

BAKING QUALITY PREDICTION OF SPELT WHEAT BASED ON RHEOLOGICAL AND MIXOLAB PARAMETERS

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The aim of this work was to test the potential of Mixolab II in the baking quality prediction of five *Triticum spelta* L. cultivars grown during growing periods with different climate conditions. Spelt cultivars varied in flour and dough properties examined by indirect baking quality indicators (wet gluten content, Falling number, Zeleny sedimentation, farinograph rheological properties, Mixolab parameters) and direct baking test, strong effect of climatic conditions was determined. Results showed significant differences in protein and starch – amylase part of Mixolab II curve, indicating the genotype and climatic effect. Spelt cultivars were characterised by high protein weakening (C2=0.32 Nm), speed of protein network weakening at the level of $\alpha = -0.07 \text{ Nm min}^{-1}$, starch gelatinisation (C3=1.61 Nm), amylolytic activity (C4=1.35 Nm), and starch retrogradation (C5=1.98 Nm). Significant correlations between indirect baking properties, farinograph and Mixolab II parameters, and direct baking test were found. Slope α of Mixolab curve was a promising parameter in estimation of direct baking parameter – specific bread volume, together with indirect indicator – Zeleny sedimentation.

Keywords: *Triticum spelta* L., Mixolab, grain and flour quality, baking quality prediction

The increasing demand for nutritionally healthy food products, the asserted therapeutic properties of foodstuff, the need for crop diversification have led to a renewed interest in ancient wheats such as einkorn, emmer, or spelt (ARZANI & ASHRAF, 2017). The study of BÉKÉES and co-workers (2017) summarizes the up-to-date knowledge on cereals-related health disorders and highlights the potential of developing “healthier” spelt-based cereal products.

Spelt grain has high nutritional value, but the rheological properties of dough made from spelt flour remain insufficiently investigated (WIWART et al., 2017). The bread making quality of wheats can be evaluated by various quality tests. The evaluation of flour and dough characteristics can be conducted using traditional rheological instruments such as Farinograph, Extensograph, Alveograph, and others. The most reliable method is direct baking test, however, it is time-consuming, requires skilled personnel, and is difficult to use for commercial purposes. Therefore, other quick methods are needed to test the suitability of

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flours in terms of baking quality (KOKSEL et al., 2009). A new rheological device – Mixolab has been developed that enables to describe the dough consistency during heating and cooling period. The apparatus measures both flour protein and starch characteristics and provides information about protein breakdown, starch gelatinisation, enzyme activity, and gel strength in a single test (DUBAT, 2010). Mixolab was used for e.g. to predict the cookie and cake quality (KAHRAMAN et al., 2008; OZTURK et al., 2008), the effects of antioxidants on dough mixing properties (ABDEL-SAMIE et al., 2010), the effect of linseed fibre on wheat flour pasting, dough properties, and bread quality (ŠVEC & HRUŠKOVÁ, 2018), etc.

The information related to Mixolab utilization on different aspects of hulled wheats' flour quality, influencing the quality of finished products, are limited.

The objectives of presented study were to evaluate the *Triticum spelta* L. cultivar on their properties related to technological grain, flour, and direct baking quality, to test the potential of Mixolab in the quality evaluation, to examine the relations between technological quality parameters, Mixolab parameters, and baking test for the prediction of spelt bread making quality, and finally to evaluate the influence of environmental conditions on the parameters under study.

1. Materials and methods

1.1. Field trials and experimental design

Field experiments were carried out at the Slovak University of Agriculture in Nitra – SUA (48°19'N, 18°07'E) as randomised – block experiment, in four replicates. The elevation of the experimental area is 177–178 meters above sea level, with continental climate, belongs to warm agro-climatic region, arid subregion with predominantly mild winter with average long-term (1961–1990) annual precipitations of 532.5 mm. Winter spelt wheat varieties were cultivated under the ecological farming conditions, within the crop rotation: common pea, spelt, spring barley. The experimental material comprised 5 winter pure spelt varieties (Altgold, Ostro, Oberkulmer Rotkorn – Swiss varieties, Ebners Rotkorn – Austrian, Rubiota – Czech variety). Grain and flour qualitative traits were analysed during two consecutive growing periods (2014–2015).

