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Cookie Making Potential of Composite Flour Containing Wheat, Barley and Hemp

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Abstract

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Correspondingly to addition levels, barley flour supplement changed the wheat SRC profile and rheological behaviour as expected, and positively influenced its cookie making potential. Dehulled or covered hemp seeds wholemeal flour types and commercial fine hemp flour differed in their impact on the wheat-barley SRC scores. Rheological behaviour of flour tri-composites was changed in terms of a reduction of dough tolerance to overmixing, and that fact was positively reflected in baking test results. Compared to cookies with 30% of barley flour in recipe, volumes increased significantly as a result of the fine hemp flour addition only (from 150.3 ml/100 g to 173.4 ml/100 g, i.e. +15%). Their spread ratio was worsened to the same extent, it diminished from 4.54 to 3.86. For sample counterparts containing 50% of barley flour, determined values were 138.3 vs. 153.2 ml/100 g (+11%) and 4.75 vs. 5.16, respectively. Within the cluster analysis, a tree-plot verified the similarity of both wheat flour standards as well as of both wheat-barley premixes. Further grouping was linked according to the barley flour ratio, and secondarily according to the hemp flour type tested.

Keywords: wheat composite flour; barley flour; hemp product; baking test; cookie; cluster analysis

Cookies are convenient food products consumed nearly by all levels of society. Some of the reasons for such wide popularity are varied taste, easy availability, longer shelf life and low cost among other processed foods. In the Czech Republic, cookies belong with bread forms to popular baked food accounting for nearly 10% of total bakery products.

Cookies are considered to be a concentrated food due to high contents of carbohydrates, fats and low moisture. As such, they are a substantial source of energy. From a nutritional point of view, their quality can be enhanced by including a number of ingredients in recipe. In this way, cookies have a great potential to become a good medium for providing special dietary needs. Another important aspect in designing cookies with improved nutritional status is the maintenance of a product's sensory characteristics because the consumer's acceptability remains the key factor which determines the successful application of a newly developed product (Škrbić & Cvejanov 2011). In terms of dough rheology, the process and machines used to produce cookies have to meet specific requirements to facilitate processing. Flour is a predominant ingredient in formulas and the primary determinant of spread and height, and it influences the structure and textural properties of the final product (Miller & Hoseney 1997). The presence of protein (8–11% of the composition) is necessary in order to produce cookies with a good texture. Higher protein in flour restricts the shape and sensory value of cookies. The starch certainly plays a role during baking, but from a technological point of view the position of gluten is more important (Miller & Hoseney 1997). The content of sugar and fat influences the cookie spread, which is represented by a diameter-to-height ratio. Spread in cookies is best understood by explaining the mechanism which starts in dough and continues in the oven. When the baking begins, the fat is melting, and as the process continues, the amount of sugar dissolved by water

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drives the spread. Sugar takes up water faster than gluten, so in dough with a higher sugar level there are worse conditions for gluten development and the result is lower spread (Poper *et al.* 2006). The flour properties and formulation influence the consistency of the dough to suit the required process. They also control the free water in dough and in turn the volume of the sugar solution that drives the spread during baking (Gaines & Donelson 1985).

As consumers have become more concerned about health, demand for functional foods has risen. Fortified cookie products containing a significant amount of non-traditional seeds and having acceptable sensory characteristics would be desirable.

Barley (*Hordeum vulgare* L.), namely its grain, is considered to be an excellent source of many valuable nutrients, such as soluble and insoluble dietary fibres (Březinová Belcredi *et al.* 2009), vitamin B complex, minerals, and phenolic compounds. The highest nutritional value has been associated with β-glucans, the major fibre constituents in barley. Health effects of β-glucans are suggested to lower plasma cholesterol, improving lipid metabolism, reducing glycaemic index and boosting the immune system. Numbers of experiments have shown that barley can be successfully incorporated in a vast array of products such as different types of bread, Asian noodles, bars, muffins, biscuits and cookies (Izydorczyk & Dexter 2008). A general conclusion is that the incorporation of barley, at low to moderate levels, results in products with acceptable sensory properties (Škrbić & Cvejanov 2011). Four recipes for wheat-barley cookie manufacturing (75 : 25, 50 : 50, 25 : 75, and 0 : 100 w/w, respectively) were developed by Sharma and Gujral (2014), and antioxidant, mechanical as well as sensory properties of the products were tested. They considered that 25% of barley flour in formula led to the most acceptable cookie sensory profile, but antioxidant activity and total phenolic content were found to be the lowest. The addition of chia and teff flour into two wheat-barley blends was studied in a previous work (Hrušková *et al.* 2015). Non-traditional plant materials caused a substantial gluten network dilution, contributing to higher cookie specific volumes and higher spread ratios. The extent of dough extensibility was greater compared to the partial thickening of tri-composite suspension. The characteristic flavour of barley flour was not registered in products with a lower portion of barley in recipe (30%), assuming its suppression by tasteless chia and teff flour. Typical partial aftertaste was identified in the event of a higher dosage of barley flour (50%), but final products were considered as still acceptable. Higher water content in all flour tri-composite cookies led to texture softening, i.e. to more pleasant mouthfeel during chewing and their better overall acceptability.

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

The addition of hemp seed and oil was used as functional ingredients to assess nutritional characteristics and antioxidant properties of gluten-free crackers. All samples with added hemp flour had much better nutritional qualities than the brown rice flour crackers in terms of higher protein, crude fibre, minerals, and essential fatty acid content. The nutritional value is described by significantly increased fibre content (39–249%) and decreased carbohydrate content (8.4–42.3%), compared to the basic crackers. The suggested value for the addition of the hemp oil press-cake was 20% (total flour weight) with 4 g of decaffeinated green tea leaves that would provide protein content of 14.1 g/100 g and fibre content of 8.4 g/100 g (Radočaj *et al.* 2014).

