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YIELD AND TECHNOLOGICAL QUALITY IN SOME MACEDONIAN WHEAT VARIETIES

Marijana Spirkovska[1*], Ljupcho Jankuloski[1], Milisav Ivanovski[2], Daniela Dimovska[1]

[1]Faculty of Agricultural Sciences and Food-Skopje, Republic of Macedonia,
[2]PSI Institute of Agriculture, Skopje, Republic of Macedonia
[*]e-mail: m.spirkovska@yahoo.com

Abstract
Common wheat (*Triticum aestivum L.*) is one of the most important cereal food crops. Breeding for high yielding what varieties is curtail role but no less is importance of breeding high quality wheat varieties that is essential for bread making industry. Wheat quality is assessed on the basis of physical, chemical, rheological and baking tests. For this reason at cereals industry has been a long history of using descriptive empirical measurements of rheological properties to predict bread-making quality. In this paper, grain yield and technological quality of five wheat varieties (Radika, Milenka, Bistra, Treska and Altana) from the breeding program at Institute of Agriculture-Skopje, Macedonia, were examined in two years (2007/2008 and 2008/2009). Bistra has shown significantly the highest yield among wheat varieties over two years of study carried out. Altana has shown the highest protein content, sedimentation value, dough energy, extensograph extensibility and ratio (resistance/extensibility).According to technological quality among varieties, Altana has shown the best quality and belongs to A1-A2 quality class, following Treska and Milenka (A2-B1) and Radika and Bistra (B1).
Key words: wheat, variety, yield, technological quality.

Introduction
Wheat (*Triticum aestivum* L.) is an important cereal crop used as staple food in Macedonia. Wheat is grown in almost every part of the country. In the period 2006-2011, the average sown area with wheat was 49,4% out of the average sown area with cereals (176666 ha). The average wheat production in the same period was 262246 t, or in average 3048,7 kg/ha (Statistical yearbook of the Republic of Macedonia, 2012). It is a principal source of carbohydrates for human beings while its straw can be used as an integral part of livestock feed. Compared with other cereals, it provides food for human with more calories and proteins in the daily diet. In many common wheat varieties grain contains carbohydrates 60-80%, protein 8-15 %, fat 1.5-2.0%, inorganic ions 1.5-2.0% and vitamins such as B complex and E (Schellenberger, 1996). Despite to higher yield potential, average yield, of different varieties, in Macedonia is much less than the most countries of the world. To meet the increasing demand of food grains, it is desired to have higher yield per unit area. A number of factors including, time of sowing, land preparation, seed bed preparation, fertilizer application, weed management, and irrigation scheduling are responsible for the variation in yield of wheat, but all these factors are agronomic and greatly influenced by temperature, rainfall and humidity. The vital factor for harvesting suitable environment into grain yield is the genetic potential of the wheat

variety. Its suitability and superiority in breadmaking with viscoelastic dough properties has been well known and documented (Branlard *et al*., 2011). The developments of high grain yield potential with good breadmaking quality and tolerance to biotic and/or abiotic stress factors and which respond to improved agricultural practices are the main achievements for bread wheat breeding programmes. It is known that the baking quality of wheat is under genetic as well as environmental control. It is genetically controlled but may vary widely depending upon the variety, climatic conditions, location, soil fertility, etc and the complex interactions between these factors. In general, high protein flours give rise to better results since they have a high loaf volume potential with higher water absorption. Genotype-by-environment (G x E) interactions and the negative correlation between grain yield and grain protein content of wheat had been established in different studies (Feil, 1997, Qury and Godin, 2007). If a genotype has a high stability and shows low interactions with the environment is desirable in plant breeding. Generally, wheat quality is defined by: physical properties (hectoliter weight, thousand kernels weight, grain hardness), protein-linked properties (total protein and gluten contents, gluten index, sedimentation volume, protein and amino-acid composition), rheological properties (farinograph test, alveograph value, extensograph test), enzymatic properties (hagberg falling number, amilograph test) and other properties (test backing, micotoxin content, residues of pesticides and insecticides). Nutrition value and bread-making quality in winter wheat depends on: starch from the endosperm, fats from the embryo and aleuronic layer, mineral substances in pericarp, vitamins in tegument and pericarp, and protein content (Bunta and Bucurean, 2011). The rheological properties of wheat-flour dough, among other parameters, include the extensibility and resistance to extension, which influence the processing behaviour very strongly, and are thus important factors of the wheat varieties' bread-making quality (Ma *et al*., 2005). The present study was, therefore, designed to determine the yield potential and quality of some Macedonian varieties namely, Radika, Milenka, Bistra, Treska and Altana.

