



The Qualities of Albanian Soft Wheat Genotypes – the Mathematical Approach

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Abstract: The purpose of this study was to evaluate some of the soft wheat genotypes cultivated in Albania, concerning the technological and rheological characteristics of the produced dough, in regard to further cultivation. The obtained results for the soft lines of wheat collected during the summer seasons of 2013 and 2014 showed high contents of protein (13.36% - 17.42%), also strong water absorption capacity (59.70%-67.40%) with high values of Mixolab parameter C2 (0.24Nm–0.54Nm), thus predicting good protein quality and very strong gelatinization C3 (1.42Nm–1.96Nm). With the exception of genotype PZA 4, the other genotypes were characterized by quite high viscosity when cold (retro gradation) (1.54Nm–2.96Nm). The statistical evaluation showed that wet gluten content has a statistically significant negative correlation with Mixolab parameters C2 ($r = -0.607$, $p < 0.01$), while the stabilities of the dough showed statistically significant correlation with protein content and gluten index ($r = -0.543$ and $r = 0.551$, respectively).

Keywords: Soft Wheat, Dough Quality, Mixolab, Zeleny Sedimentation, Principal Component Analysis

1. Introduction

Wheat is the most widely used grain in the Balkans, which is mostly used for the production of bread, pasta and other products. Numerous parameters like the milling, chemical, baking and rheological parameters of wheat influence dough quality; however the cultivar type is one of the more important factors (Borghi *et al.* 1997, Panozzo and Eagles, 2000, Lopez-Bellido *et al.* 2001; Garrido-Lestache *et al.* 2004).

Determining the rheological properties of wheat flour and dough is essential for the successful manufacturing of various bakery products because they determine the behavior of dough during mechanical handling, thereby affecting the quality of the finished products (Haros *et al.* 2006). During the baking process the flour components are subjected to mechanical work and heat treatment that promote changes in their rheological properties (Bollain&Collar, 2004). Investigations into flour and dough characteristics have been conducted using traditional instruments like a Farinograph

(Shuey 1972), Alveograph (Faridi and Rasper 1987) and Extensigraph (Rasper and Preston 1991), which provide practical information for the baking industry. The Mixolab is a relatively new instrument used for determining the rheological quality of dough. During dough processing, Mixolab measures the physical parameters (water absorption, dough development time, stability of the dough, protein network weakening, mechanical and thermal degradation) and the state of the starch behavior during gelatinization and retro gradation.

All these parameters give us complete characterizations of the flours in terms of protein qualities (Collar *et al.* 2007, Kahraman *et al.* 2008). The rheological and gelatinization properties of wheat grown in the United States were evaluated using Mixolab by Manthey *et al.* (2006). In their study considerable variability was discovered in terms of protein qualities and starch pasting properties, which indicated that Mixolab could be used for determining wheat quality. Kahraman *et al.* (2008) and Ozturk *et al.* (2008) used

Mixolab to predict the qualities of cookies and cakes, respectively. On the other hand, it was found that the parameters obtained by Mixolab showed high correlation between the physicochemical, classical rheological and viscoelastic parameters, like the gluten index (Dapčević *et al.* 2009).

The objective of this paper was to evaluate certain new genotypes of wheat related to chemical and rheological characteristics which are very important for good quality of the finished product.

2. Materials and Methods

2.1. Materials

The wholegrain wheat flour samples were obtained by milling 10 lines of soft wheat (PZA 1, PZA 2...PZA 10) on an experimental automatic mill (Fritch, Pulverisette 14). The soft wheat lines were grown during the years 2012–2013,

2013–2014 within the Experimental Didactics Economy (E.D.E) of the Agricultural University of Tirana (latitude 41°19'39"N, longitude 19°49'08"E; average altitude 89m). Each plot was planted in five rows; the plot size being 5 m×1.2 m. The soil reaction was slightly alkaline (pH = 7.80), the humus and nitrogen contents were 2.20 % and 0.15 % respectively.

2.2. Climatic Conditions During the Growth Seasons

The climatic conditions during the experiment are shown in Table 1. Average temperatures were similar during first (13.5 °C) and second (13.7 °C) investigated years. In the first year 2012-2013 the amount of precipitation (1093.7 mm) was almost twice as high as in the second year 2013-2014 (591.6 mm). The differences were mainly during the winter period when the plants were in hibernation, which did not significantly influence plant growth.

