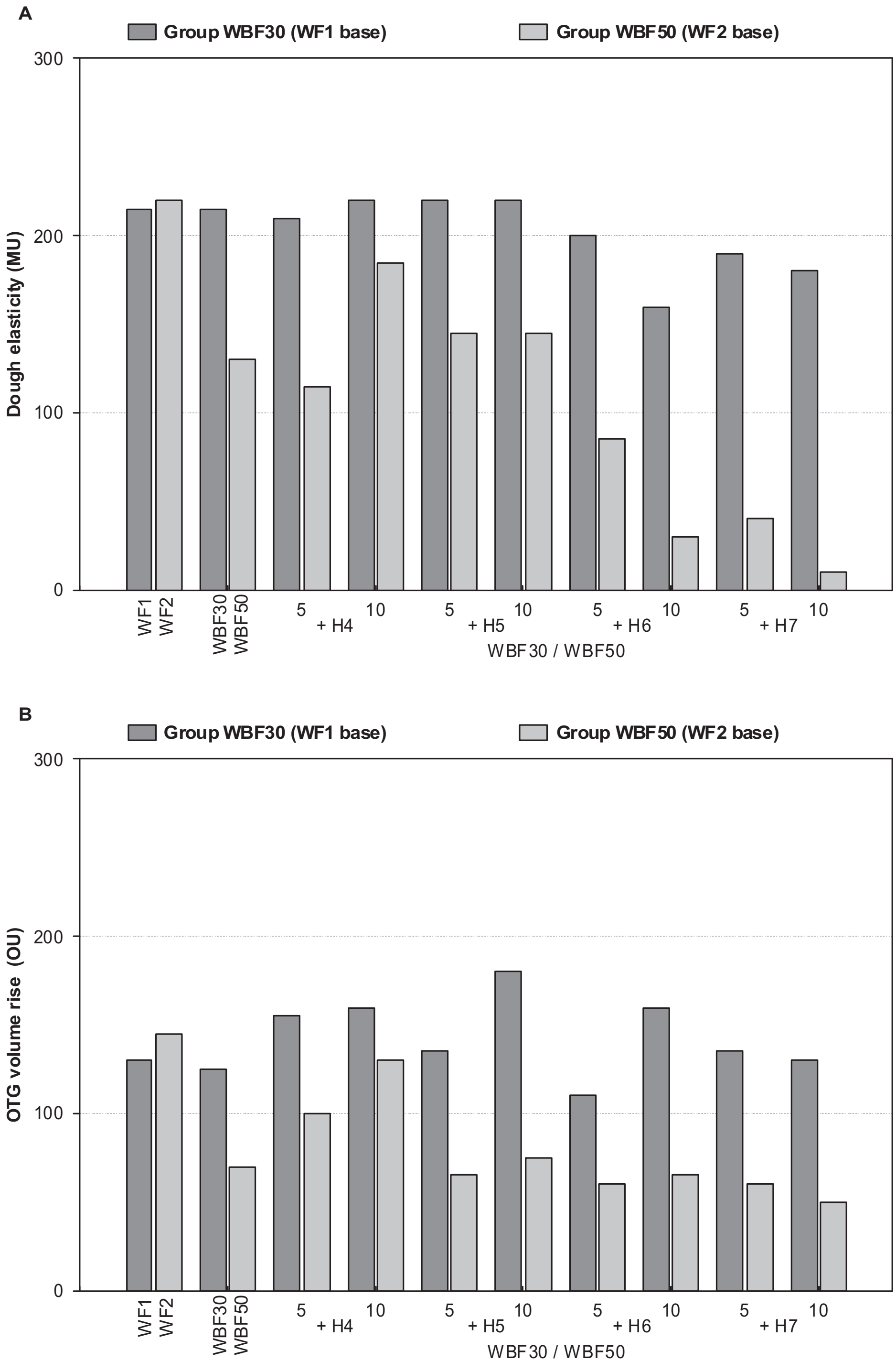
praxis. From a viewpoint of the fermentograph proof, 30% of BF addition led to the fermentation time shortening about 40%, but neither hemp type nor addition level did not demonstrate a significant effect (Tab. IIIa). In case of the WBF50 composite, observed trend was similar to the WBF30; somewhat stronger negative impact could be noticed for both fine hemp flour H6 and H7. Final dough volumes were affected in agreement with the BF portion in composite; compared to WF, the volume of WBF50 dough decreased up to one-half. Shorter fermentation time of WBF30 composite with H6 or H7 was reflected also in the final dough volume – for those samples, especially with 10% of hemp flour, a negative interaction prevailed (Tab. IIIb). Within the WBF50 group, the lowest final dough volume was recorded for the composite involving 5% of H7 (mark of equivocal impact of the tested hemp material). It could be mentioned, that recipe modification did not influenced volumes of fermentation gases, whose levels oscillated between 130–142 FeU (approx. 650–710 ml; sufficient amounts for standard fluffing up of bread; data not shown).