Methods for manufacturing cookies, biscuits or cones by using hemp seed were patented in 2008 (patents KR2009074421-A; KR969163-B1). The confectionery with other useful components such as milk powder and egg yolk is characterised by good taste and pleasant flavour and enables to control blood-sugar level and high blood cholesterol. Due to the hemp components it can be used for the cure of atopic dermatitis. The cake contains wheat flour with addition of honey, egg, milk powder, wheat bran and hemp powder that provide higher fibre content, and better mouthfeel than the corn natural cake (patent CN103380800-A).

Objectives of the present work were to study the effect of two barley flour dosages as well as the influ-

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ence of different hemp flour types on analytical and rheological properties of wheat flour. Bi- and tri-composite flour samples served also for the preparation of cookies on a laboratory scale, with the aim to evaluate sweet dough machinability and consumer's quality of the final products. Applying analysis of variance (ANOVA), correlation and hierarchical cluster analyses (HCA), differences between the tested recipes were evaluated statistically (P = 95%).

MATERIAL AND METHODS

Flour types. Based on commercial wheat flour produced in 2012, cereal blends were prepared by using barley fine flour and four hemp flour samples (designated as BF and H4–H7, respectively). Two wheat flour samples (WF1 and WF2) were obtained from a Czech industrial mill; both were described as white type (ash content max. 0.60%). Protein content was slightly higher in the latter one (11.98 and 12.80%), but protein quality was comparable (Zeleny sedimentation values ZT 44 ml and 48 ml, respectively). Barley flour, containing 9.23% of proteins, was supplied by the Křesín Czech mill. Hemp samples H4, H5, and H7 originated in a conventional system and H6 in an organic system, and all mentioned samples are of fine granulation. Samples H4 and H5 were prepared on a laboratory scale by disintegration of dehulled and covered hemp seeds to obtain wholemeal type products. Specimens H6 and H7 were produced industrially as by-products of hemp oil extraction (by milling the seed press-cake). The addition of hemp products to WF was aimed at improving the nutritional score of cookies, both in terms of dietary fibre (DF) and protein content increase. Data in Table 1 demonstrates many times higher contents of DF and its insoluble and soluble fractions for all non-traditional dietary fibre tested. Therefore the supposed DF content in cookies as the end product could be many times higher in comparison with wheat flour (the calculation predicts an increase of about 2.5, 0.7, and 3.6% for soluble, insoluble, and total DF at least). A higher contribution is ascribed to barley flour as the second main component.

Composite flour preparation. Based on WF1 and WF2, cereal premixes were prepared at wheat-barley ratios 70 : 30 and 50 : 50 (designated as C3000 and C5000, respectively). To both cereal blends, 5% or 10% of each hemp flour was added separately. In abbreviations of tri-composite blends, the code of the cereal premix (C3000, C5000) is combined with the type of hemp flour (4 = H4, 5 = H5, 6 = H6, 7 = H7) and its addition level (05 = 5%, 10 = 10%), respectively. Summarised, the code C3405 identifies a tri-composite flour based on the premix C3000, containing H4 as 5% addition, or C5710 is the composite based on C5000 with H7 in an amount of 10% on the premix base.

In total, the quality of WF1 and WF2, 2 premixes and 16 flour tri-composites was evaluated in relation to the quality of cookies within a laboratory baking trial. Due to the consecutive purchase of hemp samples during the year 2012, the evaluation of BF and hemp influence on wheat flour quality characteristics was conducted in two steps. The first set involved wheat flour WF1, BF and hemp samples H4 and H5; for the following analyses, samples WF2, BF, H6 and H7 were employed. Samples divided into two blocks explain a partial difference in WF1 and WF2 baking quality.

Flour and flour composite analytical quality. Chemical composition of the tested composites was determined in terms of protein content (PRO) according to the ČSN ISO 1871 method; their technological quality was evaluated by the Zeleny sedimentation test (ZT – ČSN ISO 5529). Determination of the Solvent Retention Capacity profiles (SRC – AACC method 56-11) allowed an assessment of proportional changes in the chemical composition of wheat-barley premixes; the procedure repeatability (standard deviations) 0.287, 0.811, 0.672, and 0.871% was determined separately for the water, sucrose, sodium carbonate and lactic acid SRC (WASRC, SUSRC, SCSRC, and LASRC, respectively).

Flour and flour composite rheological properties. The influence of non-traditional plant materials was tested during rheological proofs, employing the Farinograph, Extensigraph and Amylograph apparatuses (Brabender GmbH., Duisburg, Germany) in accordance with the standards ČSN ISO 5530-1, ČSN ISO 5530-2, and ICC 126/1. The above-mentioned tests were carried out in single measurements, and the feature repeatability is shown with data in tables. Due to an adequate expression of the effects of BF and hemp components, the proofs are represented by water absorption, mixing tolerance index, and amylograph maximum viscosity (WAF, MTI, and AMA). Extensigraph elasticity-to-extensibility ratio and energy (ERA 30 and EEN 30), determined after 30 min of dough resting, were used as supplementary variables for the hierarchical cluster analysis only (data not shown).

