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Evaluation of protein quality of wheat-rye flour blends by use of two small-scale analytical methods

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Abstract: The technological quality of the protein fraction of wheat white flour (WW) was determined by the lactic acid Solvent Retention Capacity and by the Gluten Performance Index (*LA-SRC* and *GPI*; AACC method 56-11.01). Parallelly, Perten's standard Gluten Index test (*GI*; AACC method 38-12.02) was performed with that wheat control. Consequently, the same methods were applied to 9 bi-composite blends mixed at ratios of 90 : 10, 80 : 20, 70 : 30, 60 : 40, 50 : 50, …, and 10 : 90 as WW replacement with one of the rye bread flours (RB), and the RB control itself. Unlike successful measurements in the case of the *LA-SRC* and *GPI*, washing gluten from the first 90 WW : 10 RB blend led to the clogging of the Glutomatic sieve, likely due to the interaction of wheat gluten with rye arabinoxylans. The discrepancy induced the development of a modification of the standard GI procedure; clogging was avoided by precipitating flour and centrifuging the swollen solid from suspension, similarly like in the SRC method. The settled residue transported to a standard sieve cassette was secondly centrifuged in the original apparatus Perten CF2015. The weighing of the overflow and underflow of the sieve and the calculation of the results were performed according to the original GI method. For the WW control, the standard *GI* value was 90% and the modified Gluten Index value (GI_{modif}) was 82%. As expected for WW-RB counterparts, the higher the portion of rye in the bi-composite blend, the lower the value of the GI_{modif}. For the 50 WW : 50 RB blend and the RB itself, the GI_{modif} values were 47% and 18% (the *GPI* values 0.66, 0.45, and 0.39, respectively). On the contrary, the *LA-SRC* demonstrated a convex course (118, 104, and 123%, respectively). In the plane of the principal components (PC), namely PC1 and PC2, the variables related to gluten quality formed 4 groups as a function of the stepwise change in the mixing ratio of WW and RB: *i*) flour protein content, *GPI*, and GI_{modif}; *ii*) *LA-SRC*; *iii*) dietary fibre content and ash content; *iv*) water, sucrose, and sodium carbohydrate *SRC*s. However, the modified test procedure should be revised in wheat varieties characterised by a wider spectrum of protein quality, mixed with different types of rye flour (especially wholegrain one).

Keywords: finely-milled flour; wheat-rye mixture; technological quality of proteins; Gluten Index method; Solvent Retention Capacity profile; centrifugation; precipitation; Principal Component Analysis

For the trading of cereals and other crops that can be used for the industrial production of food, quick but sufficiently accurate laboratory or operational proofs of the main quality markers are irreplaceable. Today, a substantial part of these results could be categorised among indirect methods, on the basis of known relationships between the spectral or electrochemical response of the material tested and the real content of the target analyte (or the level of the target quality parameter). By using a specialised near infrared (NIR) spectrometer, for example, wheat flour can be analysed for moisture, proteins, ash and for farinograph

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water absorption in one measurement; it takes less than one minute and consumption of the material is 20 g at maximum. If someone likes to quantify all these quality parameters, it could take a day of careful laboratory work with closely 1 kg of wheat flour, disregarding the expensive acquisition of proper specialised devices. However, these time- and material-consuming chemical analyses are a necessary base for calibration of spectrometers and similar devices, including hundreds of analysed samples covering real ranges of the target analyte content.

The evaluation of gluten quality using the tests called Gluten Index (GI) and Solvent Retention Capacity (SRC) could be dated back to the last quarter of the 20th century as research results published by the teams Hagberg–Perten (ICC method 137, published firstly in 1987) in the former case, and by Slade–Levine (1994) as well as by Haynes et al. (2009) in the latter case (nowadays, ICC method 186). But the first sedimentation test was developed by Zeleny for refined wheat flour (Zeleny 1947), followed by Axford for whole grain groats (Axford et al. 1978). Kweon et al. (2011) revised the SRC method and recommended an additional parameter Gluten Performance Index (*GPI*), which is the *LA-SRC* without interaction of the lactic acid solution with damaged starch and pentosans.