Table 1. Monthly and mean temperatures and monthly and cumulative precipitation for the two growing seasons (2012 - 2014).

Temperature/Precipitation	Period	Dec	Jan	Feb	Mar	Apr	May	Jun	Xm	CT
(°C)	2012-13	7.7	8.1	8.9	11.4	16.4	19.6	22.1	13.5	
(°C)	2013-14	8.9	10.3	11	12.3	13.8	17.1	22.3	13.7	
(mm)	2012-13	203.7	209	232.8	261	54.2	81.2	51.8	156.2	1093.7
(mm)	2013-14	11.2	127	71.8	73.6	111.8	140	56.2	84.5	591.6

CT-cumulative precipitation, X_m- means temperatures and precipitation

2.3. Chemical Analyses

Moisture content and ash were analyzed using the AOAC (1995) methods 44-10 and 08-01, respectively. The wet gluten and gluten index values for all flour samples were determined by using the Glutamic system (Patern Instrument AB, Stockholm, Sweden) and according to the AACC (2000) method 38-12.02. The total nitrogen was measured using the Kjeldahl method (AACCI 46 – 30, 01) which is converted into protein content when multiplied by the conversion factor 5.7; the sedimentation value (K-SDS) was determined according to Zeleny (Zeleny, 1947) and the starch content following the Megazyme starch determination procedure (Megazyme International, Ireland Ltd.). All solutions, reagents and buffers were prepared as described in the instructions given by Megazyme. For each sample the determination was performed on 100mg of sample. All the samples were analyzed in duplicate.

2.4. Rheological Properties

Rheological attribution was analyzed with Mixolab Chopin +, which simultaneously determines dough characteristics during the process of mixing at constant temperature, as well as during the period of constant heating and cooling. It measures the torque (Nm) produced by mixing the dough between the two kneading arms (Anonymous 2005). The rheological properties were measured in real-time, thus allowing the study of rheological and enzymatic parameters, like dough rheological characteristics (hydration, capacity, development time), protein reduction, enzymatic activity,

gelatinization and starch gelling. The procedure followed for analyzing the mixing and pasting behavior to the Mixolab was the following: dough weight 75.0g, mixing rate speed 80rpm, tank temperature 30 °C, heating rate 2 °C/min, total analysis time 45 min.

2.5. Statistical Analyses

Descriptive statistical analyses were performed for all the obtained results. All chemical and physical measurements were performed over three repetitions. Pearson's correlation between assays, the analysis of variance (ANOVA) and Principal Component Analysis (PCA) of the obtained results were performed using StatSoft Statistica 10.0 software. Significant differences were calculated according to post – hoc Tukey's (HSD) test at $p < 0.05$ significant level, 95% confidence limit. Further, principal component analysis (PCA) was applied successfully to classify and discriminate between the different cultivars of wheat. PCA was applied within the results descriptors in order to characterize and differentiate between all the varieties of wheat. In order to get a more complex observation of the rankings regarding wheat qualities, standard scores (SS) were evaluated. Min-max normalization is one of the more widely used techniques for comparing the various characteristics of complex food samples determined using multiple measurements, where samples are ranked based on the ratios of raw data and the extreme values of the used measurements. Since the units of the data scale from various rheological, chemical and Mixolab characteristics are different, the data in each data set should be transformed into normalized scores, according to

the following equations (Sun and Tanumihardjo 2007)

$$\bar{x}_i = 1 - \frac{\max_i x_i - x_i}{\max_i x_i - \min_i x_i}, \quad \forall i \quad (1)$$

in cases of “the higher, the better” criteria, or

$$\bar{x}_i = \frac{\max_i x_i - x_i}{\max_i x_i - \min_i x_i}, \quad \forall i \quad (2)$$

in cases of “the lower, the better” criteria where x_i represents the raw data. The normalized scores of samples for different measurements when averaged provide a single unit less the value termed as SS, which is a specific combination of data from different measuring methods with no unit limitation.

