EVALUATION OF MODEL WHEAT/HEMP COMPOSITES

Ivan Švec, Marie Hrušková

ABSTRACT

Model cereal blends were prepared from commercial wheat fine flour and 5 samples of hemp flour (HF), including fine (2 of conventional form, 1 of organic form) and wholemeal type (2 of conventional form). Wheat flour was substituted in 4 levels (5, 10, 15, 20%). HF addition has increased protein content independently on tested hemp flour form or type. Partial model cereal blends could be distinguished according to protein quality (Zeleny test values), especially between fine and wholemeal HF type. Both flour types affected also amylolytic activity, for which a relationship between hemp addition and determined level of Falling Number was confirmed for all five model cereal blends. Solvent retention capacity profiles (SRC) of partial models were influenced by both HF form and type, as well as by its addition level. Between both mentioned groups of quality features, significant correlation were proved - relationships among protein content/quality and lactic acid SRC were verifiable on *p <0.01* (-0.58, 0.91, respectively). By performed ANOVA, a possibility to distinguish the HF form used in model cereal blend according to the lactic acid SRC and the water SRC was demonstrated. Comparing partial cereal models containing fine and wholemeal hemp type, HF addition level demonstrated its impact on the sodium carbonate SRC and the water acid SRC.

Keywords: wheat-hemp composite flour; protein content and quality; SRC profile; correlation analysis

INTRODUCTION

Within cereal branch, an innovation goal presents non-traditional cereals, legumes and pseudocereals food usage, with accent on nutritional benefit of bakery products. To bring out new products of acceptable price on a market, commercial cereals premixes based on wheat flour of definite technological parameters are used in advantage; this way allows a keeping of produce process effectiveness at the same time. Among such basic characteristics belong protein content and quality according to the Zeleny test and prediction of starch polysaccharides behaviour when heated to 100 °C as the Falling Number. More precise description of cereal blends behaviour is enabled by the Solvent Retention Capacity Profile (SRC) determination, within which partial results correspond to hydration capability of flour components forming dough net structures, damaged starch rate together with pentosans content and quality.

The SRC method, registered as AACC 56-11 (**AACC Approved Method, 2000**; **Gaines, 2000**), represents a modern analytical procedure of quality prediction, both for milling products and wheat flour blends with non-traditional components. The test could be performed in a short time by usage of sample amount in grams. Its principle is based on gravimetric evaluation of absorbed amounts of distilled water, and water solutions of sucrose, sodium carbonate and lactic acid (50%, 5% and 5% w/w, respectively; signed as WASRC, SUSRC, SCSRC, LASRC).

A review on the SRC application in the cereal field was published in the Cereal Chemistry (**Kweon et al., 2011**). In recent literature, effect of agro technical factors as genotype, harvest year and planting locality are discussed (**Guttieri and Souza, 2003**), or wheat flour quality

assessment (**Xiao et al., 2006**; **Duyvejonck et al. 2011**). Further scope was found out for triticale or rye quality description (**Oliete et al., 2010**), and also for wheat flour enrichment by ten types of commercial fibre of different origin (e.g. wheat, oat, apple or bamboo ones; **Rosell et al., 2009**). Within the own research results of Cereal laboratory of ITC Prague, the SRC method was validated for qualitative measurement of milling inter-products (**Hrušková et al., 2010**) or of composites containing wheat, rye, barley, oat or corn wholemeal (**Hrušková et al., 2011**).

Hemp was an important plant for its fibre and oil. Nowadays *Cannabis sativa* is the mostly planted specie due to its low content of phytochemical drug component THC (δ-9-tetrahydrocannabinol). Hempseed contains 20 - 25% protein, 20 - 30% carbohydrates, 25 - 35% oil and 10 - 15% insoluble fibre and a rich array of minerals. Hemp protein is mainly edestin, globular protein type similar to albumin found in eggs or blood. Oil is composed mostly by unsaturated fatty acids and therefore is considered beneficial for human nutrition (**Callaway 2004**). With respect to affordable references, both behaviour of cereal wheat-hemp model blend and its evaluation by means of the SRC testing was not published yet.