Although GI and SRC are internationally approved tests (AACC methods 38-12.02 and 56-11.01, respectively), both are used quite rarely in the daily practice of industrial mill and bakery laboratories. The results of the GI procedure depend on the type of laboratory mill; moreover, the viscoelastic properties of laboratory-prepared flour do not generally correspond to those of industrially milled flour due to the non-linear character of their relationship (Bonfil and Posner 2012). But in general, extracted gluten is commonly classified as weak, normal and strong by the *GI* < 30%, *GI* in a range of <30; 80%>, and *GI* > 80%, respectively (with limit values of *GI* 0% and 100%). In this respect, the optimal *LA-SRC* value for bakery wheat flour is 150% (U.S. Wheat Associates 2021).

Small-scale technological tests of protein quality are used for wheat flour only because rye proteins are water soluble (Cardoso et al. 2019). This laboratory testing is aimed at estimation of the protein quality of nine blends of white wheat and rye bread flour, comparing SRC and GI procedures. Including the basic chemical composition, the collected data were evaluated by analysis of variance (ANOVA) and linear correlations (P = 95%), as well as graphically by principal component analysis (PCA).

MATERIAL AND METHODS

Material

The basic pair of flours, white wheat flour (WW) and rye bread flour (RB), was characterised by fine granulation (> 75% of particles smaller than 162 μm). Both samples were supplied by the Mlýn Perner Company (Czech Republic) and milled from the grain of 2020/2021 harvest. For mixing of 9 two-component blends, a 10% replacement step was selected; blends were coded as 90 WW : 10 RB, 80 WW : 20 RB, 70 WW : 30 RB, 60 WW : 40 RB, 50 WW : 50 RB, ... and 10 WW : 90 RB. The samples were prepared in pairs of 0.5 kg each using a laboratory homogeniser (BS-P03; Mezos, Czech Republic) during mixing for 30 min at a speed of 100 revolutions per minute (rpm).

The chemicals were produced by the Czech company PENTA, namely sucrose, sodium chloride, sodium carbonate, and lactic acid. Deionised water was produced at the DEMIWA 5*roi* reverse osmosis water station (WATEK, Czech Republic) with a conductivity of 0.20 μS.

Methods

Basic chemical composition of flour and blends. The basic chemical composition of WW and RB was determined according to the appropriate international standards (moisture, protein, total dietary fibre, fat, and ash). The amount of starch was calculated as the rest to be 100%. As a representative blend, sample 50 WW : 50 RB was analysed together with both controls.

Lactic acid Solvent Retention Capacity and Gluten Performance Index. Following AACC method 56-11.01 (2010), the SRC profile was measured with four recommended solvents [approved parameter abbreviations water (*WA-*), sucrose (*SU-*), sodium carbohydrate (*SC-*), and lactic acid *SRC* (*LA-SRC*)]. For protein quality, only the *LA-SRC* and the additional parameter *GPI* were considered; the *GPI* was calculated according to Equation 1 published by Kweon et al. (2011):

$$GPI = \frac{LA\text{-}SRC}{WA\text{-}SRC + SC\text{-}SRC} \tag{1}$$

where: *LA-*, *WA-*, *SC-SRC* – lactic acid, water, and sodium carbohydrate Solvent Retention Capacity, respectively.

Gluten Index method. For the standard GI measurement according to AACC method 38-12.02 (2000), the Glutomatic 2200 system and Perten CF2015 cen-

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trifuge (PerkinElmer, USA) were used. The WW item was tested successfully; in the case of the first 90 WW : 10 RB blend, the washing sieve was clogged almost immediately after the start of the GI test. Neither the reduction of the flour dose to 5.00 g did lead to success in the filtering of bi-composite dough.

Development of modified Gluten Index procedure. To obtain the solid phase from the suspension of the RB and 9 WW-RB blends, the SRC method was adapted. Using four standard 50 mL Falcon tubes, two pairs of two different flour samples per 2.50 g each were poured into 40 mL of standard sodium chloride (NaCl) solution. The closed tubes were shaken in the PTR-35 rotator (Grant Bio, Great Britain) for 10 min at 30 rpm. Afterwards, this group of four tubes was centrifuged in the Eppendorf 5720 centrifuge (Eppendorf SE, Germany) for 5.0 min at 3 500 rpm. After pouring the supernatant and draining for 10 min, the dewatered solid was transported to the original centrifuge sieve and routinely centrifuged in the centrifuge Perten CF2015 in two rounds. All samples, products, and by-products were continuously weighed for later calculation of the modified Gluten Index (GI_{modif}) in accordance with the international norm.

