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Grain Quality of Spring and Winter Wheat of Kazakhstan

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ABSTRACT

The steppe region of Northern Kazakhstan grows more than 12 million ha of spring wheat, and approximately 1 million ha of winter wheat, with an average grain yield around 1.2-1.7 t/ha mainly under low input production conditions. The maturity group (growth period type) is an important trait affecting adaptation to moisture deficit but its relationship with grain yield is variable. The region exports wheat and therefore grain quality is an important factor to succeed in the export market. The objective of this study was to determine the grain quality characteristics of spring and winter wheat cultivars based on grain hardness and bread making quality-related parameters, of state multiplication yield trials conducted in 1996-2006 across 56 locations in Kazakhstan. In addition, cultivars were classified into wheat quality classes using the Kazakhstan classification system, and Kazakh wheat quality classes were compared with those of neighbouring and some major wheat-exporting countries. In general, Kazakhstan wheat is characterized by high protein (14-16%) and gluten (21-40%) contents, although its gluten strength is slightly weaker than that found in Australian wheat. Winter wheat cultivars showed higher variability in grain hardness than spring wheat cultivars. It is necessary to optimize the spring and winter wheat breeding programs for grain quality according to yield level and technological end-use (pastry, mechanic bread-making, tandyr bread, noodles, industrial biotechnology, etc.).

Keywords: grain hardness, glutenins, protein content

INTRODUCTION

Kazakhstan is an important bread wheat exporter due to its acceptable grain quality and high protein content characterizing the wheat crops (Shegebaev 1997). In order to improve the efficiency of the wheat sector, and to enhance the competitiveness of Kazakhstan wheat, it is necessary to establish compatibility between wheat grain quality standards used in Kazakhstan and those used in international wheat markets (Abugalieva *et al.* 1997).

The accepted system of wheat variety classification in Kazakhstan is based on evaluation of grain, gluten, flour, dough, and bread quality. The parameters used in this classification are: grain hardness and protein content – traits widely used by wheat grain-exporting countries; flour and dough handling properties such as balance of dough elasticity and extensibility measured with instruments such as alveograph, farinograph and viscoanalyzer.

State purchases of wheat grain for the internal Kazakhstan market and the Commonwealth of Independent States is carried out according to grain vitreousness (as a substitute of grain hardness); gluten content (as an indirect measure of protein content), and the gluten elasticity/extensibility balance.

The present classification used in the breeding system is compatible with several parameters included in the standards of the US and/or Canada (**Table 1**).

There are three major steps in breeding for improved grain quality: 1) Identification of wheat class based on growth habit, grain hardness, and grain color. Hardness can be evaluated by NIRS using calibrations in 1711-2206 intervals (Abugalieva and Dracheva 1998). Evaluation of protein quality is based on protein content and the sedimentation test. Within wheat classes, gluten quality can be partly estimated by determining high molecular weight glutenin subunit composition using SDS-polyacrylamide gel electrophoresis (SDS-PAGE). If near infrared spectroscopy (NIRS) equipment is available, the following gluten protein ratios could be measured: gliadin/glutenin ratio, $\alpha+\beta+\gamma/\omega$ gliadins as S-S–rich /S-S–poor proteins ratio, high molecular/low molecular weight glutenin ratio. Bread quality can be predicted by using equations including grain hardness, protein content, and sedimentation; 2) Evaluation of dough handling properties (by alveograph, farinograph, etc.) and their comparison with grain hardness, protein content and sedimentation test; 3) Final selection of genotypes based on the objectives of the breeding program and combination of grain yield with grain quality.

The objective of this study was to describe wheat cultivars by end-use requirements and grain hardness, to identify agricultural zones providing the best growing environment according to wheat classes (Abugalieva *et al.* 2001). In addition, Kazakh wheat cultivars were assessed in relation to international requirements to determine the quality traits that deserve further attention to develop quality-competitive wheat cultivars.