Aim of the presented study is to explore model cereal blends on base of wheat and hemp flours, including different commonly available food forms (conventional, organic i.e. "bio"). Statistical pattern used should reveal out relationships between single quality features and also influence of diverse recipe composition of 20 partial models.

MATERIAL AND METHODOLOGY
Preparation of model cereal blends

Based on commercial wheat flour produced in year 2010 (signed as M), model cereal blends were prepared by using five hemp flour samples (forms) singed as K1 - K5. In detail, two diverse conventional K1 and K2 samples were provided by Czech company, while organic K3 item was bought on local market; all named samples are of fine granulation. Furthermore, samples K4 and K5 are laboratory prepared ones, from dehulled and hulled hemp seeds, respectively, thus both have a wholemeal character. Model cereal blend were mixed in ratios 95:5, 90:10, 85:15 and 80:20 (w/w) of wheat and hemp flour, respectively, and were signed according to included hemp flour form and content (e.g. K1.5, or K5.20).

Cereal mixtures quality was evaluated according to **ČSN ISO 1871** (protein content according to Kjeldahl's method; abbreviation PRO), **ČSN ISO 5529** (protein quality according to Zeleny's sedimentation; ZT) and **ČSN ISO 3039** (amylolytic activity estimation as the Falling Number; FN). The analytical features were measured in duplicate, correspondingly to the mentioned Czech norms.

To gain the SRC profiles, the AACC norm No. 56-11 was followed, i.e. standard sample of 5g was used and centrifuged by using the Eppendorf 5072 apparatus (Eppendorf AG, Germany). The method accuracy was determined in terms of the test repeatability, allowing single measurements of tested model cereal blends. Calculated relative standard deviations were 0.342%, 0.727%, 0.667% and 0.476% absolutely for the WASRC, SUSRC, SCSRC and LASRC, respectively.

Statistical analysis

Represented by 20 items, cereal blends model with hemp flour was statistically described by both linear and non-linear correlation analysis, covering all observed quality features. Analysis of variance (ANOVA) serves for assessment of partial models composition, i.e. to compare the influences of hemp flour form (HF; K1 - K5) or hemp flour type (HT; fine vs. wholemeal) and hemp component addition level (AL) in pairs (HF vs. AL, HT vs. AL). The factors impact was quantified by variance components analysis (*F*-test), considering HF or HT as fixed effects and AL as a random one. The statistics mentioned were calculated using the Statistica 7.1 software (Statsoft, USA).

RESULTS AND DISCUSSION
Technological properties of model cereal blends

Basic component - wheat flour M - is characterised by higher PRO (12.5%) with standard quality (ZT 41 mL). Estimated amylolytic activity as FN equal to 310 s corresponds to that harvest year average and in terms of flour bakery usage, it is close to technological optimum.

Related to all five hemp flour forms, PRO has approx. linearly increased up to about one-quarter in relation to wheat flour standard M. The least influence was recognized during K5 fortification, while for cereal blends containing K1 and K2 on one side and for ones with K3 and K4 on the other, approx. 4% and 7% increments were found, respectively (Figure 1). According to ANOVA results, that parameter was not able to distinguish partial models with different hemp flour types, despite a revealed soft interaction of observed factors.

Reversal to content, protein quality has been significantly dwindled in all wheat-hemp flour blends in a range 7%-38% (Table 1). A negative influence was milder at fortification by commercial fine hemp K1 sample. Conversely to that, verifiable loss in protein quality was registered for wholemeal hemp flour K4 or K5 hemp forms (maximal decrease of ZT about 37%, about 68% and 66% for blends involving 20% of non-traditional flour, respectively). In this regard, cereal models containing conventional fine hemp flour could be partially distinguished from the wholemeal ones. ANOVA results also proved softly stronger impact of AL compared to one of HF factor.

Hemp component affected the SRC profile of model cereal blends, both by used form and by added amount. The broadest change was recorded for LASRC, a diminishing from 182.5% to less than one half has occurred (Table 2, variability a-d for both effects studied). Vice versa, the lowest impact of variation in cereal blend composition was noticed for WASRC. As is documented by whisker plot, arithmetic mean covering the K3 blends was similar to standard value (89.8 % vs. 90.9 % for basic sample M; Figure 2a). There is obvious dependence of the SRC profile of each blend on both fine and wholemeal hemp flour type.