Data statistical treatment. Differences and relationships within the collected results were described by ANOVA and linear correlations (P = 95%) in Statistica (version 13.1). On the basis of correlations, the principal component analysis was used to create a scatter biplot of variable loadings and sample scores. The fat content was excluded due to the narrow scatter of the data. The parameters *WA-*, *SU-*, and *SC-SRC* were considered as supplementary variables because they are included in the *GPI*, and moreover, the latter two are associated mainly with polysaccharide content.

RESULTS AND DISCUSSION

Composition of basic wheat and rye bread flour

The measured composition of the WW-RB controls and the 50 WW : 50 RB blend fell into common ranges of nutritional characteristics. According to the fat level in WW and RB, the controls were statistically similar (P = 95%). The milling process is governed by the ash content, which oscillates between 0.3% and 0.5% in grain endosperm and between 5.5% and 6.5% in grain outer layers – bran (Sapirstein 2016). For example, ash content of 0.63% and 0.99% in Czech flour types T530 and T960 corresponds to a wheat milling scheme in Portugal. In their wheat type T55 and rye type T85, Cardoso et al. (2019) determined the ash content of 0.61% and 0.99%. In terms of protein content, both Portuguese flours were significantly richer: the wheat flour T55 contained 13.2%, while the rye counterpart 8.2% proteins (*vs*. 11.8% for WW and 7.1% for RB). Finally, the lipid portions were 0.92% and 1.29% *vs*. 1.11% and 1.10%, respectively.

An acceptable agreement could be observed between the calculated and measured chemical composition of the 50 WW : 50 RB blend. For the target component, proteins, the internal repeatability of the method is equal to 0.20% points (pt.) – considering it, calculated and measured values of 9.42% and 9.13% are statistically comparable with each other. In wheat and wheat-rye dough, dietary fibre is the second constituent responsible for water binding. Regardless of the internal accuracy of the method 0.22% pt., the calculated and measured levels were almost identical (7.23% and 7.29%; Table 1).

Solvent Retention Capacity profile

Solvent Retention Capacity of water, sucrose, and sodium carbohydrate. As the *WA-*, *SU-*, and *SC-SRC* were considered additional parameters, values for only a pair of WW-RB controls and for representative 50 WW : 50 RB blend are presented (Table 2). Contrary to wheat proteins, the binding capacity of rye arabinoxylans is many times higher; it was reflected in all three *SRC*s. From the threesomes of values, a linear increase could be noticed in agreement with the rising RB ratio. But pair standard deviations rose to four times higher values at least, for example,

Table 1. Chemical composition of tested flour samples and selected wheat-rye blend

Cereal, flour type/wheat-rye blend		Moisture (%)	Starch (%)	Dietary fibre (%)	Proteins (%)	Fat (%)	Ash (%)
Wheat white (WW)		11.00	71.45	4.06	11.76	1.11	0.63
Rye bread (RB)		10.43	70.01	10.40	7.08	1.10	0.99
50 WW : 50 RB	**calculated**	**10.72**	**70.73**	**7.23**	**9.42**	**1.11**	**0.81**
	measured	11.46	70.18	7.29	9.13	1.13	0.83

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Table 2. Water (*WA-*), sucrose (*SU-*), and sodium carbonate Solvent Retention Capacity (*SC-SRC*) values of control wheat white flour (WW), control rye bread flour (RB), and the representative blend

Flour/blend sample†	*WA-SRC* (%)	*SU-SRC* (%)	*SC-SRC* (%)
100 WW : 0 RB	66.4 ± 2.2[de]	102.6 ± 3.4[de]	75.9 ± 1.6[d]
0 WW : 100 RB	106.1 ± 17.2[e]	145.9 ± 12.5[e]	133.4 ± 15.5[a]
50 WW : 50 RB	85.1 ± 8.2[ab]	123.9 ± 6.8[ab]	98.1 ± 6.3[ab]
Average SD (N = 11)	9.2 % pt.	7.6 % pt.	15.0 % pt.

† Blend code 100 WW : 0 RB expresses a non-fortified WW flour; similarly, 0 WW : 100 RB indicates pure RB flour; [a–e] averages in rows, signed with the same letter, are not statistically different (P = 95%); SD – standard deviation; pt. – points

from 3.4% to 12.5% pt. in the case of the *SU-SRC* and WW and RB samples (Table 2). This finding was unexpected, as if 30 min of mixing in a laboratory homogeniser were not sufficient. The *SC-SRC* parameter has a relationship to the damaged starch fraction, which also partially occurs during industrial milling of grain. Han et al. (2022) studied wheat starch fragmentation using the ball mill after 5 operational times ranging from 10 min up to 60 min. Their findings confirmed a dependence of damaged starch and amylose contents on the milling time; similarly, the longer the effect of friction and shear between steel balls and starch granules, as well as starch granules themselves, the more intensive heat treatment occurred concurrently. Furthermore, smaller B-size starch granules were more susceptible to damage than larger A-sized ones (similarly to enzymatic degradation).