3. Results and Discussion

The moisture content within the analyzed flour samples ranged from 10.50 % (PZA 2) to 13.57% (PZA 7) for the year 2012-2013 and from 12.21% (PZA 1) to 13.13% (PZA 2) for the year 2013-2014. The ash content was high, ranging from 1.39% (PZA 1) to 1.90% (PZA 9) for the year 2012-2013 and for the year 2013-2014 this parameter ranged from 1.33% (PZA 1) to 1.84% (PZA 4) (Table 2).

The moisture and ash content, wet gluten content, gluten index, protein and starch contents, as well as K-SDS were influenced by the year and the genotype. All the lines presented during the two years of this study reached high protein contents (13.36% for PZA8 to 16.41% for PZA3 for the year 2012-2013 and 13.36 % for PZA 8 to 17.42% PZA 9 for the year 2013-2014) and generally a high content of wet gluten. Protein content and composition of wheat is the most important criteria in the determination of wheat quality (Bilgin *et al.* 2005). In addition the importance of the protein content lies in the ability of gluten to produce dough with the desired rheological properties. The content of proteins displayed content of protein could have been due to the

presence of a bran fraction (seed coat and embryo) within the wholegrain wheat flour analyzed during this study. The starch content ranged from 49.50% for line PZA 5 to 58.75% for line PZA 1 (for the year 2012-2013) and from 53.24% (PZA 2) to 66.46% (PZA 10) for the year 2013-2014. The Gluten Index (GI) methods are relatively new methods for determining the gluten quantities and qualities in wheat (AACC 2000). The gluten GI value expresses the mass fraction of gluten remaining on a sieve after automatic washing in a salt solution and centrifugation (Curic *et al.* 2001, Dowell *et al.*, 2008). According to Curic *et al.* 2001, 60 <GI< 90 provides the optimum bread making quality for Central European cultivars. The Gluten index was the highest in PZA 5 (94.33%–95.60%) on average for all lines and years and the lowest in PZA 4 (23.37%–25.30%).

According to Curic *et al.* 2001, the lines PZA 1, PZA 3, PZA 5 and PZA 10 provide optimum bread making qualities for two successive years. The indices of the Gluten index were significantly different within ten lines of soft wheat, thus suggesting differing baking properties. The wheat genotype is considered the most important factor influencing the characteristics of gluten and consequently the value of GI (GI value) (Simic *et al.* 2006).

In addition to GI, another important test used to discriminate between wheat genotypes based on their gluten qualities and protein quantities is Zeleny sedimentation (K-SDS sedimentation volume) (Carter BP *et al.* 1999). Zeleny sedimentation as an average for both years was the highest in PZA 5 (50.99 ml). The bread making qualities of the wheat depend on the content and quality of protein within the grain (Lasztity, 2003), meaning that a high content of protein and respectively the amount and quality of gluten exert a very positive effect on the volume and shape of the bread (Pomeranz, 1998). In our investigation significant differences among cultivars and years were identified for sedimentation value and gluten index.

Those results agreed with the findings of Geleta *et al.* 2002, who reported significant differences among the environments and genotypes of wheat.

Table 2. Descriptive statistics for the physical and chemical attributes of the flours obtained from 10 lines of wheat.

Year	Parameter	Moisture content(%)	Ash (%)	Wet gluten (%)	Gluten index (%)	Protein content (%)	Starch content (%)	K-SDS (ml)
2012/2013	Average	12.58	1.61	28.94	56.75	15.00	55.60	50.40
	SD	0.84	0.17	3.19	25.83	0.89	3.06	5.83
	Min.	10.50	1.39	23.43	23.37	13.57	49.50	42.33
	Max.	13.57	1.90	33.20	94.33	16.41	58.75	61.33
	Variance	0.70	0.03	10.16	667.29	0.78	9.35	34.04
2013/2014	Average	12.68	1.59	28.83	56.58	15.25	58.26	38.17
	SD	0.29	0.16	3.76	26.04	1.55	4.85	4.68
	Min.	12.21	1.33	22.60	25.30	13.36	52.73	31.25
	Max.	13.13	1.84	34.15	95.60	17.42	66.46	47.32
	Variance	0.09	0.03	14.16	678.27	2.40	23.51	21.90
CV	1.54	1.23	1.75	0.64	0.10	9.40	2.73	
Polarity		-	+	+	-	+	-	+