MATERIALS AND METHODS

77 commercial and perspective spring bread wheat cultivars from 1996-2006, yield trials and grown in 56 state nursery trials of North, West, Center and East Kazakhstan and 58 commercial and perspective winter wheat cultivars grown in 12 state nursery trials of South Kazakhstan.

Grain samples were tested on a Single Kernel Characterization System (SKCS 4100, Perten Instruments), to determine 1000-kernel weight (TKW), hardness index (HI), grain diameter, and grain moisture. Hardness was also determined by using NIRS (Pacific Scientific 4250) using the calibration developed by Abugalieva *et al.* (1998).

Grain and flour protein, sedimentation, and flour/dough properties were determined and statistical analysis was performed as described in Abugalieva *et al*. (2008).

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Research Note

Table 1 Grain quality parameters used in wheat breeding, testing, purchase, and export.

Grain quality traits	Breeding			State trials	Purchase	Export
	USA	Europe	KZ	Kazakhstan (KZ)		
Hardness	+		+	+		
Vitreousness			+	+	+	
Sedimentation: SDS	+	+				+
Sedimentation: Zeleny		+				+
Sedimentation: AC			+			
Protein content	+		+	+		+
Mixograph	+					
HMW glutenin subunit composition		+	+			
Gluten content and quality			+	+	+	+
Milling	+	+	+	+		
Gluten content (flour)		+				+
Protein content (flour)	+			+		+
Dough mixing properties (Farinograph)	+		+	+		
Dough strength and extensibility (Alveograph)		+	+	+	-	+
Grain sprouting susceptibility (Falling number)		+	+	+		+
Bread making quality	+	+	+	+		

RESULTS AND DISCUSSION

Spring wheat quality characteristics

Comparative analysis of Kazakhstan varieties classified by hardness in state trials and breeding programs showed a wide range of variation from soft type to very hard wheat classes (**Table 2**). In state trials and breeding programs medium-hard to hard wheat predominated in spring wheat (**Table 2**). Few super-hard spring wheat were encountered and soft wheat does not exist in Kazakh spring wheat.

16 out of 26 strong cultivars had a hard endosperm (‘Akmola 2’, ‘Kazakhstanskaja ranniespelaya’, ‘Kazakstanskaja 19’, ‘Kazakhstanskaja 25’, ‘Karagandinskaja 70’, ‘Kenjegali’ , ‘Luthescense 32’, ‘Tselinnaja 24’, ‘Tselinnaja Jubileinaja’, and ‘Tselinnaja 3c’). These strong spring cultivars meet the most restrictive international requirements and could be considered as competitive in the export market. Eight strong wheats were identified as medium-hard ‘Kazakhstanskaja 15’, ‘Karabalykskaja’, ‘Kutuluckskaja’, ‘Omskaja 18’, ‘Omskaja 19’, ‘Pavlodarskaja 93’, ‘Saratovskaja 29’, ‘Tselinnaja 26’. The American standard for hard wheats is satisfied by 52.5% of the commercial cultivars and 70% of the strong cultivars (Abugalieva and Dracheva 1999; Dracheva 1999). On the whole, 95.3% of all KASIP-4, 5 (of the Kazakhstan-Siberian Spring Wheat Improvement Network 2003-2004 crop) specimens belong to the class of hard and medium-hard, 3% to mixtures, and 1.7% to the semi-soft class. The next set (2005-2006 crop) genotypes includes mainly (>80%) hard and medium-hard forms (Abugalieva 2009).

On the quality score of Payne (Payne *et al.* 1987) based on high molecular weight glutenin (HMW-G) subunit composition, the commercial cultivars showed scores from 7 to 10 (7.8 on average), while perspective cultivars showed scores 5 to 10 (7.0 on average). Diversity level (H) was low - 0.27 and 0.39 for commercial and perspective cultivars, respectively. The frequency (%) of prevalent HMW-G subunits was as follows: subunit 2* (*Glu-A1*) - 68% and 61%; subunit 7+9 (*Glu-B1*) - 86% and 90%; subunit 5+10 (*Glu-D1*) - 46% and 57%; and subunit 2+12 (*Glu-D1*) - 44% and 33%, in commercial and perspective cultivars, respectively. The rare HMW-G subunit *Glu-D1* 5.5+10 was observed in three cultivars: ‘Akmola 3’, ‘Tselinnaya 24’ and ‘Tselinogradka’ (**Table 3**).