Lactic acid Solvent Retention Capacity and Gluten Performance Index. The wheat breeding programme includes many different genotypes according to the final planned use of the wheat variety (the resulting flour). For the industrial manufacturing of salty types of products such as pastry, bread, crackers or pizza on the one hand, and sweet ones such as wafers, biscuits, or cookies on the other, different protein content and their flow (viscoelastic) properties in wheat dough are necessary. The physicomechanical properties of developed gluten, basically elasticity and extensibility, must match the ranges given by long-term practice for each category of this cereal food. By the SRC profile, a new wheat genotype could be pre-sorted for its potential final use. Ram et al. (2005) tested 192 Indian wheat genotypes using a flour dose lowered to 1.0 g. They determined the grain protein content between 8.0% and 14.2%. These samples demonstrated *LA-SRC* in a range of 72.0% to 122.8% and *GPI* from 0.518 to 0.663 (averages 91.9% and 0.563, respectively). As the final quality test of the wheat flour, they used the Farinograph rheometer: the water absorption levels were 55.5% and 69.5% of the flour weight. As expected, the mixing tolerance index of the farinograph proof, which indicates wheat dough resistance to overkneading, was found to be negatively correlated with the *LA-SRC* at P = 99.9%; this as well as other parameters of the farinograph curve already have a direct connection with the bread volume, manufactured within a laboratory baking trial.

For the production of yeast bakery products, the value of the *LA-SRC* of wheat flour should be 100% at least (AACC method 56-11.01), while the *GPI* ratio is not specified there. However, according to Equation 1, the *GPI* of this flour should be min. 0.595. In the recommendation of the U.S. Wheat Associates, quality demand is stricter – the optimal *LA-SRC* for baker's wheat flour is even 150% and the *GPI* min. 0.75 (U.S. Wheat Associates 2021). In contrast, the SRC profile of wafer wheat flour is characterised in both references by lowered limits (in the case of *LA-SRC*, for example, to ≥ 87% and between 80–100%, respectively), due to the processing of dough with different viscoelastic properties. With *LA-SRC* and *GPI* equal to 118.2% and 0.662, the WW wheat control met the limits of the AACC norm, but these values were about one-fifth and one-tenth lower compared to the standard of the U.S. Associates.

Within the 11-member set, the measured *LA-SRC* values demonstrated a convex course with a trough for the blends 80 WW : 20 RB and 70 WW : 30 RB. In Figure 1, the decrease in *LA-SRC* had a steeper slope than its gradual recovery to values close to the WW control (i.e. 111.3% for the 10 WW : 90 RB blend and 110.5% for the RB control). In verification of the pilot study, additional solvents such as ethanol, sodium dodecyl sulphate (SDS), metabisulphite (MBS), or even a combination of SDS + MBS could be tested simultaneously to confirm or reject the linearity of the recorded values. Pilná (2022) modelled the quality of common wheat white flour by mixing a low-gluten wafer type with a high-gluten pizza type and recognised that ethyl alcohol $EtOH_{65\%}$-*SRC* at a flour dose of 5.0 g, as well