1.2. Quality traits

Indirect baking quality indicators were determined in four replicates. Wet gluten (G_{tot}) was analysed by Glutomatic 2200 (Perten Instruments, Sweden) according to the ICC 155 method. Sedimentation value (Zeleny in ml, ZT) was determined using Shaker – Type SDZT4 apparatus (Santec, Slovakia) in accordance with ICC 116/1.

The rheological properties of dough were assessed using Brabender Farinograph (Brabender, Germany), to determine the dough development time in minutes (DDT), stability of dough in minutes (DS), and dough softening after 12 min in FU (SD).

Baking test was performed according to the ICC 131 method at the water level of Farinograph absorption with some modifications, with the baking formula: flour (600 g, 14% moisture basis), compressed yeast (9.46 g), salt (7.89 g), and sugar (9.78 g). Doughs were mixed for 3 min in KitchenAid 5KSM 150 equipment (KitchenAid, USA), left to rise for 30 min in fermentation chamber. The dough was punched, moulded, put into a baking pan, and left for fermentation for another 90 min. Doughs were baked for 20 min at 225 °C (UNOX

XF 195, Italy). Baking tests were performed in triplicate. Bread volume was determined by the rapeseed displacement method (AACCI 10-05.01) using volumeter OBK (Mezos, Czech Republic) and specific loaf volume (SLV) was calculated.

Dough mixing and pasting behaviours were analysed in flour using the Mixolab II (CHOPIN Technologies, France), according to the AACCI International Method 54-60.01 (DUBAT, 2010). The parameters evaluated at Mixolab curve:

Torque C1 – maximum point of the first mixing phase

Torque C2 – end point of the phase 2, protein weakening

Torque C3 – end point of the phase 3, the rate of starch gelatinisation

Torque C4 – end point of the phase 4, amylolytic activity and hot gel stability

Torque C5 – end point of the phase 5, starch retrogradation in the cooling phase

C3–C4 – shows amylase activity and is linked to Falling number

Slope α – between end of 30 °C period and C2 – speed of the protein weakening under heating effect

Slope β – between C2 and C3, indicator of pasting (gelatinisation) speed

Slope γ – between C3 and C4, enzymatic (α -amylase) degradation speed

1.3. Statistical analysis

Collected data were subjected to multifactorial analysis of variance, significant differences between factors were determined by F-test at * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$ probability levels. When significant, it was followed by Fisher's least significant difference test at $P < 0.05$, to identify significantly different means. Correlation analysis were applied in order to evaluate the strength of the correlation between the parameters under study at a significance level of $P < 0.01$. The statistical analyses were performed with the software STATISTICA version 10.0 (StatSoft, USA).

2. Results and discussion

Indirect parameters used for evaluation of the quality and baking value of flour are gluten content and its quality. Total gluten content (G_{tot}), Zeleny sedimentation (ZT) mean values of spelt cultivars were 35.18–40.38% and 19.50–28.17 ml, respectively (Table 1), with significant differences between cultivars, growing years, and their interaction. Influence of climate conditions was recorded; in 2015, lower precipitations and higher temperature during grain filling resulted in significantly higher G_{tot} and ZT. The highest G_{tot} of all tested wheat species (*Tr. aestivum*, *durum*, *spelta*, *dicoccum*) reported by RACHOŇ and co-workers (2016) was found for spelt, but low gluten index (25) indicated that spelt was weak for bread production.