Although bread wheat grain quality is partly defined by the composition of gluten proteins, cultivars with identical glutenin formulas sometimes show different flour and dough properties, and different making quality. This is partly due to the fact that expression of the genetic grain quality potential of a cultivar depends partly on the environmental conditions and year of growth. Grain protein content in Kazakhstan spring wheat varies between 11.4 and 19.8% generally depending on genetic, environment factors and GxE interactions.

Table 2 Classification of Kazakhstan wheat varieties (trials, breeding) by hardness.

Wheat class	Spring				Winter	
	State trial		Breeding trials		State trial	
	1998	2005	2004	2006	1998	2005
Super hard	3	3	-	-	-	-
Hard	65	60	68	22	25	20
Medium hard	25	23	4	59	50	45
Mixed	7	9	17	19	12	15
Medium soft	-	5	9		13	13
Soft	-		-		-	8

Table 3 Distribution (%) of spring and winter wheat varieties from Kazakhstan and neighbor countries based on HMW glutenin subunits and according to the Payne quality score (Payne *et al.* 1987).

Country	10	9	8	7	6	5	4
Spring wheat							
Kazakhstan	8.2	40.4	2.0	44.4	1.0	4.0	-
Russia	5.0	32.5	12.5	47.5	2.5	-	-
Winter wheat							
Kazakhstan	23.6	54.6	12.7	7.3	1.8	-	-
Uzbekistan	10.5	63.1	10.5	5.3	5.3	-	5.3
Kyrgyzstan	22.5	50.0	17.5	7.5	2.5	-	-
Tadzhikistan	18.2	36.4	18.2	9.0	18.2	-	-
Turkmenistan	11.1	44.4	11.1	-	33.4	-	-

According to results of the Additive Main Effects and Multiplicative Interactions analysis (Gomez-Becerra *et al.* 2007) in the case of genetic gains for grain protein content, the high heritability h^2 value of 0.91 indicates that the estimated 1.6% of the grain protein gains after one selection cycle is close to the maximum theoretical gain of 1.7% (Gomez Becerra *et al*. 2007), which implies that increasing the number of testing environments will not necessarily allow to further select for higher than the current protein content levels achieved in the region.

Grain quality of Kazakh wheat was compared to Australian wheat (Abugalieva *et al.* 2008). Kazakh wheat is similar in hardness to Australian wheat (medium-hard to hard). Grain protein and ash content are higher and flour yield lower in Kazakh wheat. Wet gluten and gluten index of the three Kazakh samples are similar to APH (Australian Prime Hard) and AH (Australian Hard) grades, but extensi- and alveographs indicate that the Kazakh samples have strong gluten types with extensibility at least as good as the Australian APH and AH grades (Abugalieva *et al.* 2008). Considering that the Kazakh flour samples showed higher protein content than the AH grade, it appears that the gluten

Table 4 Average grain quality attributes of Kazakh cultivars and Australian wheat classes.

Grain quality / Trait	Omskaya 18	Saratov-skaya 29	Kazakh-stanskaya rannje-spelaya	Australian Premium Hard	Australian Hard	Australian Premium White
Protein, %	13.2	14.9	13.9	13.7	13.0	11.0
Falling number, sec	398	251	250	497	448	437
Extraction rate, %	75.3	73.3	73.6	76.4	76.4	76.2
Wet gluten, %	30.0	38.4	34.0	35.8	30.3	28.5
Development time, sec	6.9	4.7	5.4	6.3	6.9	5.0
Deformation Energy, W, e.a.	412	332	373	330	316	261
P/L ratio	1.11	0.48	0.70	0.43	0.53	0.54
Loaf volume, cm^3	750	925	780	1015	905	835

of the Kazakh samples is slightly weaker than that of Australian hard wheat, but stronger than that of the APW (Australian Premium White) grade. These results suggest that Kazakh wheat shows high values for gluten parameters and some are also high with respect to dough strength but importantly influenced by high protein levels. Gluten/dough extensibility is acceptable but if grain/flour protein content decreases, gluten extensibility is also expected to decrease and then bread making quality will not be satisfactory (**Table 4**).