During the maturograph proof, dough leavening times of 34 and 60 min (WF1 and WF2, respectively) were shortened by BF (to 18 and 16 min for WBF30 and WBF50, respectively). Interacted with hemp products in recipe, leavening times fell to 12 min and 10 min in case of WBF30 and WBF50 base, respectively (mainly due to addition of H6 and H7). Repeatability determined for the dough level allows a distinguishing of WF and WBF30 blend against WBF30 composites with H6 or H7 at least (Tab. IIIa); those fine hemp flour items had the strongest negative impact (lessening to approx. 60% of standard). The finding is confirmed within the WBF50 group, in which the dough level fell up to 40% of the control by addition of H6 or H7 independently on addition level. Dough elasticity course was more or less similar within the WBF30 and WBF50 groups – as during the fermentograph test, supplement of barley flour caused elasticity decrease adequately to its proportion in composite (Fig. 1A). Addition of fine hemp flour into WBF50 base had a destroying impact on the maturograph curves course – dough level was diminished to approx. 270 MU and the elasticity values were

III: *Influence of hemp addition on fermented dough traits of wheat-barley composites*

Flour, blend	Hemp addition (%)	Fermentograph		Maturograph	Oven rise apparatus	
		Fermentation time (min)	Dough volume (FeU)	Dough resistance (MU)	Initial dough volume (OU)	Sample volume (OU)
a) Composites 70:30 (w/w)						
WF1	0	47	80	690	405	530
WBF30	0	34	59	465	320	445
WBF30 + H4	5	28	54	480	320	480
	10	34	53	520	320	490
WBF30 + H5	5	32	58	450	275	380
	10	33	50	460	280	455
WBF30 + H6	5	28	51	440	320	425
	10	28	43	400	240	360
WBF30 + H7	5	29	55	430	265	350
	10	20	43	420	220	325
b) Composites 50:50 (w/w)						
WF2	0	36	76	700	425	460
WBF50	0	31	37	365	225	275
WBF50 + H4	5	26	37	350	220	305
	10	17	30	425	270	400
WBF50 + H5	5	21	29	380	240	300
	10	23	37	380	235	330
WBF50 + H6	5	18	26	320	180	230
	10	21	24	260	190	245
WBF50 + H7	5	18	19	275	160	215
	10	18	21	240	160	230
	Repeatability	*1*	*1*	*15*	*22*	*23*