Sweet dough preparation and baking procedure. Cookies were prepared according to an internal method of the Cereal Laboratory [based on the book edited by

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Kulp (1994)], using the basic formula of 300 g wheat flour (wheat-barley premix or premix plus 15 g or 30 g of non-traditional flour), 30 g fine granulated sugar, 10 ml sunflower oil, 4.5 g baking powder ($NaHCO_3$ of analytical grade), 1.8 g salt (NaCl, analytical grade), 0.15 g ascorbic acid (analytical grade) and distilled water. Dry substances were homogenised together for 10 min in the farinograph kneader, then oil was added and the blend was mixed for 1 min; finally, a water amount necessary to reach the consistency of 600 Brabender units (BU) was titrated from a burette (registered as water absorption of baking test – WAB). Properly developed dough was obtained after 3 min mixing on the target consistency. Dough resting took 30 min in a fermentation chamber (30°C, relative humidity 95%). Dough mass was split into halves and a plate 5 mm thick was formed, using a wooden rolling pin and special desk sprinkled by flour to eliminate dough affixing. Cookies were cut out with a metal circle cutter of 55 mm in diameter and placed onto a baking sheet. Besides, two pairs of raw cookies were evaluated in terms of the specific volume of raw cookies (SVR, volume measurement by the rapeseed displacement method). Without pre-steaming, baking 15 min long was performed in a laboratory oven preheated to 180°C. Baked products were transported onto a filter paper sheet to cool for 10 min at ambient temperature; cookie characteristics were examined immediately after it. Specific volume of baked cookies (SVB) was determined for a triple of sample pairs. Cookie height and diameter were determined with a slide ruler (calliper) to evaluate the spread ratio (diameter-to-height, SPR). Both diameter and height were measured three times and an average value was calculated. Without any delay, three trained persons quantified the sensory profile of the just prepared product (firstly each alone and then they made a final agreement), distinguishing six attributes as follows:

– Colour: pale – standard – dark;
– Aroma: acceptable – typical – strange;
– Taste: acceptable – typical – strange;
– Consistency: hard – standard – melting;
– Stickiness: crumble – none – sticky;
– Overall acceptability: acceptable – pleasant – unacceptable.

Due to the small number of panellists, results of the sensory analysis have an informative character only.

In statistical analyses, the descriptors were quantified on a point scale 1–2–3, with inter-point categorisation allowed – e.g. colour/taste 2.5 meaning semi-dark shade/soft strange aftertaste). A graphical table was developed for a general overview of the sensory profile of cookies as affected by the recipe formulation.

Multi-factor statistical analyses. Considering barley and hemp flour and their dosage levels the multiple-factor HSD test (ANOVA, P = 95%) was carried out, using the Statistica v. 7.1 software (StatSoft Inc., Tulsa, USA). In total, 21 variables (6 analytical, 5 rheological, 4 qualitative ones, and 6 sensory attributes) and 20 cases were also processed by the hierarchical cluster analysis (HCA) to find relations between quality descriptors of tested materials on the one hand and recipe modification on the other. Within both cases, the most precise difference was reached using Euclidean squared distance metrics and Ward's clustering algorithm. Due to different scales of the features, data was automatically standardised before tree-plotting (dendrogram construction). The tightness of relationships between the features of recorded quality was also particularised by correlation analysis (P = 95%).

RESULTS AND DISCUSSION

Blend chemical composition. The addition of a hemp constituent into wheat-barley premixes partially recovered a PRO decrease that occurred due to the BF presence in the flour composite (Švec & Hrušková 2015). A stronger impact was confirmed by ANOVA for commercial hemp flour H6 and H7, reflecting defatting treatment of seeds (variance a–g vs. a–e between sample C5605–C5710 and C5405–C5510 foursomes, respectively).

The baking quality of protein, evaluated by the ZT, was clearly lowered by the addition of both non-traditional flours (Table 2), up to about 66% maximally. The higher the ratio of WF substitution, the greater the statistically significant fall was recorded, demonstrating the inclusion of non-gluten lower molecular weight proteins. According to ANOVA results, addition levels of barley and hemp flour play a significant role.

The SRC profiles of both control WF differed significantly in the WASRC and the SCSRC (P = 95%, Table 2). Compared to the profile of the Czech wheat flour used for the preparation of analogous tri-composites involving chia and teff (59.6, 97.7, 77.0, and 119.3% for WASRC, SUSRC, SCSRC, and LASRC, respectively; Hrušková *et al.* 2015), both WF1 and WF2 differed mainly in the LASRC values.

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Table 1. Dietary fibre content in flour composite constituents

Flour	IDF (%)	SDF (%)	TDF (%)
WF	2.26	1.66	3.27
BF	10.12	3.65	14.21
H4	8.49	4.02	11.92
H5	8.01	4.29	12.63
H6	7.53	4.08	11.28
H7	7.99	3.63	11.09

WF – wheat flour, BF – barley flour; H4, H5 – dehulled and covered hemp seeds wholemeal flour, H6, H7 – commercial defatted fine flour samples (conventional and organic; IDF, SDF, TDF – insoluble, soluble, and total dietary fibre content, respectively

All three above-mentioned standards were comparable with the SRC profiles of 19 European wheat flour samples (Duyvejonck *et al.* 2012). Barley β-glucans and arabinoxylans are categorised among hydrocolloids supporting the WASRC and SCSRC increase mainly for WF2 in premix C5000 and its hemp counterparts. A trend of import could be found during the SRC testing of tri-composite samples, hemp products did not vary in the WASRC seriously (Table 2). Laboratory treatment of H4 and H5 samples contributed to a moderate extent of starch damage, hence a range of the SUSCR of blends containing the hemp wholemeal flour was about one tenth lower compared to that of the samples with commercial hemp flour. Diminishing of protein quality screened by the Zeleny test was confirmed by the LASRC, where the effect of BF and hemp flour negatively interacted, causing a drop of about 40 units in total. From a statistical point of view, only WASRC and SCSRC could be considered as dependent on the flour blend composition (variation a–g and a–l, respectively; Table 2).