Farinograph rheological properties such as dough development time (DDT), dough stability (DS), and softening of dough (SD) confirmed great differences among cultivars, which exhibited the characteristics of weak to strong flour, with significant influence of environmental conditions, cultivars, and their interaction. Higher values of SD indicate that dough will not be able to sustain long mechanical processing treatments. Strong wheat is characterised with longer DDT and higher DS. Spelt cultivars used in this study varied in flour and dough properties, therefore bread produced differed in the specific loaf volume (SLV), ranging from 372.07 cm³/100 g to 434.03 cm³/100 g. The best rheological properties were determined for modern cultivar Rubiota, with the highest values of DDT, DS and lowest

Table 1. Grain and flour quality parameters of *Tr. spelta* cultivars

Cultivar/Year	G _{tot} (%)	ZT (ml)	DDT (min)	DS (min)	SD (FU)	SLV (cm ³ /100 g)
Cultivar means±S _b						
Altgold	35.40±5.64 a	19.50±0.55 a	1.47±0.76 a	2.35±0.14 a	106.83±18.99 d	374.51±4.85 a
Ebners Rotkorn	35.18±1.51 a	23.83±2.40 b	2.03±0.03 b	3.39±1.32 b	91.17±25.84 c	372.07±15.46 a
Oberkulmer Rotkorn	40.38±3.89 d	28.17±1.72 d	2.58±0.69 c	5.48±1.33 c	60.83±6.79 b	434.03±24.80 b
Ostro	36.23±1.15 b	23.83±1.33 b	1.71±0.43 ab	3.24±0.09 b	87.00±5.22 c	378.29±17.38 a
Rubiota	38.05±6.16 c	25.33±6.25 c	2.82±1.18 c	6.24±1.71 d	48.17±8.57 a	378.40±22.58 a
Mean	37.05±4.38 ***	24.13±4.09 ***	2.12±0.85 ***	4.14±1.83 ***	78.80±25.92 ***	387.46±29.30 a ***
P cultivar						
Annual means±S _b						
2014	34.25±2.64 a	22.53±3.96 a	1.60±0.60 a	4.91±2.12 b	68.47±19.16 a	382.12±38.76 a
2015	39.85±3.99 b ***	25.73±3.67 b ***	2.65±0.74 b ***	3.37±1.08 a ***	89.13±28.21 b ***	392.80±14.64 b **
P year						
P cultivar × year						

Note: G_{tot}: gluten content, ZT: Zeleny test, DDT: dough development time, DS: dough stability, SD: softening of dough, SLV: specific loaf volume. Values in column followed by different letters are significantly different at P<0.05. Mean values and standard deviations (S_b) are shown.
 : P<0.01; *: P<0.001

SD, but the highest SLV was achieved by cultivar Oberkulmer Rotkorn, with the best ZT and second best parameters of DS and SD. SCHÖBER and co-workers (2002) pointed out the relationship between baking results and gluten properties of 27 European spelt cultivars, great diversity within spelt material, but also similarities between several cultivars were determined. Differences between *T. spelta* technological properties of grain and flour and common wheat were confirmed by BODROŽA-SOLAROV and co-workers (2009) and KONVALINA and co-workers (2014) in higher gluten (30.2–54.4%), higher protein content (12.37–19.4%), but lower Gluten index (4.0–52%), high variability in ZT (18.9–35 ml), which indicates differences in terms of bread making quality.

The Mixolab process has the advantage of being able to measure properties of proteins, starch, and associated enzymes in one test. The Mixolab results are summarised in Table 2 and in Figure 1. At the beginning of heating, decrease in dough consistency is the result of protein weakening. The greater the decrease in consistency, the lower the protein quality (SCHMIELE et al., 2017). C2 values were significantly affected by cultivar, growing year, and their interactions. The mean C2 value was 0.32 Nm, the highest value was recorded for Rubiota (0.39 Nm). C2 values below 0.4 Nm indicates that dough from this wheat species can be less tolerant to mixing. Good quality proteins are represented by C2 0.5–0.6 Nm. The difference C1–C2 was significant for all factors and interaction, averaging 0.78 Nm, the lowest value, indicating stronger gluten properties, was determined for Rubiota. In the study of WIWART and co-workers (2017), C2 values for pure spelt cultivars were 0.4 Nm, which suggests that the resulting dough is less tolerant to mixing. Slope α , as an indicator of the speed of the protein network weakening due to the effects of heat, varied from $-0.04 \text{ Nm min}^{-1}$ to $-0.11 \text{ Nm min}^{-1}$, the factor cultivar was significant with lowest value for Rubiota cultivar.