Polarity: “+” = the higher the better criteria, “-” = the lower the better criteria

Table 3 presents the results obtained from the Mixolab. The wholegrain wheat flour analyzed in this study which, due

to the presence of the bran fraction (seed coat and embryo), had a high level of protein (table 1), was also characterized as

having higher water absorption (WA) which ranged from 60.6% (PZA 8) to 67.4% (PZA 9) and lower stability, which ranged from 3.37 min (PZA 9) to 10.03 min (PZA 5). The

high hydration capacity of the wholegrain flour was also reported by Tamara Dapcevic Hadnavac *et al.* (2011).

Table 3. Descriptive statistics for the Mixolab characteristics of the flour samples.

Year	Parameter	Stability (min)	C1 (Nm)	C2 (Nm)	C21 (Nm)	C3 (Nm)	C4 (Nm)	C5 (Nm)	Water Absorption (%)
2012/2013	Average	6.87	1.12	0.47	-0.65	1.81	1.50	2.51	63.01
	SD	2.12	0.04	0.04	0.07	0.08	0.12	0.35	1.87
	Min.	3.37	1.04	0.41	-0.73	1.71	1.29	1.83	60.60
	Max.	10.03	1.19	0.54	-0.54	1.96	1.74	2.95	65.20
	Variance	4.51	0.00	0.00	0.00	0.01	0.01	0.12	3.50
2013/2014	Average	5.62	1.11	0.35	-0.75	1.58	1.24	2.05	64.00
	SD	1.68	0.03	0.07	0.05	0.12	0.37	0.27	2.52
	Min.	3.40	1.06	0.24	-0.85	1.42	0.24	1.54	59.70
	Max.	7.77	1.14	0.46	-0.66	1.77	1.52	2.43	67.40
	Variance	2.81	0.00	0.00	0.00	0.01	0.14	0.07	6.36
Polarity		+	-	-	-	+	+	+	+

Polarity: “+” = the higher the better criteria, “-” = the lower the better criteria

On heating, the dough consistency decreases (C2) because of the aggregation and denaturation of proteins (Rosell and Foegeding, 2007). The softer lines of wheat showed high values of Mixolab parameter C1 (1.04Nm – 1.19Nm) and C2 (0.24Nm – 0.54Nm), which predicted a good protein quality (Banu *et al.* 2011). Also, the difference between Mixolab C1 and C2 values (C21) is related to gluten quality and higher values indicate weaker gluten properties. As heating proceeded, the increase in viscosity and thus in the torque is the result of the starch granules swelling due to the water uptake and amylase chain leaching into the aqueous intergranular phase (Rosell *et al.* 2010). All lines of soft wheat were characterized by strong starch gelatinization (C31 44Nm–1.96Nm) and quite high viscosity when cold (retrogradation) C5 (1.54Nm–2.96Nm). The physical breakdown of the starch granules due to the mechanical shear stress and the temperature constrains caused further reduction in viscosity (C4 value) (Arendt *et al.* 2002). From Table 3, it can be seen that the C4 parameter decreased for PZA 4 in the year 2013-2014. According to Banu *et al.* (2011), the C4 parameter is low for samples with high α -amylase activity.

Pearson’s correlation coefficients were calculated between the Mixolab parameters and the flour quality characteristics

(e.g. protein, starch and gluten index) for a better understanding of the types’ properties. Table 4 indicates a significant positive linear correlation between the protein quantity and wet gluten ($r = 0.519^*$). An increase in protein quantity resulted in an increase in gluten quantity in the flour. Similar results were reported by Curic *et al.* (2001). On the other hand, the correlation analyses showed that wet gluten content had a statistically significant negative correlation with Mixolab parameter C2 ($r = -0.607, p < 0.01$), while the stability of the dough showed statistically significant correlation between the protein content and gluten index ($r = -0.543$ and $r = 0.551$, respectively, $p < 0.05$). The stability of the dough was negatively correlated to wet gluten and water absorption, statistically significant at $p < 0.01$ level ($r = -0.565$ and $r = -0.617$, respectively). The protein content was positively correlated with water absorption ($r=0.836, p<0.01$), while the gluten index was negatively correlated with water absorption ($r = -0.552, p < 0.05$) (Table 4). Our results were in agreement with the observation of Kahraman *et al.* (2008) and Dapcevic *et al.* (2009), who indicated a significant correlation between the technological parameters and Mixolab characteristics.