Table 2. Solvent retention capacity profiles of tested flour composites

Flour, flour composite	PRO (%)	ZT (ml)	WASRC (%)	SUSRC (%)	SCSRC (%)	LASRC (%)
WF1	11.98^{bcde}	44^{j}	66.0^{b}	116.3^{a}	88.6^{de}	148.3^{d}
C3000	11.28^{abc}	33^{i}	68.7^{ef}	61.8^{a}	95.4^{gh}	123.6^{bcd}
C3405	11.88^{bcde}	28^{ghi}	68.3^{def}	99.2^{a}	86.8^{d}	95.9^{ab}
C3410	12.66^{def}	23^{cdefg}	66.2^{bc}	88.4^{a}	82.1^{b}	79.9^{a}
C3505	11.76^{bcd}	28^{ghi}	67.6^{cde}	103.5^{a}	89.2^{de}	101.5^{abc}
C3510	12.16^{cdef}	23^{cdefg}	67.0^{bcd}	91.5^{a}	83.0^{bc}	86.8^{a}
C3605	12.62^{def}	26^{fgh}	69.1^{fg}	109.7^{a}	93.9^{fg}	94.7^{ab}
C3610	13.89^{g}	19^{abcd}	68.7^{ef}	108.5^{a}	91.2^{ef}	84.9^{a}
C3705	11.99^{bcde}	29^{hi}	66.4^{bc}	109.1^{a}	89.3^{de}	98.2^{ab}
C3710	12.65^{def}	24^{defgh}	66.2^{bc}	106.3^{a}	86.4^{cd}	84.5^{a}
WF2	12.80^{ef}	48^{j}	41.5^{a}	90.9^{a}	74.8^{a}	125.1^{bcd}
C5000	10.40^{a}	25^{efgh}	70.5^{g}	121.1^{a}	104.1^{kl}	133.6^{cd}
C5405	11.10^{ab}	19^{abcd}	69.1^{fg}	109.0^{a}	97.4^{hi}	92.1^{ab}
C5510	11.85^{bcde}	14^{a}	67.6^{cde}	92.9^{a}	91.7^{ef}	88.6^{a}
C5505	11.25^{abc}	22^{cdef}	68.7^{ef}	108.6^{a}	99.9^{ij}	91.6^{ab}
C5510	11.44^{bc}	18^{abc}	67.0^{bcd}	98.8^{a}	104.6^{l}	85.6^{a}
C5605	11.71^{bcd}	20^{bcde}	70.3^{g}	119.3^{a}	101.1^{jk}	91.0^{ab}
C5610	13.07^{fg}	16^{ab}	70.5^{g}	119.1^{a}	100.1^{ij}	88.7^{a}
C5705	11.00^{ab}	20^{bcde}	67.4^{cbde}	119.1^{a}	100.5^{ij}	88.7^{a}
C5710	11.96^{bcde}	16^{ab}	68.3^{def}	117.1^{a}	106.1^{l}	85.2^{a}
Repeatability	0.20	2.0	0.287	0.811	0.672	0.871

WF – wheat flour; C3000/C5000 – wheat-barley premixes 70:30 and 50:50 (w/w); tri-composite C3405 consists of C3000 premix, and H4 hemp wholemeal as 5% on a premix base; PRO – protein content (f = 5.7); ZT – Zeleny sedimentation test; WASRC, SUSRC, SCSRC, LASRC – water, sucrose, sodium carbonate, and lactic acid solvent retention capacity; $^{a–l}$column means designated by the same letter are not statistically different (P = 95%)

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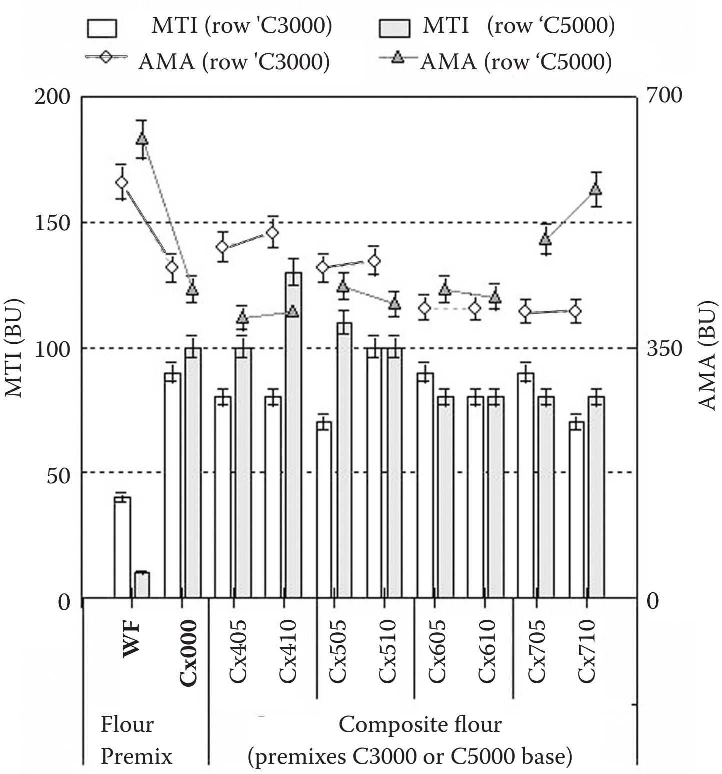

Figure 1. Influence of flour blend composition on rheological properties

MTI – mixing tolerance index (degree of dough softening, farinograph proof); AMA – maximum viscosity (amylograph proof); BU – Brabender unit; for abbreviations of samples see Table 2 (x = 3 or 5)

Rheological behaviour of non-fermented dough. The farinograph and the amylograph representative features demonstrated a reciprocal negative dependence, noticeable principally for wheat controls and tri-composites C5705 and C5710 (Figure 1). According to the MTI (40 and 10 BU) and the AMA levels (580 and 640 BU, respectively), both controls WF1 and WF2 could be considered as bakery strong flour with amylase activity close to the optimum (the MTI empirically less than 50 BU and the AMA between 200 and 600 BU). In terms of the better cookie shape development, data variance shows a positive impact of barley flour – MTI was increased twice and AMA diminished to 460 and 430 BU for C3000 and C5000 samples, respectively. For the 4 hemp types tested, the influence of the hemp addition level prevailed over the hemp type alone; among samples, partial differentiation could be observed between laboratory prepared and commercial hemp flour. With respect to measurement accuracy, subsets based on C3000 and C5000 premixes could be statistically distinguished from both wheat flour samples only. Within an analogous tri-composite set, chia enhancement of WF led to a twofold increase of the MTI level at least (Hrušková *et al*. 2015). Alaunyte *et al*. (2012) presented a comparable medium-strong reduction of tolerance to overmixing for wheat flour and its mixture with 10% of teff flour (61.7 and 108.3 BU). Further, the RVA test of wheat-teff 90:10 blend showed different behaviour – the alternative flour added had an insignificant effect on viscosity (48.97 units for wheat flour, 49.58 units for the composite).