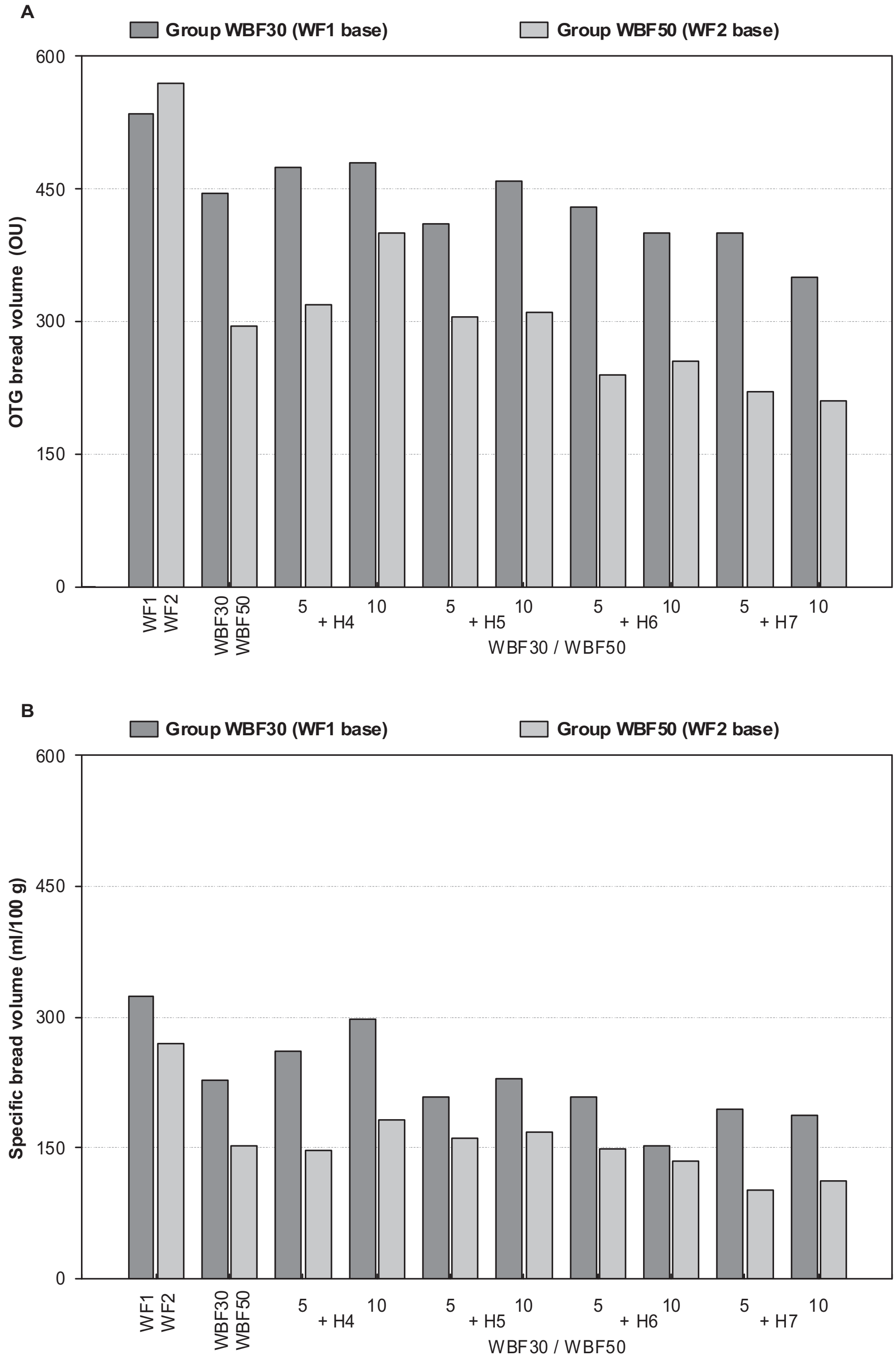
WF – wheat flour; WBF30, WBF50 – blend of wheat and barley flour 70:30 and 50:50 (w/w) based on WF1 and WF2, respectively.
Hemp flour: H4 – dehulled wholemeal, H5 – hulled wholemeal, H6 – conventional fine, H7 – organic fine.
FeU, MU, OU – fermentograph, maturograph and OTG unit, respectively.