Among tested cereal models with selected hemp flour concentrations, comparable trends were identified for pairs WASRC-SCSRC and SUSRC-LASRC (Figure 2b). In the former case, both SRC's level of samples enhanced by 5% and 20% of hemp flour differed minimally (about 2% and 6%), representing approx. 87% and 81% of the standard M value, respectively. Within the second couple, determined decrease was more significant, considering averages levels 83% and 58% of standard M. Such exploration of cereal blend composition brings also knowledge about the largest data scatter for LASRC parameter, likewise to case of tested hemp flour comparison. Owing to that, the parameter should be identified as identification sign of each cereal blend item.

Statistical analysis of model cereal blends

Trends observed within correlation matrixes resulted from linear or non-linear approaches were similar (data not shown), therefore only linear relationships are discussed (Table 3).

To depict quality by alternative way, the SRC profile application possibilities are nowadays studied extensively. Global properties of partial items of the model cereal blend were characterised by the procedure similarly, demonstrating possible alterations between the single SRC. The tightest correlation was found in pair WASRC and SCSRC (r = 0.96; *p <0.01*; Table 3).

For the four single SRC, the best relationships correspondence was revealed to ZT parameter (all 6 links provable), and the fittest to LASRC (*r* = 0.91, *p <0.01*). Also PRO was connected to LASRC, but correlations provability is weaker (*r* = -0.58, *p <0.01*). Summarised, the LASRC has a potential to distinguish the tested partial models containing fine and wholemeal form of hemp component. Within the set of wheat, rye and triticale

testing, similar findings published **Oliete et al., 2010** for relationships of PRO to WASRC, SUSRC, and SCSRC ($r = -0.64$; -0.64 and -0.69; $p < 0.05$). In a pair PRO-LASRC, the Pearson's coefficient reached approx. a half level ($r = 0.35$). Within the set of wheat flour composites containing wheat, rye, barley, oat or corn wholemeal, verifiable links between quality features and the SRC profiles were published in our previous study (**Hrušková et al., 2011**). The strongest relationship was determined between ZT and LASRC ($r = 0.93$, $p < 0.01$).
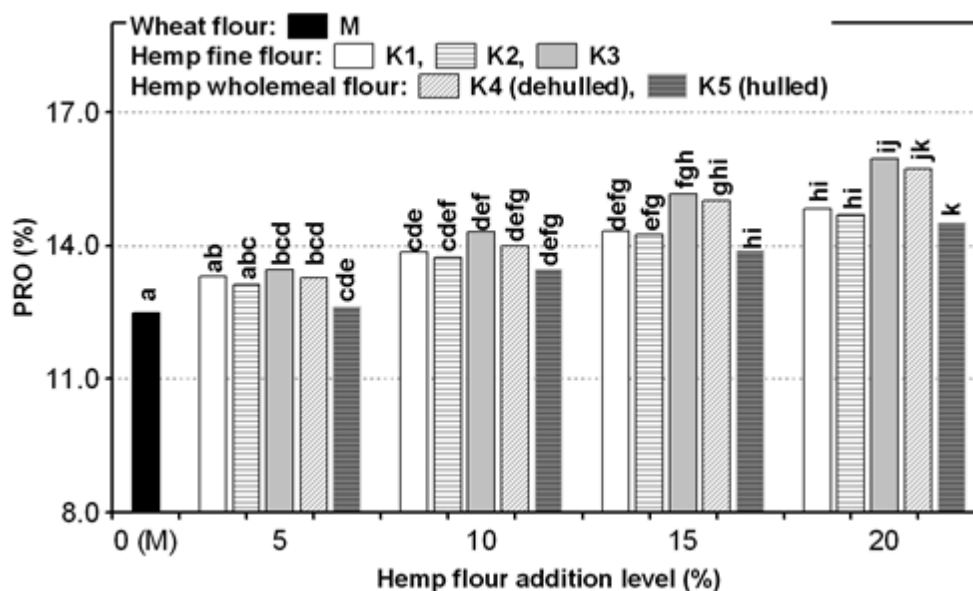

Figure 1 hemp form and addition level influences on protein content (PRO) in cereal blend models.