Baking test results. During the sweet dough preparation, WF1 and WF2 reached similar WAB levels (55.4 and 54.0%). According to results published by Hrušková *et al*. (2015), those values were significantly lower than that in the wheat-barley-chia set (decrease about 6%). For 19 European commercial wheat flour samples, somewhat higher WAB (mean 59.8%) reflects the standard performance of the farinograph test, using a flour-water system (Duyvejonck *et al*. 2012). The addition of barley flour did not influence the amount of added water insofar as expected, only in the case of the composite C5000 the WAB rose about 2.1% (Table 3). With the exception of the sample C3605–C3710 foursome, a lower volume of water was needed to reach the target dough consistency by hemp supplemented premixes. The lower water-binding capacity of hemp wholemeal H4 and H5 specimens could result from the oil presence in flour. During the preparation of extruded energy bars, Norajit *et al*. (2011) observed a similar effect for 20, 30, and 40% of hemp powder added into rice flour, both for defatted and whole hemp powder types. They attributed a decrease in the used water amount to a reduction of the starch degradation rate.

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Table 3. Physical parameters of composite cookies in raw and baked form

Flour, flour composite	Raw biscuits		Baked biscuits		
	WAB	SVR	SVB	SPR (–)	SPR (% of control)
WF1	55.4[gh]	69.8 ± 5.60[abcd]	136.4 ± 1.378[a]	4.11 ± 0.28[abc]	100[ab]
C3000	55.4[gh]	94.7 ± 3.77[cd]	150.3 ± 2.870[abcd]	4.54 ± 0.14[abc]	110.66 ± 5.5[ab]
C3405	51.0[d]	65.8 ± 0.66[ab]	153.2 ± 7.129[abcde]	4.32 ± 0.29[abc]	105.60 ± 9.2[ab]
C3410	46.6[a]	74.1 ± 1.68[abcd]	154.5 ± 1.352[abcde]	3.92 ± 0.18[ab]	95.52 ± 3.7[ab]
C3505	51.0[d]	76.1 ± 7.10[abcd]	154.3 ± 3.779[abcde]	3.76 ± 0.12[ab]	91.75 ± 4.5[a]
C3510	48.0[b]	77.0 ± 8.32[abcd]	169.1 ± 1.772[cdef]	4.32 ± 1.13[ab]	106.94 ± 14.0[ab]
C3605	58.0[i]	86.6 ± 7.81[abcd]	168.8 ± 2.443[cdef]	3.76 ± 0.20[ab]	92.12 ± 10.9[a]
C3610	58.0[i]	73.3 ± 1.21[abcd]	178.0 ± 4.736[ef]	3.95 ± 0.46[ab]	96.90 ± 14.6[ab]
C3705	57.5[i]	67.8 ± 7.26[abc]	149.9 ± 6.029[abcd]	4.94 ± 0.42[abc]	120.78 ± 13.6[ab]
C3710	57.2[i]	79.8 ± 5.88[abcd]	185.7 ± 2.996[f]	3.73 ± 0.22[a]	91.08 ± 6.6[a]
WF2	54.0[f]	65.2 ± 2.46[a]	144.2 ± 3.485[abc]	4.11 ± 0.14[abc]	100[ab]
C5000	56.1[h]	92.4 ± 0.34[bcd]	140.8 ± 5.196[ab]	4.75 ± 0.15[abc]	115.83 ± 7.3[ab]
C5405	54.0[f]	92.0 ± 0.85[abcd]	163.7 ± 7.589[bcdef]	5.33 ± 0.12[c]	129.72 ± 2.2[ab]
C5510	50.0[de]	86.6 ± 5.00[abcd]	166.1 ± 2.250[bcdef]	4.68 ± 0.19[abc]	114.06 ± 6.9[ab]
C5505	50.0[c]	88.7 ± 7.32[abcd]	163.6 ± 7.698[bcdef]	4.88 ± 0.23[abc]	118.72 ± 2.8[ab]
C5510	47.5[ab]	96.3 ± 2.20[d]	173.8 ± 9.282[def]	3.93 ± 0.16[ab]	95.83 ± 6.8[ab]
C5605	54.5[fg]	83.0 ± 0.11[abcd]	149.9 ± 5.891[abcd]	5.27 ± 0.12[c]	128.19 ± 5.2[ab]
C5610	54.5[fg]	92.8 ± 2.32[bcd]	150.7 ± 9.454[abcd]	5.04 ± 0.24[bc]	122.91 ± 9.8[ab]
C5705	52.2[d]	85.6 ± 2.52[abcd]	157.2 ± 4.376[abcde]	5.39 ± 0.28[c]	131.12 ± 5.8[b]
C5710	51.5[de]	93.6 ± 5.66[cd]	149.8 ± 2.290[abcd]	4.52 ± 0.07[abc]	109.93 ± 4.9[ab]

For sample abbreviations see Table 2; WAB – water absorption – baking test (repeatability 0.19%); SVR – specific volume of raw cookie; SVB – specific volume of baked cookie; SPR – spread ratio (diameter-to-thickness ratio); [a–f]column means designated by the same letter are not statistically different (*P* = 95%)