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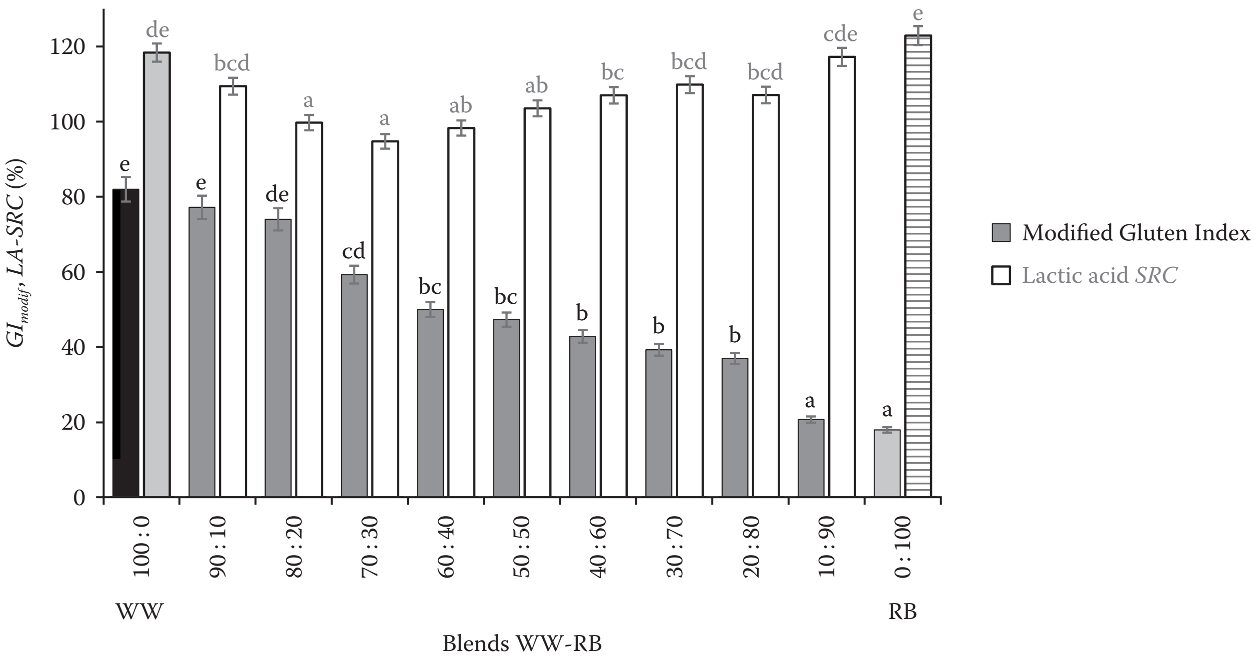

Figure 1. Comparison of protein quality according to the parameters lactic acid Solvent Retention Capacity (*LA-SRC*) and modified Gluten Index (GI_{modif}) for wheat white flour (WW), rye bread flour (RB), and their 9 blends

a–e – columns denoted with the same letter indicate statistically similar averages (*P* = 95%)

as *SDS-SRC* with 1.5 g of flour, have a prediction power as standard *LA-SRC*.

For the *GPI* parameter, a linear decreasing tendency was observed within the set of 11 members tested (Table 3). Due to this, the *GPI* has shown a higher prediction ability than the *LA-SRC* itself, and it is in agreement with the presumption of the authors of the revised method (Kweon et al. 2011). The calculated values ranged from 0.661 to 0.388, but a stepwise pair difference clearly decreased compared to a portion of the RB present in the blend. It could be explained by a loss of gluten as the primary water absorbent *versus* the many times higher absorption capacity of rye arabinoxylans, which seemed not to be strictly linear. Based on this, samples 100 WW : 0 RB (WW control) and blend 90 WW : 10 RB could be considered statistically distinguishable from the threesome 20 WW : 80 RB, 10 WW : 90 RB, and 0 WW : 100 RB only (group means 0.603 and 0.396; *P* = 95%).

Modified Gluten Index procedure – Testing of wheat flour, rye flour, and their blends

As mentioned in the footnote of Table 3, the weight of both flour controls and 9 WW-RB blends was adjusted in a range of 2.50 to 2.55 g. After the first centrifugation in the Eppendorf 5720 centrifuge, the weight of the swelling solid residue increased to 3.92–4.63 g (estimated absorption around 169%). These data did not show any significant trend, as the contributions of wheat gluten and rye fibre to water absorption would be levelled together. At the same time, the setting of the first centrifugation was sufficient to separate the majority of the solid phase in the 11 cases. The weight of the intermediate products of the second centrifugation, i.e. solid overflows and underflows, confirms a reverse relation with each other in terms of the supposed worsening of the technological quality (overflow parts diminishing). Regardless of this, amounts of centrifuged solvent did not show a linear tendency, probably the nearly symmetric convex one with trough for 50 WW : 50 RB sample.

The GI_{modif} was quantified as 82, 47, and 18% for WW, 50 WW : 50 RB, and RB, respectively (Figure 1). Based on the ANOVA results, the tested set could be sorted into three unique groups: *i*) 100 WW : 0 RB – 70 WW : 30 RB, *ii*) 40 WW : 60 RB – 20 WW : 80 RB, and *iii*) 10 WW : 90 RB – 0 WW : 100 RB, characterised by arithmetic means of GI_{modif} as 73, 40, and 20%, respectively. For the rest of the blends (70 WW : 30 RB – 50 WW : 50 RB), the arithmetic mean was equal to 49%.