Starch properties such as gelatinisation (C3), amylolytic activity (C4), and starch retrogradation (C5), determined by Mixolab II, were significantly influenced by both experimental factors. Maximum value of torque in the heating phase C3 averaged 1.62 Nm and was the highest for Rubiota, indicating higher starch gelatinisation temperature and higher dough viscosity. Stability of the hot paste in the test, phase C4 – when consistency decreases as a result of amylolytic activity, was the highest for Rubiota and Ostro (1.51 Nm). Difference between C3 and C4, the stability of the starch gel when heated, was not influenced by experimental factors. Higher torque in the phase C5, a measure of retrogradation of starch molecules in the dough during cooling stage of cultivars Rubiota and Altgold indicates lower amylolytic activities of these cultivars.

Correlations were determined between Mixolab parameters and bread quality parameters to identify those Mixolab parameters, which can demonstrate the suitability for estimating bread making quality (Table S1). Strong correlation was found between Farinograph DS and C2 ($r=0.69$), medium strong between DS and C3 ($r=0.62$) and DS and C5 ($r=-0.60$). Medium strong correlations were determined for SD and C2, C3, and C5 (negative). The only Mixolab parameter strongly correlated with specific loaf volume was slope α ($r=-0.71$), showing the importance of protein weakening speed in bread volume. Medium strong correlation between C5 and SLV indicated the role of starch phase – retrogradation and amylolytic activity for bread making quality. The promising parameter for direct baking quality of spelt is ZT, strong correlation with SLV ($r=0.75$) was found. The rheological properties of spelt dough, analysed by Mixolab test, and their relation to other indirect and direct baking quality indicators have not yet been sufficiently investigated and reported in the scientific literature. By other researchers, different results are reported, depending on cereal species, cultivars, pedo-

Table 2. Mixolab parameters of spelt wheat in relation to protein and starch characteristics

Cultivar/Year	C2 Nm	α Nm min ⁻¹	C1-C2 Nm	C3 Nm	C4 Nm	C3-C4 Nm	C5 Nm
Cultivar means \pm S _b							
Altgold	0.28 \pm 0.03 a	-0.07 \pm 0.01 b	0.82 \pm 0.05 c	1.63 \pm 0.01 a	1.31 \pm 0.08 a	0.32 \pm 0.08	2.83 \pm 0.22 b
Ebners Rotkorn	0.27 \pm 0.02 a	-0.07 \pm 0.02 b	0.82 \pm 0.02 c	1.65 \pm 0.14 a	1.33 \pm 0.36 a	0.32 \pm 0.22	2.23 \pm 0.80 a
Oberkulmer Rotkorn	0.34 \pm 0.04 c	-0.11 \pm 0.02 d	0.75 \pm 0.04ab	1.61 \pm 0.05 a	1.34 \pm 0.03 ab	0.26 \pm 0.03	1.97 \pm 0.03 a
Ostro	0.33 \pm 0.08 b	-0.08 \pm 0.02 c	0.78 \pm 0.11bc	1.66 \pm 0.16 a	1.51 \pm 0.19 b	0.15 \pm 0.03	2.27 \pm 0.53 a
Rubiota	0.39 \pm 0.05 d	-0.04 \pm 0.02 a	0.71 \pm 0.05 a	1.80 \pm 0.24 b	1.51 \pm 0.01 b	0.29 \pm 0.25	2.96 \pm 0.43 b
Mean	0.32 \pm 0.07	-0.07 \pm 0.03	0.78 \pm 0.07	1.67 \pm 0.15	1.40 \pm 0.20	0.27 \pm 0.16	2.45 \pm 0.59
P cultivar	***	***	***	**	*	ns	***
Annual means \pm S _b							
2014	0.36 \pm 0.08 b	-0.07 \pm 0.04 b	0.73 \pm 0.07 a	1.78 \pm 0.14 b	1.52 \pm 0.14 b	0.26 \pm 0.15	2.81 \pm 0.49 b
2015	0.29 \pm 0.03 a	-0.07 \pm 0.01 a	0.82 \pm 0.05 b	1.56 \pm 0.05 a	1.28 \pm 0.17 a	0.28 \pm 0.17	2.10 \pm 0.45 a
P year	***	***	***	***	***	ns	***
P cultivar \times year	***	***	**	ns	ns	ns	**