With respect to similar ANOVA results, the volume of raw cookie pieces (SVR) showed a dependence on WASRC, SCSRC, AMA, and MTI characteristics. Apart from protein viscoelastic properties, water absorption ability and pentosan proportion might have an effect on dough cohesiveness during mixing, its machinability and on ease to hold a designed cookie shape. Loosened protein skeleton and swelled starch of lower viscosity mainly of C5000 based tri-composite dough allowed a greater spread of cookies. However, there were comparable rises of cookie volumes in raw and baked stages (approx. 20–30 ml/100 g), only the SVB variation pointed to a partial diverse impact of the types of wholemeal and fine hemp flour. It is interesting that better volume of cookies with 30% BF was supported by fine hemp flour, while the trend in the C5000 subset was opposite. Chia and teff flour addition into analogous wheat-barley premixes caused a comparable increase in the SVB, from 156 ml/100 g to 172 ml/100 g and from 164 ml/100 g to 194 ml/100 g for tri-composite cookie containing 30 and 50% of BF, respectively (Hrušková *et al*. 2015).

The consumer quality of pure wheat cookies was characterised by lower SPR (4.11), corresponding to the highest thickness within the sample set. As mentioned above, proteins of good baking quality (with higher elasticity) did not allow the cookie spread in diameter. Hrušková *et al*. (2015), as well as Škrbić and Cvejanov (2011), mentioned a slightly lower SPR in the wheat-barley-chia/teff collection (SPR 3.17 and 3.39, respectively). All values are approx. half compared to results published by Gupta *et al*. (2011), Khouryieh and Aramouni (2011) or Duyvejonck *et al*. (2012) (the SPR from 7.69 to 11.15), reflecting different formulas and mixing procedures used on the one hand and higher protein quality (ZT) of WF1 and WF2 on the other.

For the cookie shape, the observed tendency could be considered as rather negative in relation to the product volume – in the C5000 group, somewhat higher SPR was calculated for cookies described

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Table 4. Sensory profile of baked cookies prepared from flour composites

Flour, flour composite	Colour 1 pale	Colour 2 standard	Colour 3 dark	Colour Variance	Aroma 1 acceptable	Aroma 2 typical	Aroma 3 strange	Aroma variance	Taste 1 acceptable	Taste 2 typical	Taste 3 strange	Taste variance	Consistency 1 hard	Consistency 2 standard	Consistency 3 melting	Consistency variance	Stickiness 1 crumble	Stickiness 2 none	Stickiness 3 sticky	Stickiness Variance	Overall acceptability 1 acceptable	Overall acceptability 2 pleasant	Overall acceptability 3 unacceptable	Overall acceptability Variance
WF1				c				b				b				b				a				b
C3000				c				b				b				b				b				b
C3405				c				b				a				c				b				a
C3410				c				b				b				c				b				b
C3505				b				b				c				b				b				c
C3510				b				c				c				c				b				c
C3605				c				a				b				b				b				b
C3610				d				a				c				b				b				c
C3705				a				b				b				b				a				c
C3710				b				b				c				b				b				c
WF2				c				b				b				b				a				b
C5000				c				b				b				b				b				b
C5405				c				b				b				b				b				b
C5510				c				b				b				b				b				b
C5505				c				b				c				b				b				b
C5510				c				b				d				a				a				c
C5605				c				b				b				c				b				b
C5610				b				b				b				c				b				b
C5705				c				c				c				b				a				a
C5710				c				c				c				b				a				a

For sample codes see Table 2; a–c = column means designated by the same letter are not statistically different (P = 95%)

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by lower SVB (averages 4.78 and 167.90 ml/100 g vs. 5.16 and 153.28 ml/100 g for sample foursomes C5405–C5510 and C5605–C5710, respectively; Table 3). Expressing the SPR in relation to the control (Nanditha *et al.* 2009), some information about the recipe modification on the cookie shape was lost; but diversity of samples based on the C5000 premix is highlighted (Table 3).

The sensory character of pure H4–H7 flour differs basically in relation to the raw material form and its treatment. Both wholemeal H4 and H5 have greyish shade and sweet oily taste; the pleasant mouthfeel of covered seeds wholemeal H5 cookies was partially diminished by the presence of hard outer shell particles. The tint of commercial fine flours H6 and H7 was middle-brown cocoa powder alike, and their flavour was slightly bitter in taste. With respect to hemp addition levels, cookie sensory profiles were moderately changed in all six attributes. With a somewhat higher frequency, half-point shifts could be observed in the C3000 subset (Table 4). The hemp wholemeal flour enhancement of cookies has a potential to mask characteristic BF flavour, and the occurrence of dark points in the surface of covered hemp seeds wholemeal cookies could contribute to higher product attractiveness. In combination with fine hemp flour, a higher portion of BF in recipe resulted in the worsened overall acceptability of baked pastry.

Statistical analysis. Tree-plots were constructed for recorded parameters and blend composites/recipe variants separately (Figure 2). Formed groups of determined quality features and sensory attributes demonstrated a great deal of reciprocal interchangeability, showing the results of correlation analysis in a different way. A triple ZT-EEN 30-LASRC covers unambiguously protein quality. A pair WASRC-SCSRC influenced MTI and ERA 30 parameters and all four mentioned features contributed to the volume of raw cookies and shape of baked ones (SVR and SPR, respectively; Figure 2A). Similar evaluation of relationships between quality parameters can be seen in a correlation matrix (Table 5). For recorded quality parameters of cookies (described by SPR, SVB), 8 out of 13 relations were significant at the level $P = 95\%$ (r from −0.45 to −0.64). Similar association of characteristics was observed in the PC1 × PC2 loadings plot in our previous study of cookie quality prepared from wheat, barley and chia or teff flour (Hrušková *et al.* 2015).