Statistical analysis of data

Due to the 11-member set of tested samples and linear trends in the data, significant pair correlations

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Table 3. Gluten Performance Index (*GPI*) and modified Gluten Index (GI_{modif}) values for wheat white flour (WW), rye bread flour (RB), and their 9 blends

Flour/blend sample†	Solvent Retention Capacity profile	Modified Gluten Index				
		weight of interproducts (g)*				GI_{modif} (%)
	GPI (Equation 1)	solid rest after 1st centrifugation**	fractions after 2nd centrifugation***			
			solid rest (underflow)	solid rest (overflow)	centrifuged (solvent)	
100 WW : 0 RB	0.661 ± 0.012^{d}	4.11	0.65	3.10	0.36	82 ± 1^{e}
90 WW : 10 RB	0.546 ± 0.027^{c}	4.21	1.11	2.90	0.20	77 ± 7^{e}
80 WW : 20 RB	0.485 ± 0.021^{bc}	4.07	0.83	3.03	0.21	74 ± 6^{de}
70 WW : 30 RB	0.456 ± 0.009^{ab}	4.07	1.60	2.33	0.14	59 ± 0^{c}
60 WW : 40 RB	0.442 ± 0.010^{ab}	4.24	2.05	2.07	0.12	50 ± 0^{bc}
50 WW : 50 RB	0.445 ± 0.003^{ab}	4.27	2.25	1.91	0.11	47 ± 2^{bc}
40 WW : 60 RB	0.428 ± 0.010^{ab}	4.37	2.42	1.80	0.15	43 ± 0^{b}
30 WW : 70 RB	0.441 ± 0.019^{ab}	3.92	2.61	1.38	–0.07	39 ± 7^{b}
20 WW : 80 RB	0.404 ± 0.003^{a}	4.37	2.69	1.59	0.09	37 ± 0^{b}
10 WW : 90 RB	0.396 ± 0.006^{a}	4.63	3.26	1.07	0.30	21 ± 6^{a}
0 WW : 100 RB	0.388 ± 0.006^{a}	4.29	3.25	0.78	0.26	18 ± 2^{a}
Average SD (*N* = 11)	0.011% pt.	–	–	–	–	3% pt.

† Blend code 100 WW : 0 RB expresses a non-fortified WW flour; similarly, 0 WW : 100 RB indicates pure RB flour; * doses of raw material for the test (i.e. of flour or flour blend) maintained in the range 2.50–2.55 g; **, *** the first and the second centrifugation carried out by using of machines Eppendorf 5702 and the original Perten CF2015, respectively; a–e averages in columns, signed with the same letter, are not statistically different (*P* = 95%); SD – standard deviation; pt. – points

were highly provable (Table 4). In the pair *GPI*–GI_{modif}, the tightest relation $r = 0.821$ ($P = 99.9\%$) was found. Among the four *SRC*s, partial correspondence in measured data was verified in the *LA-SRC* – *SU-SRC* and *LA-SRC* – *SC-SRC*; this finding corresponds to the introduction of pentosans and damaged starch into wheat-based blends through additions of RB. Protein, dietary fibre, and ash in the blends also demonstrated

Table 4. Correlation analysis between the Solvent Retention Capacity profile, Gluten Performance Index (*GPI*), and modified Gluten Index (GI_{modif}) for wheat white flour, rye bread flour, and their 9 blends (*N* = 22)

Quality parameter	*LA-SRC*	*GPI*	GI_{modif}
LA-SRC	1	0.246^{ns}	-0.026^{ns}
GPI	0.246^{ns}	1	0.821^{***}
GI_{modif}	-0.026^{ns}	0.821^{***}	1
Quality parameter	*WA-SRC*	*SU-SRC*	*SC-SRC*
LA-SRC	0.339^{ns}	0.592^{**}	0.452^{*}
GPI	-0.737^{***}	-0.618^{**}	-0.718^{***}
GI_{modif}	-0.735^{***}	-0.698^{***}	-0.749^{***}
Quality parameter	*proteins*	*TDF*	*ash*
LA-SRC	0.016^{ns}	0.023^{ns}	0.010^{ns}
GPI	0.818^{***}	-0.857^{***}	-0.847^{***}
GI_{modif}	0.972^{***}	-0.974^{***}	-0.976^{***}

*, **, *** Pair correlation significant at *P* = 95, 99, and 99.9% (*N* = 22); ; ns non-significant pair correlation; *WA-*, *SU-*, *SC-*, *LA-SRC* – water, sucrose, sodium carbohydrate, and lactid acid Solvent Retention Capacity, respectively; *TDF* – content of total dietary fibre

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linear tendencies, so their positive correlations with *GPI* or GI_{modif} could be assumed in advance.