Table 1 Hemp form and addition level effects on analytical properties of model cereal blends.

Flour type	Sample	ZT (mL)			FN (s)		
		Range	Variability		Range	Variability	
			HF	AL		HF	AL
Wheat flour	M	41	d	E	310	ab	B
Fine hemp flour	K1.5 - K1.20	38 - 26	b-c	A-D	308 - 297	a-ab	A-C
	K2.5 - K2.20	36 - 20			309 - 292		
	K3.5 - K3.20	34 - 16			315 - 278		
Wholemeal hemp flour	K4.5 - K4.20	19 - 13	a-b		333 - 278	ab-b	
	K5.5 - K5.20	34 - 14			333 - 286		

M - commercial fine wheat flour; Hemp forms: K1, K2, K3 - commercial hemp flour of fine type;
K4, K5 - dehulled and hulled hemp flour of wholemeal type, respectively.
ZT - Zeleny sedimentation test, FN - Falling Number.
ANOVA factors: HF - hemp form, AL - addition level.
a-d, A-E: group means for HF and AL, respectively, signed by the same letter are not statistically different at
$p < 0.05$.

Table 2a) Hemp form and addition level effects on the SRC profile of model cereal blends.

Flour type	Sample	WASRC (%)			SUSRC (%)		
		Range	Variability		Range	Variability	
			HF	AL		HF	AL
Wheat flour	M	90.9	b	B	112.1	a	A
Fine hemp flour	K1.5 - K1.20	86.5 - 86.5	b	A-AB	109.4 - 102.3	a	A
	K2.5 - K2.20	86.3 - 86.4			100.9 - 106.7		
	K3.5 - K3.20	86.9 - 87.9			93.0 - 99.8		
Wholemeal hemp flour	K4.5 - K4.20	70.3 - 61.7	a		102.3 - 64.1	a	
	K5.5 - K5.20	69.5 - 68.3			102.5 - 74.3		

Table 2b) Hemp form and addition level effects on the SRC profile of model cereal blends.

Flour type	Sample	SCSRC (%)			LASRC (%)		
		Range	Variability		Range	Variability	
			HF	AL		HF	AL
Wheat flour	M	117.1	b	B	182.5	d	D
Fine hemp flour	K1.5 - K1.20	108.8 - 106.7	b	A	153.7 - 112.1	b-c	A-C
	K2.5 - K2.20	107.5 - 108.2			141.2 - 109.9		
	K3.5 - K3.20	106.2 - 106.9			137.1 - 102.7		
Wholemeal hemp flour	K4.5 - K4.20	88.2 - 70.5	a		108.0 - 78.3	a	
	K5.5 - K5.20	88.4 - 76.1			120.6 - 77.2		

M - commercial fine wheat flour; Hemp forms: K1, K2, K3 - commercial hemp flour of fine type; K4, K5 - dehulled and hulled hemp flour of wholemeal type, respectively.
WA-, SU-, SC-, LASRC: water, sucrose, sodium carbonate and lactic acid solvent retention capacity, respectively.
ANOVA factors: HF - hemp form, AL - addition level.
a-d, A-D: group means for HF and AL, respectively, signed by the same letter are not statistically different on $p < 0.05$.
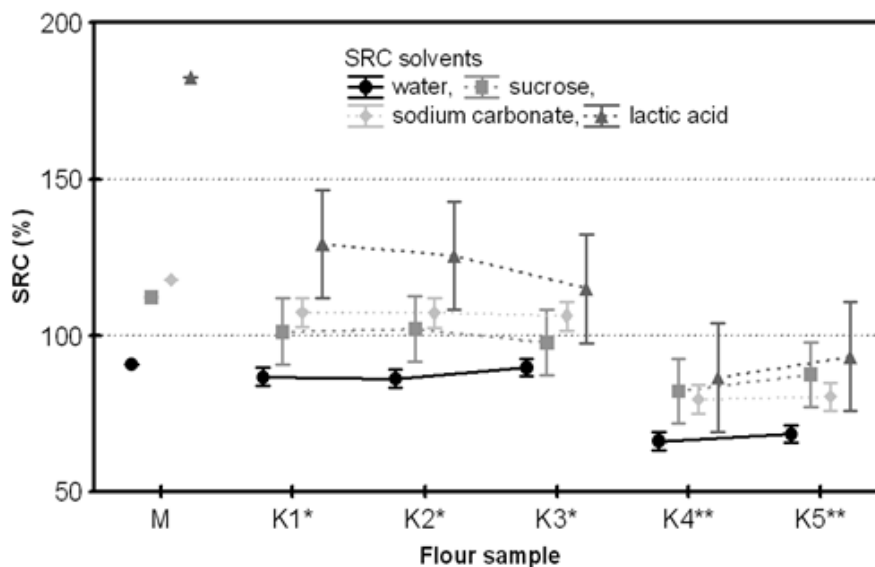