Material and methods

Five Macedonian wheat varieties (Radika, Milenka, Bistra, Treska and Altana) were used to study yield and technological quality. The field experiment was carried out in Skopje in 2007/2008 and 2008/2009. The experiment was designed as a completely randomized block with three replicates. The plots consisted of 5 m^2, spaced at a distance of 12,5 cm. The harvested grain from three replicates was subjected to yield and quality analyses. Determination of hectolitre weight was determined by standard methods. Grain protein content was determined by Kjeldahl method (ICC standard method No.105, 2001). The preparation of test flour from wheat samples for sedimentation test was performed according to ICC standard method No.118 (ICC, 2001) and determination of Zeleny sedimentation value according to standard methods described in ICC (ICC standard method No.116, 2001). Determination of water absorption of flours, dough stability and quality number was performed by Brabender farinograph according to ICC standard method No.115 (ICC, 2001). Determination of rheological properties of wheat flour dough (energy, resistance and extensibility) was done by Brabender extensograph according to ICC standard method No.115 (ICC, 2001). Wheat yield and quality parameters are agronomic and greatly influenced by temperature, rainfall and humidity. The average temperature and total rainfall prevailing in Skopje region is given in Table 1.

SPSS software was used for statistical analysis. Mean values were tested by ANOVA, whereas differences among individual mean values were determined by Tukey test at significance level of 0,05.

Table 1. Weather data for Skopje region

Climatic parameters	Years	Months									
		X	XI	XII	I	II	III	IV	V	VI	
Average	2007/08	12,7	4,3	1,0	1,4	5,6	9,6	13,7	18,0	22,4	
temperature	2008/09	14,2	8,5	5,0	1,0	3,3	7,1	13,4	18,0	21,0	
(ºC)	1951-90	12,4	5,9	1,3	0,0	3,1	7,5	12,2	17,2	20,6	
											Sum
Total	2007/08	140,0	69,4	14,6	7,7	0,5	29,8	18,7	40,7	46,9	368,3
rainfall	2008/09	27,3	37,5	68,3	72,8	12,2	68,6	65,3	70,2	104,3	526,5
(mm)	1951-90	41,0	51,0	50,0	36,0	36,0	37,0	40,0	61,0	48,0	400,0

Results and discussion

Wheat grain yield is influenced by genotype, environment, planting date, crop rotation, seeding rate, fertilization, biotic-abiotic stresses, etc and their interactions. Year-to year variations in climate gave rise to considerable variations in grain yield in the study. The distribution of rainfall over wheat growing seasons is of great importance. And also daily high temperatures and water stress in spring time shorten the grain filling period, resulting in earlier maturity of the grain, which result in lower grain yield with higher protein content. Grain yield is a polygenic trait and is a product of expressions of many genes (number of tillers/plant, 1000-grain weight, spike length, numbers of grains per spike and spikelet etc.). Several research studies have been carried out on relationship of various yield component and also climatic factors with grain yield and its related traits (Kneževic *et al*., 2008, Yousaf *et al*., 2008). There is large gap between yield potential of our modern wheat varieties and yield production which indicated that crop yield can be improved through better crop husbandry.