1: *Barley and hemp flour effects on fermented dough features. A) – Maturograph dough elasticity, B) – OTG oven volume rise. WF – wheat flour; WBF30, WBF50 – wheat-barley blends 70:30 and 50:50, respectively; H4, H5 – dehulled and hulled hemp wholemeal, respectively; H6, H7 – commercial conventional and organic fine hemp flour, respectively. MU, OU – maturograph and Oven rise apparatus (OTG) units*

almost unevaluatable (e.g. 40 and 10 MU for WBF50 with 5% or 10% H7).

Volume increase of optimally fermented and leavened dough in gradually heated oil bath (oven rise record) correlates well to the maturograph dough level. Both dosages of BF decreased initial OTG dough volume correspondingly to an actual recipe tested. Within groups WBF30 and WFB50, a weaker negative effect of hemp wholemeal type was also confirmed as during the previous rheological tests (Tab. III). Mentioned data accordance as well as reciprocal distinguishing of composites with diverse



2: *Barley and hemp flour effects on bread volumes. A) OTG bread volume V_{22}, B) specific bread volume. WF – wheat flour, WBF30, WBF50 – wheat-barley blends 70:30 and 50:50, respectively; H4, H5 – dehulled and hulled hemp wholemeal, respectively; H6, H7 – commercial conventional and organic fine hemp flour, respectively. OU – Oven rise apparatus (OTG) units*

hemp types is obvious on Fig. 1B. Diminishing of oven rise caused by BF was partially compensated by H4 even in the case of the WBF50 composites, overcoming the oven rise value of the WF sample. Fat in recipe supports dough fluffing up, and the H4 sample as dehulled wholemeal has the highest fat content among tested hemp products. Those findings could be attributed also to OTG bread volumes, which course was copied by specific bread volume (Fig. 2A, 2B).

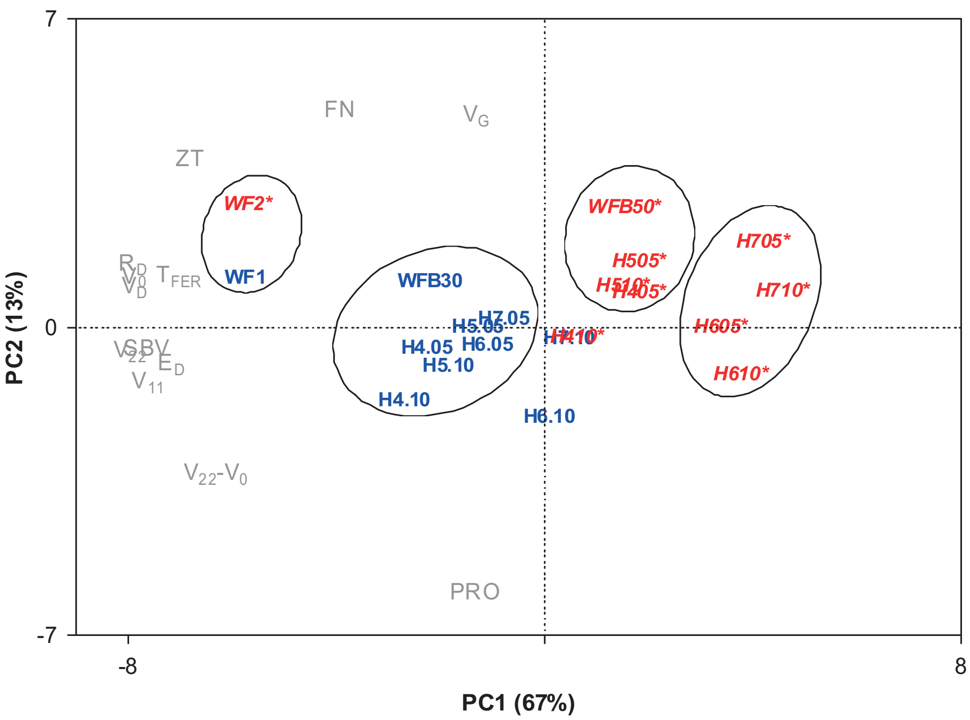
Specific bread volume: between specific bread volumes of WF1 and WF2, a significant difference was evaluated (324 and 271 ml/100 g; Fig. 2B). Addition of 30% or 50% of BF caused the parameter decrease about 30% and 56%, respectively, in higher extent understandably found for bakery weaker WF2 sample. The negative change corresponds to lower resistance to extension (elasticity) of wheat-barley dough, whose extensibility maintained approx. the same. A further negative influence followed as result of the fine flour H6 and H7 incorporation in wheat-barley flour, similarly for both tested bases (approx. 80% specific volume of WBF30 and WBF50 bread). A reversal effect was determined for tri-composites containing 10% H4, perhaps due to removed cover layer and high oil content in the wholemeal – composite bread volumes of 70:30 and 50:50 base reached 298 and 182 ml/100 g.