Statistical closeness of the quality of both wheat controls was approx. 80%, and their substitution by 30% or 50% resulted in a tighter relationship of wheat-barley premixes C3000 and C5000 (Figure 2B). Tri-composite clusters were created according to a barley flour portion, equalizing them into couples of 8 members in each (C3405-C3710 and C5405–C5710). Hemp type H6 only demonstrates a statistically stronger influence on the composite flour and cookie quality, because samples C3605–C3610 and C5605–C5610) were joined together with similarity over 85%. Based on this finding, both

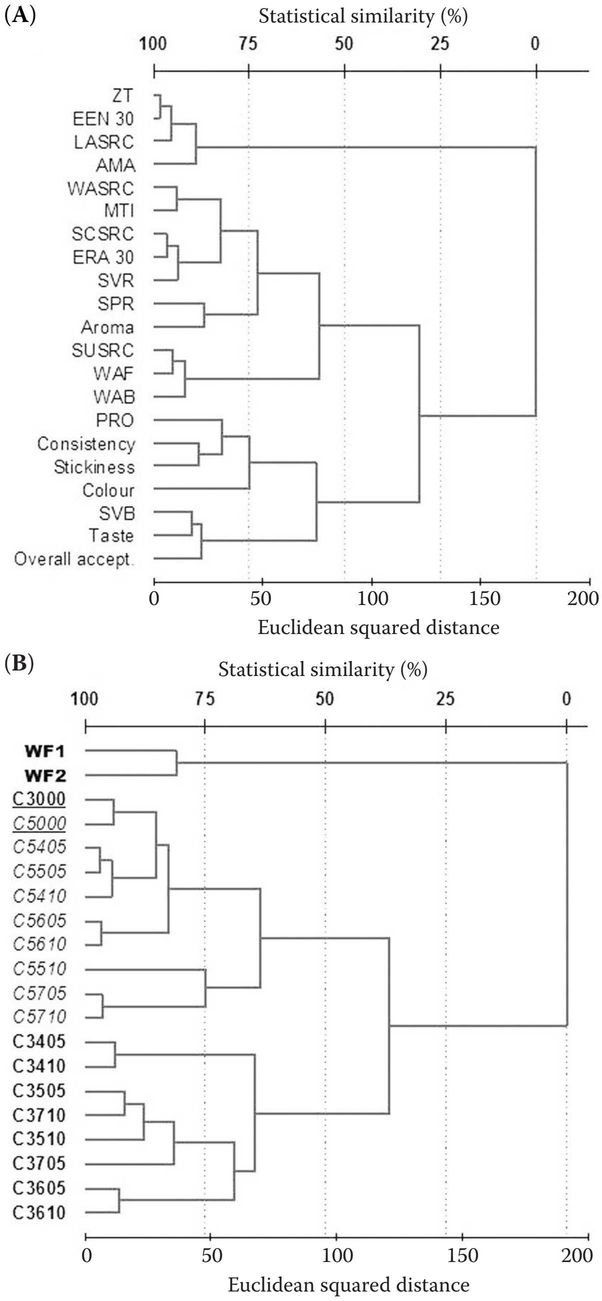

Figure 2. Cluster analysis of recipe modification effect: (A) dendrogram of variables and (B) dendrogram of samples. For abbreviations of variables and samples see Tables 2–5

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Table 5. Results of correlation analysis (P = 95%)

	Cookie overall acceptability	SPR	SVB	SVR	WAB	AMA	EEN 30	ERA 30	MTI	WAF	LASRC	SCSRC	SUSRC	WASRC
PRO	ns	−0.50	ns	ns	ns	ns	ns	ns	ns	ns	ns	−0.51	ns	ns
ZT	ns	ns	−0.50	−0.59	ns	0.63	0.93	−0.67	−0.77	ns	0.87	−0.60	ns	−0.67
WASRC	ns	ns	ns	0.48	ns	−0.65	−0.74	0.45	0.71	ns	ns	0.62	0.47	
SUSRC	ns	0.49	ns	ns	0.57	ns	ns	0.55	ns	0.77	ns	0.71		
SCSRC	ns	0.50	ns	0.82	ns	ns	−0.72	0.84	0.50	0.53	ns			
LASRC	ns	ns	−0.64	ns	ns	0.52	0.77	−0.50	−0.57	ns				
WAF	ns	ns	ns	ns	0.74	ns	ns	0.56	ns					
MTI	ns	ns	ns	0.56	ns	−0.74	−0.80	0.48						
ERA 30	ns	0.48	ns	0.67	ns	ns	−0.73							
EEN 30	ns	−0.46	ns	−0.64	ns	0.66								
AMA	−0.45	ns	−0.58	ns	ns									
WAB	ns	ns	ns	ns										
SVB	0.47	ns												

PRO – protein content; ZT – Zeleny test value; WASRC, SUSRC, SCSRC, LASRC – water, sucrose, sodium carbonate and lactic acid solvent retention capacity, respectively; WAF – water absorption (farinograph); MTI – mixing tolerance index (degree of dough softening); ERA – extensigraph ratio (elasticity-to-extensibility); EEN – extensigraph energy; 30 – dough resting time (in minutes); AMA – amylograph maximum viscosity; WAB – recipe water addition (water addition during cookie preparation); SVR, SVB – specific volume of raw and baked cookies, respectively; SPR – spread ratio (diameter-to-height); cookie overall acceptability – representative feature of final product sensory score, covering cookie colour, aroma, taste, consistency, and stickiness during mastication; ns – not significant

hemp type and hemp addition level had a similar weight in tri-composite sample clustering.