From the results in this study over two years the average grain yield was 6,11 t/ha (Table 2). The average grain yield in 2009 (6,40 t/ha) was 10% higher compared to 2008 (5,82 t/ha) due to the total rainfall and distribution of rainfall (Table 1). In 2008 variety Bistra had significantly higher yield (6,30 t/ha) among varieties used in this study, except to variety Treska (6,10 t/ha) where significant differences were not found. In 2009, also Bistra (7,20 t/ha) has shown the highest grain yield significantly higher compared to other varieties. In both sessions the highest average grain yield was obtained from Bistra (6,75 t/ha).

Table 2. Grain yield of the varieties investigated over two years

	Year	Varieties					Average
		Radika	Milenka	Bistra	Treska	Altana	
Grain	2008	5,40 a	5,70 abc	6,30 c	6,10 bc	5,58 ab	5,82
yield	2009	6,40 b	6,50 b	7,20 c	5,70 a	6,20 ab	6,40
(t/ha)	Average	5,90 a	6,10 a	6,75 b	5,90 a	5,89 a	6,11

Note:Values with the same letter in one row are not significantly different from each other

Hectolitre mass or test weight, usually expressed as kilograms per hectolitre (kg hl^{-1}), is a measure of volume grain per unit and it is an important wheat grading factor (Donelson *et al*., 2002). Well-filled, plump kernels result in higher hectolitre mass, because they pack more uniformly compared to small, longer kernels which exhibit lower hectolitre mass because they pack more randomly.

Although some cultivars might have the ability to always have higher hectolitre mass than others grown under similar conditions, hectolitre mass is affected by growing conditions as well as genetic factors (Bordes *et al*., 2008). A hectolitre mass of 74.00 kg hl^{-1} is required for bread making purposes (Nel *et al*., 1998), but Koekemoer (2003) reported a hectolitre mass of 76.00 kg hl^{-1} and higher to be preferable. Posner and Hibbs (1997) stated that hectolitre mass can be an indication of expected flour yield to millers.

The hectoliter mass was in the range of 73,0 kg hl^{-1} to 80,3 kg hl^{-1} in wheat varieties over two years of experiment. In average, the hectoliter mass had higher value among wheat varieties in 2009 (78,9 kg hl^{-1}) compared to 2008 (75,7 kg hl^{-1}). Altana had shown significantly the highest hectoliter mass among varieties used in this study in 2008 (79,3 kg hl^{-1}). Although Altana (80,3 kg hl^{-1}) had a highest hectoliter mass in 2009, the differences were not significant to Milenka (79.4 kg hl^{-1}) and Treska (80,1 kg hl^{-1}), except for Radika (76,5 kg hl^{-1}) and Bistra (78,4 kg hl^{-1}).

Protein content (quantity) as well as protein quality (composition) determines wheat flour quality. Stable flour composition and quality are desired traits in wheat quality despite the environmental influence (DuPont *et al*., 2007). According to their solubility, four protein-types, namely albumins, globulins, prolamins and glutelins were originally classified by Osborne (1907). Gluten, the storage protein in wheat, mainly located in the endosperm and known for having an influence on functional properties of wheat as determined on a mixograph, farinograph, alveograph, SDS-sedimentation volumes and loaf volumes (Finney *et al*., 1987, Branlard *et al*., 2001; Rakszegi *et al*., 2005) can vary within and between genotypes regarding their proportions, structures and properties. Protein content is strongly affected by environment and less affected by genotype. Depending on environmental conditions, wheat grain protein content can vary between 6% and 25% as affected by nitrogen availability. Total protein content as well as the amount of each different protein is mainly determined by genotype.

Flour protein content between wheat varieties was between 12,7% to 15,5% over two sessions of study. The average protein content among varieties in 2008 and 2009 was 14,1%.