Principal component analysis: similar trends in determined quality characteristic of fermented dough allowed a successful exploration of data

IV: *Portion (%) of explained variability by the first three principal components (PC)*

Proof	Feature	Abbreviation	PC1	PC2	PC3
Analytics	Protein content	PRO	3	62***	9
	Zeleny test	ZT	71***	17	6
	Falling number	FN	24*	31*	31*
Fermentograph	Fermentation time	V_G	75***	1	0
	Gases volume	T_{FER}	3	28*	48**
	Dough volume	V_D	94***	0	0
Maturograph	Dough level	R_D	95***	1	1
	Dough elasticity	E_D	78***	2	8
Oven rise	Initial dough volume	V_0	94***	1	0
	Sample volume	V_{11}	88***	4	2
	Bread volume	V_{22}	96***	1	0
	Oven rise	$V_{22}–V_0$	61***	21*	5
Baking test	Specific bread volume	SBV	89***	1	0
	Total		*67*	*13*	*9*

*, **, *** – pair correlation of the feature and proper PC significant on $p < 0.05$, 0.01 and 0.001, respectively.



3: *Principal component biplot of variables (loadings) and samples (scores) in PC1 x PC2 area. WF – wheat flour, WBF30, WBF50 – wheat-barley blends 70:30 and 50:50, respectively; H4, H5 – dehulled and hulled hemp wholemeal, respectively; H6, H7 – commercial conventional and organic fine hemp flour, respectively. An asterisk (*) identifies tri-composites based on the WBF50 (i.e. WF2). Within circles, samples of statistically different PC1 group mean scores are distinguished (p < 0.05). Variable abbreviations are summarised in Tab. IV* variability by principal component analysis. Eighty-nine percent of variation was clarified by the first three principal components (PC), 67% by PC1, 13% by PC2 and 9% by PC3 (Tab. IV). Steeping values of explained variation are based on eigenvalues 8.70, 1.72 and 1.11, respectively; for the others PC, their eigenvalues were found lower than 1. As is demonstrated on variables and scores biplot (Fig. 3), the PC1 and PC2 comprise sufficient information for adequate samples discrimination. A horizontal samples sorting (along PC1) reflects protein quality (ZT), dough volumes (fermentograph, maturograph and oven rise recorder ones) and specific bread volume. Regardless to some provable differences in baking quality of WF standards, recipe modification by BF played a primary role. Lowering of those characteristic values resulted in highest distance between pair WF1-WF2 and WBF50 group. In the biplot vertical line (along PC2), protein content and quality (PRO and ZT, respectively), fermentograph gases volume V_G and partially Falling number (FN) separated cereal premixes from their blends with tested hemp products. In detail, properties of dough containing H4 or H5 were closer to ones of single WBF bases. Reversely, dough with H6 or H7 flour more or less preserved its character without respect to BF portion in composite, located aside from the others composites tested (distinctly within the WBF50 group).