In their extensive study of wheat genotypes (N = 192), Ram et al. (2005) verified the links of *SU-SRC* and *LA-SRC* to the grain protein content (r = 0.55 and 0.56; P = 99.9%). Additionally, *SU-SRC* and *LA-SRC* could serve to predict the farinograph characteristics of dough: water absorption, dough development time, and dough softening degree (P = 99.9%). Similarly, the resistance of dough at the mixograph peak time was correlated with the grain protein content at the same probability level.

The method of principal components (PC) was based on a correlation matrix in which 9 variables and pair measurements of 11 samples were included. In summary, 30 out of 36 pair correlations with the *LA-SRC* were provable (83%); due to this, the first PC explained 75% and the second PC 18% of the data scatter. The remaining 7% of the information in the data, which could be neglected, was distributed among six additional PCs (PC3–PC8). The constructed biplot of variable loadings and sample scores (Figure 2) unequivocally clarifies the information originally included in the correlation matrix. In the set of WW-RB controls and their 9 blends, the opposite role could be observed between protein and dietary fibre contents. On the contrary, the content of dietary fibre and ash could alternate with each other. Within four items of the SRC profile, the *LA-SRC* had an outstanding role in sample discrimination, mainly

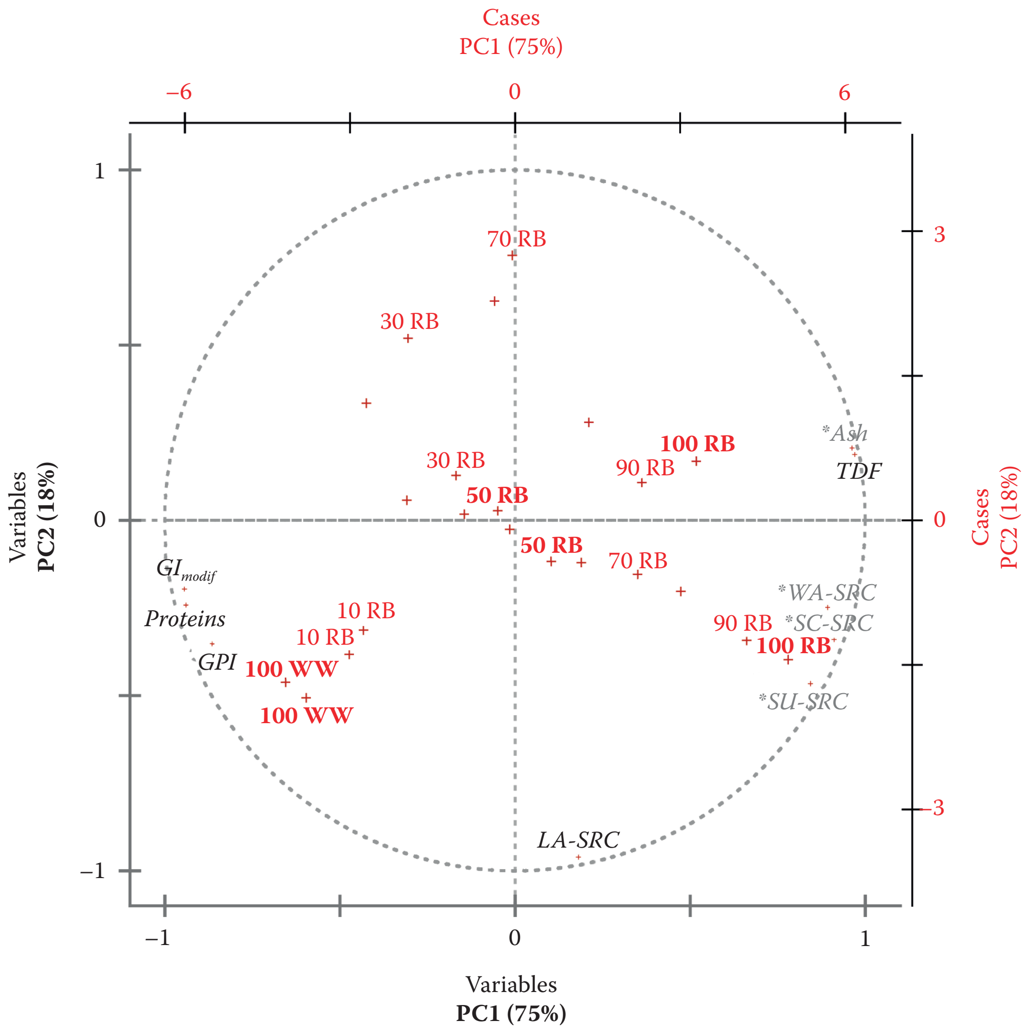

Figure 2. Biplot of principal components (PC) of protein quality in wheat white flour (100 WW), rye bread flour (100 RB), and their 9 blends (measured in pairs)