Table 4. Correlation coefficient between Mixolab characteristics and certain technological parameters.

	C ₂	C ₂₁	C ₃	C ₄	C ₅	Stability	Protein	Gluten index	Wet gluten	Water absorption
C ₁	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
C ₂		0.900**	0.926**	NS	0.534*	0.549*	NS	NS	-0.607*	NS
C ₂₁			0.818**	NS	0.528*	0.595**	NS	NS	NS	NS
C ₃				NS	0.598**	0.589**	NS	NS	NS	NS
C ₄					0.512*	NS	NS	NS	NS	NS
C ₅						NS	NS	NS	NS	NS
Stability							-0.543*	0.551*	-0.565**	-0.617**
Protein								NS	0.519*	0.836**
Gluten index									NS	-0.552*
Wet gluten										NS

** Correlation is statistically significant at $p < 0.01$ level, * Correlation is statistically significant at $p < 0.05$ level, NS: Not significant.

We calculated standard scores for technological characteristics and also for the parameters obtained by Mixolab. The technological characteristics of SS are

presented on abscissa and the Mixolab characteristics are presented along the ordinate axis. Standard score analyses could be used as a reference for developing strategies for

improving the genotype characteristics. Scores above 0.5 stand for a high standard of physical and chemical characteristics, as well as of Mixolab values. The best overall standard scores (SS) over the two successive years were calculated for the line PZA 4 (0.69 for technological properties scored, and 0.54 for Mixolab), while the standard

scores for PZA7 were also above 0.5 over the two successive years (Figure 1). The dashed line in Figure 1 represents the overall SS limit of 0.5; samples located to the right from this line gained SS values above 0.5, while samples located to the left gained SS values below 0.5.

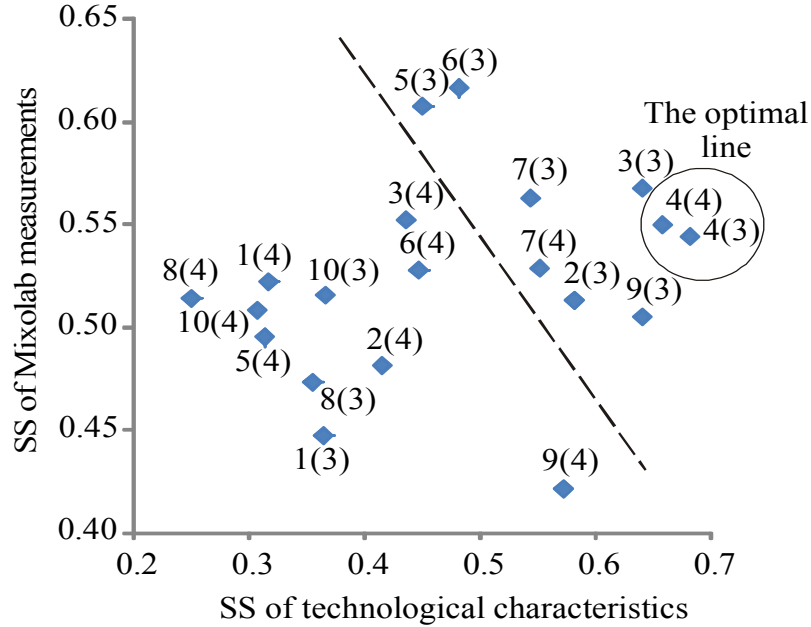


Figure 1. Standard Scores (SS) of technological characteristics vs. Standard Scores (SS) of Mixolab measurements for Albanian wheat lines. The numbers between 1 and 10 represent the wheat lines PZA 1-10 and the numbers between the brackets represent the seasons: 3 for 2012-2013 and 4 for 2013-2014.