Figure 2a Effect of fine(*) and wholemeal (**) hemp flour on wheat flour M solvent retention capacity (SRC) profile.
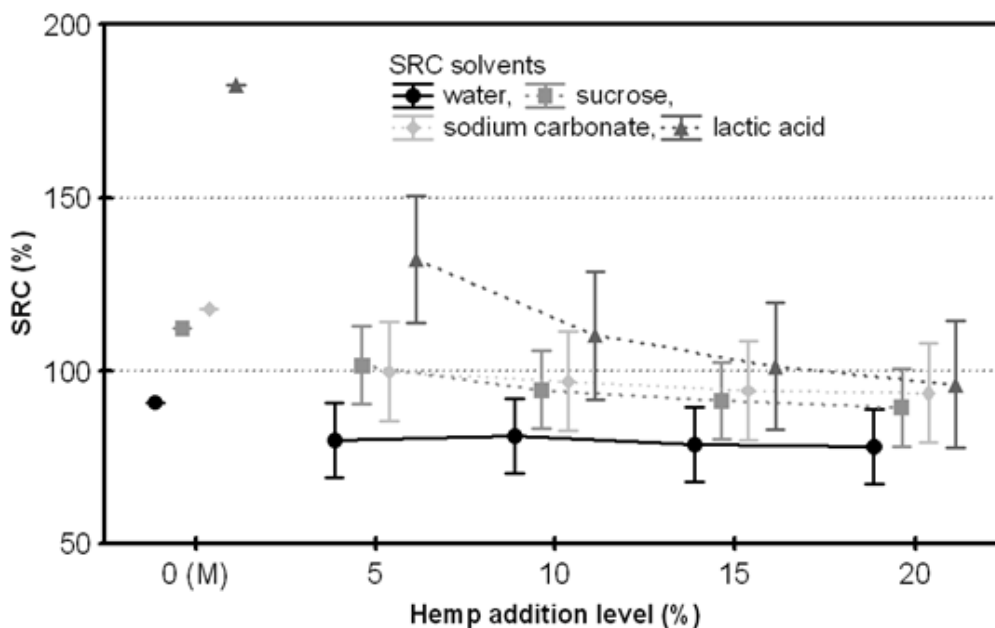
Figure 2b Effect of hemp addition level on wheat flour M solvent retention capacity (SRC) profile.

Table 3 Significant linear relationships between analytical features and SRC profiles of tested model blends

Feature	PRO	ZT	FN	WASRC	SUSRC	SCSRC	LASRC
PRO	1						
ZT	-0.73**	1					
FN	-0.79**	0.44**	1				
WASRC	*ns*	0.56**	*ns*	1			
SUSRC	-0.44**	0.66**	*ns*	0.74**	1		
SCSRC	*ns*	0.66**	*ns*	0.96**	0.84**	1	
LASRC	-0.58**	0.91**	*ns*	0.71**	0.78**	0.82**	1

PRO - protein content, ZT - Zeleny sedimentation test, FN - Falling Number.
WA-, SU-, SC-, LASRC: water, sucrose, sodium carbonate and lactic acid solvent retention capacity, respectively.
*, ** - relationships provable on *p < 0.05* and *0.01,* respectively; *ns* - non-significant.