Comparison is based on basic chemical composition (*contents of proteins*, *TDF*, and *ash*), lactic acid Solvent Retention Capacity (*LA-SRC*), Gluten Performance Index (*GPI*), and modified Gluten Index (GI_{modif}); variables denoted with an asterisk [i.e. *ash content* and water (*WA-*), sucrose (*SU-*), and sodium carbohydrate (*SC-SRC*)] were considered as supplementary ones; *TDF* – content of total dietary fibre

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for wheat-rye counterparts (100–60% WW in flour blend; negative semiaxis PC1) and rye-wheat counterparts (40–0% WW in flour blend; positive semiaxis PC1). By linearisation of the *SRC* data (Equation 1), the *GPI* also allowed a correct qualitative description of the tested bi-composite materials. The closeness of GI_{modif} to the protein content and *GPI* leads to the conclusion that the modified procedure of the GI test may be useful for the first qualitative estimation of wheat flour-based mixtures.

CONCLUSION

The internationally approved Solvent Retention Capacity (SRC) profile (AACC method 56-11.01) is a small-scale test used for a complex description of absorption capacity of different wheat flour types, especially for their irreplaceable role in human nutrition. Wheat gluten consists of two fractions, linear prolamins and spatially arranged glutelins, whose technological importance lies in the formation of a dough skeleton able to capture fermentation gases and so produce fluffed-up bread. To estimate gluten quality, lactic acid *SRC* is measured and the Gluten Performance Index (*GPI*) could be calculated as an additional criterion. The SRC method basis lies in solid phase precipitation and centrifugation from a suspension. Concurrently, gluten quality could be quantified using another small-scale test, called the Gluten Index (GI) test (AACC method 38-12.02). The test has been known over 60 years; gluten is washed out on a grid from a dose of standard wheat flour or wholegrain counterpart by 2% aqueous solution of NaCl instrumentally, and separation by a centrifugation on inox sieve allows expressing the *GI* as an overflow-to-underflow ratio. The higher the portion of the former fraction, the higher the baking potential of the flour specimen tested. The pilot study offered a variation of the GI proof for the same quality testing of blends prepared from common wheat and rye bread flour. As 10% of the rye flour in the wheat blend clogged the washing-out sieve, an alternative step was based on precipitation and centrifugation similarly like in the SRC method. The sediment was centrifuged secondly in accordance with the original GI procedure, and the modified Gluten Index (GI_{modif}) parameter was expressed also in the same way (overflow-to-underflow ratio). The results of both methods in a set of wheat and rye standards plus 9 specimens of their blends, namely the parameters lactic acid SRC–GPI–GI_{modif} *per contra* contents of proteins, dietary fibre and ash, confirmed a closeness of GI_{modif} to protein content and the *GPI* feature. The structure of wheat-rye and rye-wheat dough consists of a complex of polysaccharides and proteins cross-linked by the disulphide bonds and present ferulic acid. From the multivariate statistics of the principal components, qualitative closeness of the wheat flour control and tested blends with up to 30% of rye bread flour reflected a common practice in bakeries – original common wheat-rye bread usually contains 40% of rye flour, and such dough is still easily processable regardless of a higher recipe dose of water and potential dough stickiness.

However, the modified procedure should be checked by testing of different types of wheat and rye flour – wafer, cookie, bread, and especially wholegrain. In central and Eastern Europe, rye flour is traditionally processed and consumed – similarly like barley and oat fibre with proven nutritional benefit, also rye aids in human digestion and microbiome wellness. As the importance to increase the attractiveness of bakery products with high fibre content has emerged recently, a modified procedure could potentially help cereal researchers and bakery technologists predict the rheological behaviour of wholegrain dough types and the properties of wholegrain final products, in which the essential role of wheat gluten is limited by non-starch polysaccharides of hydrocolloid nature.

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