Further important finding lies in quality characteristic clustering (Fig. 3). The three analytical features (PRO, ZT, and FN) could not be altered within the evaluated set; the fermentograph gases volume V_G could be predicted according to the latter analytical feature (both depend on starch physic-chemical stage and amyloses activity). Considering positions of dough level R_D and dough elasticity E_D, the former was joined to the fermentation stage (V_D, T_{FER} – fermentograph test) and initial dough volume V_0 before baking (oven rise proof). The E_D has a relationship to the volume of final bakery product – the oven rise bread volume V_{22} and the specific bread volume (SBV). Standing alone position of oven rise parameter $V_{22} – V_0$ combines a dependence on protein ability to capture and hold fermentation gases as well as on gradual evolution of these gases.

DISCUSSION

To develop a wheat flour blend applicable in praxis, containing non-traditional plant materials, its baking potential should be changed as little as possible when compared to standard. Considering future usage of such composites, their quality should be examined in possible aspects of technology, i.e. by analytical proofs, by test describing dough rheology properties and finalised by baking test.

Non-traditional plant materials usually have non-gluten character of proteins, although their total content could be multiply higher than in wheat flour. As was demonstrated for WBF30 and WBF50 mixtures enhanced by hemp, corresponding tendencies published Hrušková and Švec (2014) for wheat-hemp bi-composites – 10% of fine hemp flour K1 caused PRO increase about 7% and protein quality (ZT) lowering to 80%. Our study verified that hemp is a good source of dietary fibre, and that recipe modification could cover also gluten-free crackers (Radočaj *et al.*, 2014).

Modification in tri-composite dough behaviour during fermentation tested Wang *et al.* (2013) for wheat-hemp-rice dough during test taking 180 min. After 80 min of fermentation, volumes of dough with 15% of hemp-rice flour 20/80 and 40/60 were lower than both wheat and wheat-rice controls. Authors refer to slower increase of extensigraph resistance of tri-composite dough allowing a partial escape of fermentation gases.

The main role in specific bread volumes decrease could be attributed to barley flour; Rieder *et al.* (2012) found a similar trend for composite bread containing 40% of barley flour with amylose and normal starch. Bread volumes lessening reached 35% in relation to wheat control (350 ml and 351 ml vs. 544 ml, respectively). Using these barley flours in a sourdough form, bread volumes were statistically comparable to ones containing non-treated flour (346 mL and 320 mL, respectively). In contrast to that, Wang *et al.* (2013) evaluated comparable loaf sizes of wheat composite bread, containing always 15% of three hemp/rice mixtures 0/100, 20/80 and 40/60. Although volumes of these dough during fermentation was verifiably lower compared to control, weaker differences in their extensigraph energy supported development of similar bread volumes during baking. Increasing dosages of hemp seed oil press-cake (vs. diminishing amount of decaffeinated green tea leaves) affected shape of gluten-free crackers in terms of significant rise in samples weight and height and reversely in their diameter (Radočaj *et al.*, 2014) – a lowering of crackers volume could be presumed.

CONCLUSION

Besides a known nutritional benefit, the substitution of wheat flour by barley one alone led to worsening of fermented dough quality characteristics during three fermentation phases as well as diminishing of specific bread volume as a main characteristic of final bakery product. Dough level and dough elasticity gained during the maturograph test belong to the most affected ones. Two hemp wholemeal samples in tri-composites have partially corrected such diminishing of technological quality, mainly the one from dehulled seeds (specific bread volume increase up to about one-fifth). Two different samples of partially defatted fine hemp flour caused negative changes of a larger extent,

diminishing the specific bread volume from 228 to 188 ml/100 g and from 153 to 102 ml/100 g (30%, and 50% of barley flour in recipe, respectively), compared to wheat-barley product. A major impact of barley flour on technological quality was verified by principal component analysis – wheat flour standards were discriminated from two single groups containing wheat-barley blends 70:30 or 50:50 and their composites with 4 types of hemp products. To separate these groups, unequivocal role was attributed to protein content and quality (Zeleny test) as well as to amylase activity estimation (Falling number) and specific bread volume. Multivariate statistics also revealed out a possibility to alternate some fermented dough quality characteristics together, or to predict the specific volume of bread according to maturograph elasticity, oven rise initial dough volume and OTG bread volume.

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