Table 4 a) Comparison of factors hemp form and hemp components addition level impact on analytical features and SRC profiles of model cereal blends.

a) Hemp form: samples K1 - K5

Feature	Factor	
	HF	AL
PRO	16***	79***
ZT	51***	64***
FN	3*	33***
WASRC	73***	1
SUSRC	4*	2
SCSRC	67***	3
LASRC	91***	79***

Table 4 b) Comparison of factors hemp form and hemp components addition level impact on analytical features and SRC profiles of model cereal blends.

b) Hemp flour type: fine (K1 - K3) vs. wholemeal samples (K4, K5)

Feature	Factor		
	HT	AL	HT x AL
PRO	1	12***	0
ZT	33***	16***	0
FN	14***	59***	9***
WASRC	246***	1	1
SUSRC	47***	9*	11***
SCSRC	1448***	23***	18***
LASRC	97***	23***	0

PRO - protein content, ZT - Zeleny sedimentation test, FN - Falling Number.

Comparing influence of the observed factors, i.e. HF (K1-K5), HT (fine K1-K3 vs. wholemeal K4, K5), and AL (ratio in certain model blend) by the *F*-test, discrimination of partial cereal models was testified with different statistical reliability levels. In a case of the HF and the AL effects exploration, the latter factor seriously impacted protein and starch properties of model blends (e.g. PRO *F*-values 79 vs. 16, respectively; *p <0.001*, Table 4a).

Almost levelled influence of the factors was found for the ZT parameter - calculated *F*-values were 51 and 64, respectively (*p <0.001*). On the other hand, the SRC profiles could be distinguished according to the HF (*F* = 73 and 67, respectively; *p < 0.001*). Likewise to ZT characteristic, the LASRC presents its own capability to describe a diversity among cereal blend models, both in terms of the HF or the AL factor (*F* = 91 and 79, *p <0.001*) (Table 4a). In contrast, the softest effect of hemp flour form was identified for the SUSRC, as could be noticed in whisker plots (Figures 2a, 2b).

Taking account of the HT factor (together with the AL one), protein properties (PRO and ZT) importance in model blends distinguishing was lessened (Table 4b). Reversely to that, *F*-value levels related to polysaccharides behaviour (i.e. FN) were magnified at least twice (*F* = 14 a 59, *p <0.001*). Therefore it could be assumed a prediction of model cereal blends composition by indirect determination of amylolytic activity of present starch.

Investigated factors (type and added amount) influenced the SRC profiles in a different way compared to the previous evaluation. According to *F*-test, hemp component type could be traced in most precise way by the SCSRC and with somewhat higher statistical error by the WASRC (*F* = 1448 and 246, respectively; *p <0.001*) (Table 4b). And finally, properties prediction of models with hemp wholemeal flour could be built on the SCSRC and LASRC (a larger data extent, Table 2).

CONCLUSION

Model cereal blends were prepared on base of commercial fine wheat flour and five samples of hemp components, differing in their type - fine or wholemeal one (3 and 2 samples, respectively). Hemp components partially replaced wheat flour, chosen ratios ranged between 5% and 20%. From a viewpoint of chemical components, added amounts significantly increased protein content, independently on tested hemp form. Partial model blends were distinguishable according to protein quality (Zeleny's sedimentation values), especially between fine and wholemeal hemp component type. Estimation of amylolytic activity as the Falling Number also signified differences between mentioned hemp types, counting all 20 tested cereal mixtures. Considering consecutively hemp form, hemp type and added amount as data variability factors, the SRC profiles of studied wheat-hemp model blends were verifiably affected by all three mentioned influences. Between features belonging into analytical-quality group on the one and into the SRC profile on the other side, correlation analysis confirmed presumed as well as revealed new statistically important relationships in correspondence with results of other researchers. For example, a link between protein content or their quality and lactic acid SRC could be consider as tight even as very tight on p <0.01. A possibility to distinguish model cereal blends was signified by performed ANOVA test. Pair comparison of hemp form vs. added amount effects shown that capability for the lactic acid and the water SRC's. For factors' hemp type and added amount influence, such importance had the sodium carbonate and the water SRC's.