The PCA allows a considerable reduction in the number of variables and the detection of structure in the relationship between measuring parameters and different lines of wheat that give complimentary information. The number of factors retained in the model for proper classification of experiment

data, in the original matrix regarding loading (wheat cultivars) and scores (technological characteristics and Mixolab values), the matrices were determined by applying Kaiser and Rice's rule (Bodroža-Solarov *et al.* 2014).

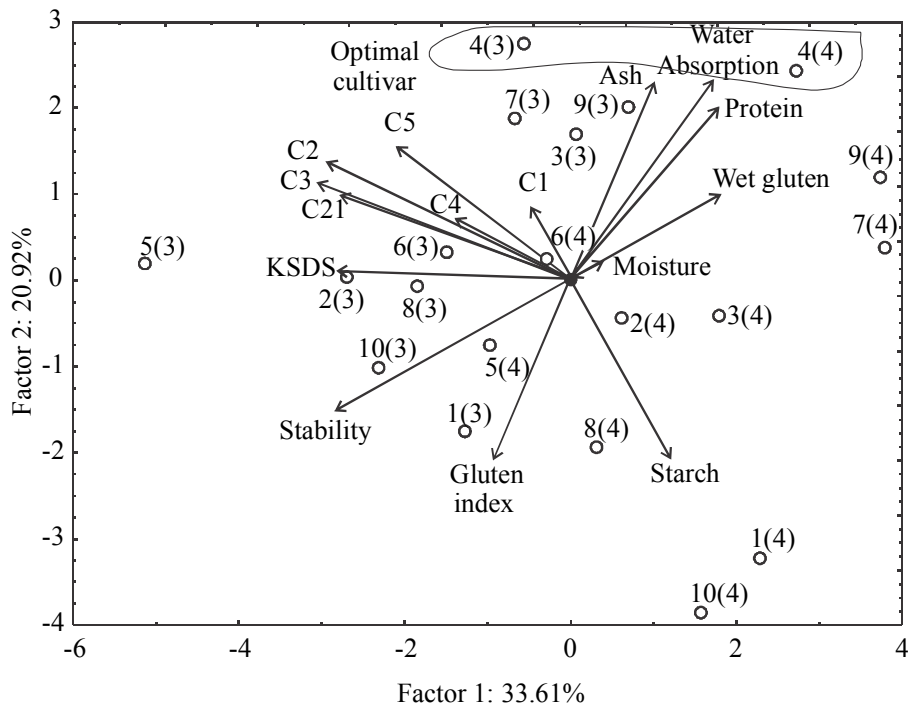


Figure 2. Bi-plot for the technological characteristics and Mixolab values of Albanian wheat lines.

This criterion retains only principal components with Eigenvalues > 1. The full autoscaled data matrix consisting of ten different varieties of wheat lines were submitted to PCA. For visualizing the data trends and the discriminating efficiencies of the used descriptors, a scatter plot of samples using the first two principal components (PCs) issued from PCA of the data matrix were obtained (Figure 2). As could be seen, there was a neat separation of the ten lines of wheat, according to the applied assays for technological quality and the Mixolab values. Quality results showed that the first two principal components, accounting for 54.53% of the total variability could be considered sufficient for data representation. PC1 correlated well with Mixolab parameters, C2 (the variable contributed 14.1% for PC1 calculation), C3 (15.1%), C4 (4.9%), stability (13.1%), while the second component PC2, correlated well with the technological parameters: ash content (15.2%), gluten index (11.7%), protein (11.4%) and starch content (11.8%).

4. Conclusion

The investigated quality parameters (protein content, sedimentation values, wet gluten content, gluten index, starch and rheological characteristics) varied significantly between genotypes and years. From the results of this research carried out under the same agro-ecological conditions, all the lines of soft wheat were characterized with high values of protein content and with significant variability of Zeleny sedimentation and gluten index values. All these lines also showed high values for C1 and C2 (dough development and the stability of protein) which predicted good protein qualities. Based on the obtained results of the chemical-technological indices and Mixolab characteristics for two successive years we can recommend as appropriate genotypes for further cultivation, the lines PZA1, PZA 5 and PZA10. This information and the results presented in this study could be used for developing programs on wheat cultivation in the future.

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