Note: Values in column followed by different letters are significantly different at P<0.05. Mean values and standard deviations (S_b) are shown, ns: not significant.

** : P<0.01; *** : P<0.001

climatic conditions, intensity of technology, etc. RACHOŇ and co-workers (2016) found correlations between C_s , difference C_s-C_2 and G_{tot} , DHAKA and co-workers (2012) between C_2 and SLV for common wheat. In the work of WIWART and co-workers (2017), the difference C_s-C_2 was more strongly correlated with spelt protein content ($r=0.79$) than other Mixolab parameters. KYPTOVA and co-workers (2017) reported noticeably slower starch gelatinisation speed of spelt wheat than common wheat and lower slope γ , therefore spelt dough requires shorter time of baking and lower temperature.

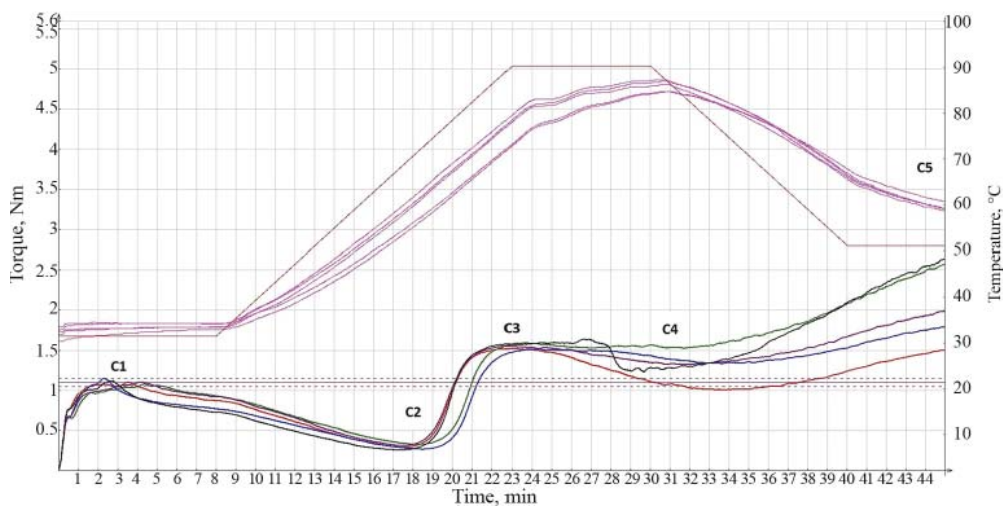


Fig. 1. Example of Mixolab curves of spelt cultivars

-----: Altgold; - - - - -: Rubiota; - - - - -: Oberklumer Rotkorn; - - - - -: Ostro; - - - - -: Ebners Rotkorn

3. Conclusions

Results of the study indicated that Mixolab II can be used to predict the baking quality of *Triticum spelta* and differentiate the genotype and climate conditions for quality characteristics. Genotypes and climatic factors affected the parameters related to the protein and starch properties of Mixolab II curves. Results indicated significant positive and negative correlations between Farinograph, Mixolab, and direct baking quality indicators. Strong correlation between Farinograph DS and C_2 demonstrated the suitability of Mixolab II for bread making quality prediction of spelt flour. Slope α was also promising Mixolab parameter, showing the importance of protein weakening speed in estimation of direct baking parameter – bread volume of spelt, together with indirect baking quality indicator Zeleny test.

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