Winter wheat quality characteristics

Winter wheat is widely grown in the South and South-East Kazakhstan, covering 1 million ha under irrigation and rainfed conditions. Grain quality of common winter wheat varies depending on cultivar and growing conditions. Winter wheat was not previously ranged according to their end-use quality. Grain hardness index is an important criterion for bread wheat classification according to their technological end use (Ranum *et al*. 2006). Although it is one of the first traits in the list of grain quality classification norms accepted in Kazakhstan and Country Independent State countries, it has been not determined due to the lack of methodical and laboratory background in grain quality evaluation, breeding, testing, and grain purchase. So that to date the genetic differentiation of cultivars into hard and soft types was difficult.

Analysis of winter bread wheat cultivars revealed a large variation in grain hardness types (**Table 2**). Some samples of cultivars belong to middle soft according to the minimal hardness indices: 'Zhetysu' (43); 'Kazakhstanskaya 10' (44); 'Progress' (38); 'Spartanka' (46). One sample of the cultivars 'Bezostaya 1' (53); 'Karlygash' (52); 'Mironovskaya 808' (53) showed mixtures of hardness types. The accessions of the other commercial and perspective cultivars have middle and high hardness indices. 68% of commercial cultivars belonging to the bread type wheat class had high to medium grain-hardness (**Table 2**). 'Zhetysu', 'Kazakhstanskaya 10', 'Spartanka', 'Komsomolskaya 75', 'Progress', and 'Rausin' were medium-soft accessions while 'Bezostaya 1', 'Karlygash', 'Mironovskaya 808', 'Koksu', and 'Sapaly' were mixed hardness types (48-53 SKCS values). New soft winter cultivars 'Batyr' (22-47SKCS) and 'Akdan' (22-37 SKCS) with 10.5-13.0% protein content were revealed as perspective types for pastry wheat. 14% of soft and medium cultivars and 21% of hardness mixtures, characterized by low to intermediate protein content (11.7-13.1%), were formed under irrigated conditions. A winter wheat breeding program needs to develop cultivars with the appropriate proportion of grain hardness types.

The Payne quality score based on HMW glutenin subunits (composition for the winter wheat cultivars varied from 6 ('Krasnaya Zvezda', 'Taza') to 10 ('Krasnovodopadskaya 210', 'Octyabrina 70', 'OPAKS 26', 'Steklovidnaya 24') with the average for Kazakh winter wheat cultivars being 9.1. The index in 'Batyr', 'Bayandy', 'Zhetysu', 'Odesskaya 120', 'Yuzhnaya 12' cultivars was 9.5 (**Table 4**).

The environment is one of the major factors negatively affecting both grain yield and quality attributes in Kazakhstan. At high temperature (>32°C) for long periods (>36 h) some cultivars form shriveled grain, which results in reduced milling quality and decreased gluten protein quality (due to excessive content of gliadin-like protein), impairing breadmaking quality (Blumenthal *et al.* 1993). In contrast, in high humidity environment pre-harvest sprouting is promoted with the undesirable increase in enzymatic activity negatively affecting bread-making quality.

CONCLUSIONS

There is an inverse relationship between grain yield and protein content. Since bread making quality is influenced by both protein quantity and quality, breeders must apply breeding strategies to increase one without affecting the other to achieve specific wheat quality classes. The basic principles for quality improvement are 1) understanding effects of G×E interactions on the expression of quality traits; 2) understanding genetic control and diversity associated with quality traits; 3) emphasis on improving specific genotypic quality traits (hardness, gluten strength and extensibility); 4) intensify the use of marker-assisted selection (MAS) to screen for specific genes or alleles effective in improving critical quality traits (Quarrie *et al*. 2005; Abugalieva *et al.* 2008).

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