CONCLUSION

The addition of hemp wholemeal flour into two wheat-barley flour premixes increased protein content and lowered their quality, as it is suitable in the case of cookie manufacturing. Owing to SRC profile measurement, partial changes occurred in the polysaccharide complex composition, reflected in the rheological behaviour of evaluated mixtures. During the farinograph proof, barley flour caused primary gluten network weakening as presumed – tolerance to overmixing (MTI) of wheat flour was reduced from ca 25 BU to 100 BU for both composites containing 30% or 50% of barley flour. Further, dough weakening occurred as a result of hemp product incorporation. Interaction with higher barley flour dosage, flour composites with wholemeal and fine hemp flour type could be distinguished from one another (average MTI 110 and 80 BU). From a practical point of view, amylograph records showed comparable viscosity of wheat flour control, wheat-barley blend and tri-composite samples (e.g. 580, 460, and 400–510 BU, respectively, for the set with 30% of barley flour). The incorporation of barley and hemp gave a significant effect towards higher specific volume and spread ratio of baked cookies. Sensory profiles of wheat-barley cookies were almost comparable with the control, partial stickiness occurred only in both cases of barley flour application. The quality of cookies containing 30% of barley flour in recipe was improved by commercial fine hemp flour. On the other hand, the sensory profile of cookies with 50% of barley flour in recipe was improved by hemp wholemeal flour. Somewhat strange taste was registered for products containing 10% of covered seeds wholemeal hemp flour – firm particles (disintegrated outer shells) were identified during chewing. The fine hemp flour was identified in cookie taste according to bitter aftertaste. Clustering analysis confirmed qualitative differences

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between wheat flour, wheat-barley blends and flour tri-composites, which were primarily caused by different barley flour portions and secondarily according to the type of hemp sample tested.

References

Alaunyte I., Stojceska V., Plunkett A., Ainsworth P., Derbyshire E. (2012): Improving the quality of nutrient-rich Teff (*Eragrostis tef*) breads by combination of enzymes in straight dough and sourdough breadmaking. Journal of Cereal Science, 53: 192–197.

Březinová Belcredi N., Ehrenbergerová J., Běláková S., Vaculová K. (2009): Barley grain as a source of health-beneficial substances. Czech Journal of Food Sciences, 27: 242–244.

Callaway J.C. (2004): Hempseed as a nutritional resource: an overview. Euphytica, 140: 65–72.

Dimić E., Romanić R., Vujasinović V. (2009): Essential fatty acids, nutritive value and oxidative stability of cold pressed hempseed (*Cannabis sativa* L.) oil from different varieties. Acta Alimentaria, 38: 229–236.

Duyvejonck A.E., Lagrain B., Pareyt B., Courtin C.M., Delcour J.A. (2012): Relative contribution of wheat flour constituents to solvent retention capacity profiles of European wheats. Journal of Cereal Science, 53: 312–318.

Gaines C.S., Donelson J.R. (1985): Evaluating cookie spread potential of whole wheat flours from soft wheat cultivar. Cereal Chemistry, 62: 134–136.

Gupta M., Bawa A.S., Abu-Ghannam N. (2011): Effect of barley and freeze-thaw cycles on textural, nutritional and functional properties of cookies. Food and Bioproducts Proccesing, 89: 520–527.

Hrušková M., Švec I., Heroudková K. (2015): Chemical and rheological evaluation of composite flour with chia and teff for cookies produce. Cereal Chemistry, 2: 74–87.

Izydorczyk M.S., Dexter J.E. (2008): Barley β-glucans and arabinoxylans: molecular structure, physicochemical properties, and uses in food products – a review. Food Research International, 41: 850–868.

Khouryieh H., Aramouni F. (2013): Effect of flaxseed flour incorporation on the physical properties and consumer acceptability of cereal bars. Food Science and Technology International, 19: 549–556.

Kulp K. (ed.) (1994): Cookie Chemistry and Technology. 1st Ed. Manhattan, American Institute of Baking: 280–283.

Miller R.A., Hoseney R.C. (1997): Factors in hard wheat flour responsible for reduced cookie spread. Cereal Chemistry, 74: 330–336.

Nanditha B.R., Jena B.S., Prabhasankar P. (2009): Influence of natural antioxidants and their carry-through property in biscuit processing. Journal of the Science of Food and Agriculture, 8: 288–298.

Norajit K., Gu B.-J., Ryu G.-H. (2011): Effects of the addition of hemp powder on the physicochemical properties and energy bar qualities of extruded rice. Food Chemistry, 129: 1919–1925.

Patents KR2009074421-A; KR969163-B1. Manufacturing confectionery, particularly pie, cookie, biscuit or cone, involves utilizing hemp seed or hemp oil, where dried milk powder, starch and also mixed to prepare hemp powder (published 06/2009). Availabel at http://apps.webofknowledge.com/full_record.do?colName=DIIDW&recordID=2009L80887&page=1&qid=1&log_event=yes&viewType=fullRecord&SID=S1agYVo38kfrGFoawZ3&product=UA&doc=1&search_mode=GeneralSearch (accessed at 01/2015).

Patent CN103380800-A Hemp sweet cake preparation method involves putting mold box into steamer, and cutting cake mixture into strips and putting in oven at constant temperature" (published 11/2013). Available at http://www.google.com/patents/CN103380800A?cl=en (accessed at 01/2015).

Poper L., Schafer W., Freund W. (2006): Future of Flour. 1st Ed. Clenze, AgriMedia GmbH: 303–307.

Radočaj O., Dimić E., Tsao R. (2014): Effects of hemp (*Cannabis sativa* L.) seed oil press-cake and decaffeinated green tea leaves (*Camellia sinensis*) on functional characteristics of gluten-free crackers. Journal of Food Science, 79: C318–C325.

Sharma P., Gujral H.S. (2014): Cookie making behavior of wheat–barley flour blends and effects on antioxidant properties. LWT-Food Science and Technology, 55: 301–307.

Škrbić B., Cvejanov J. (2011): The enrichment of wheat cookies with high-oleic sunflower seed and hull-less barley flour: Impact on nutritional composition, content of heavy elements and physical properties. Food Chemistry, 124: 1416–1422.

Švec I., Hrušková M. (2015): Characteristics of wheat, barley and hemp model composites. Czech Journal of Food Sciences, 33: 66–71.

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