REFERENCES

AACC Method 56-11. Solvent retention capacity profile. In: Approved methods of the American Association of Cereal Chemists. 10th ed. St. Paul: The American Association of Cereal Chemists, 2000. ISBN 1891127128.

Callaway, J. C., 2004. Hempseed as a nutritional resource: An overview. *Euphytica*, vol. 140, no. 1-2, p. 65-72. http://dx.doi.org/10.1007/s10681-004-4811-6

ČSN ISO 1871. Food and feed products - General guidelines for the determination of nitrogen by the Kjeldahl method. Praha: Czech Office for Standards, Metrology and Testing ÚNMZ, 2010. 5 p.

ČSN ISO 5529. Wheat - Determination of the sedimentation index - Zeleny test. Praha: Czech Office for Standards, Metrology and Testing ÚNMZ, 2011. 9 p.

ČSN ISO 3039. Determination of the falling number according to Hagberg-Perten. Praha: Czech Office for Standards, Metrology and Testing ÚNMZ, 2011. 8 p.

Duyvejonck, A. E., Lagrain, B., Pareyt, B., Courtin, C. M., Delcour, J. A., 2011. Relative contribution of wheat flour constituents to Solvent Retention Capacity profiles of European wheats. *Journal of Cereal Science*, vol. 53, p. 312-318. http://dx.doi.org/10.1016/j.jcs.2011.01.014

Gaines, C. S., 2000. Report of the AACC committee on soft wheat flour. Method 56-11. Solvent Retention Capacity Profile. *Cereal Foods World*, vol. 45, p. 303-306.

Guttieri, M. J., Souza, E., 2003. Sources of variation in the Solvent Retention Capacity test of wheat flour. *Crop Science*, vol. 43, p. 1628-1633. http://dx.doi.org/10.2135/cropsci2003.1628

Hrušková, M., Karas, J., Švec, I., 2010. Retenční kapacita - příklad užití pro hodnocení ve mlýně (Solvent Retention Capacity - usage example for quality evaluation in a commercial mill). *Mlynářské noviny*, vol. 4, p. 10-12. [In Czech]

Hrušková, M., Hofmanová, T., Švec, I., 2011. Hodnocení vybraných druhů kompozitní mouky (Evaluation of selected types of composite flour). *Mlynářské noviny*, vol. 2, p. 10-12. [In Czech]

Kweon, M., Slade, L., Levine, H., 2011. Solvent retention capacity (SRC) testing of wheat flour: Principles and value in predicting flour functionality in different wheat-based food processes and in wheat breeding. A review. *Cereal Chemistry*, vol. 88, no. 6, p. 537-552. http://dx.doi.org/10.1094/CCHEM-07-11-0092

Oliete, B., Pérez, G. T., Gómez, M., Ribotta, P. D., Moiraghi, M., León, A. E., 2010. Use of wheat, triticale and rye flours in layer cake production. *International Journal of Food Science and Technology*, vol. 45, no. 4, p. 697-706. http://dx.doi.org/10.1111/j.1365-2621.2010.02183.x

Rosell, C. M., Santos, E., Collar, C., 2009. Physico-chemical properties of commercial fibres from different sources: A comparative approach. *Food Research International*, vol. 42, no. 1, p. 176-184. http://dx.doi.org/10.1016/j.foodres.2008.10.003

Xiao, Z. S., Park, S. H., Chung, O. K., Caley, M. S., Seib, P. A., 2006. Solvent retention capacity values in relation to hard winter wheat and flour properties and straight-dough breadmaking quality. *Cereal Chemistry*, vol. 83, no. 5, p. 465-471. http://dx.doi.org/10.1094/CC-83-0465

Contact address:
Ivan Švec, Institute of Chemical Technology Prague, Department of Carbohydrates and Cereals, Technicka 5, 166 28 Praha 6 - Dejvice, Czech Republic, E-mail: Ivan.Svec@vscht.cz

Marie Hrušková, Institute of Chemical Technology Prague, Department of Carbohydrates and Cereals, Technicka 5, 166 28 Praha 6 - Dejvice, Czech Republic, E-mail: marie.hruskova@vscht.cz