The flour protein content was significantly higher in Altana in both sessions (15,1 % and 15,5%, respectively). While in 2008 no significant differences were found among Radika, Milenka Bistra and Treska, in 2009 there were significant differences among these varieties. The lowest protein content was obtained in Radika (12,7%) in 2009.

The obtained results for grain yield and protein content confirm the negative correlation with grain yield and protein content. The high yielding variety Bistra was among lowest wheat varieties containing 13,9% protein content in 2008 and had a moderate protein content (13,5%) among varieties in 2009.

Sedimentation test is a good indicator of end-use quality, especially where wheat contains a low to medium protein content. SDS-sedimentation volume is effective in differentiating between different wheat quality-types. In addition, the sedimentation volume is independent of whether whole meal or white flour is used, but a disadvantage is the ineffectiveness of this test to distinguish between medium to strong quality flour samples when protein content is higher than 13% (Carter *et al*., 1999). Higher SDS-sedimentation volumes usually indicate stronger gluten and better quality (Eckert *et al*., 1993, Carter *et al*., 1999). Fowler and De la Roche reported (1975) that SDS-sedimentation volume reflects protein quantity and dough development time, both being important basic quality characteristics. Wheat breeding programmes utilise this test to get an indication of differences in protein content as well as gluten quality, where both these characteristics are of great importance regarding end-use quality.

Table 3. Quality characteristics of the varieties investigated over two years

Quality parameters	Year	Radika	Milenka	Bistra	Treska	Altana	Average
		Varieties					
HLM (kg hl^{-1})	2008	73,0 a	74,3 a	75,8 b	76,3 b	79,3 c	75,7
	2009	76,5 a	79,4 bc	78,4 b	80,1 c	80,3 c	78,9
FPC (%)	2008	14,0 a	13,8 a	13,9 a	13,9 a	15,1 b	14,1
	2009	12,7 a	14,4 c	13,5 b	14,4 c	15,5 d	14,1
S (mL)	2008	32,0 a	42,0 c	32,0 a	37,0 b	53,0 d	39,2
	2009	34,0 a	46,0 c	38,0 b	46,0 c	64,0 d	45,6
FARINOGRAPH							
FABS (%)	2008	57,0 c	58,0 d	56,0 b	53,0 a	58,0 d	56,4
	2009	62,0 b	62,0 b	63,0 c	63,0 c	61,0 a	62,2
DS (min)	2008	1,0 a	3,0 d	1,5 b	2,5 c	4,0 e	2,4
	2009	2,5 a	6,5 d	3,5 b	5,0 c	6,5 d	4,8
QN	2008	55,2 a	67,8 c	55,6 a	66,7 b	83,5 d	65,8
	2009	71,0 a	75,6 c	74,5 b	76,5 d	88,5 e	77,2
Quality level		B1	A2/B1	B1	A2/B1	A1/A2	
EXTENSIOGRAPH							
En (cm^2)	2008	37,0 a	77,0 c	40,0 b	78,0 d	85,0 e	63,4
	2009	44,0 b	86,0 d	43,0 a	82,0 c	102,0 e	71,4
R (BU)	2008	230,0 a	310,0 e	270,0 b	290,0 d	280,0 c	276,0
	2009	260,0 c	290,0 d	240,0 a	250,0 b	340,0 e	276,0
Ex (mm)	2008	150,0 b	157,0 d	125,0 a	155,0 c	157,0 d	148,8
	2009	150,0 a	160,0 c	155,0 b	170,0 d	180,0 e	163,0
Ratio (R/Ex)	2008	1,73 c	1,81 d	1,55 b	1,47 a	1,90 e	1,7
	2009	1,53 a	1,97 d	2,16 e	1,87 c	1,78 b	1,9

HLM=Hectolitre mass, FPC=flour protein content, S=Sedimentation value, FABS=Farinograph water absorption,
DS=Dough stability, QN=Quality number, En=Energy, R=Resistance (BU=Brabender Units), Ex=Extensibility
* Values with the same letter in one row are not significantly different from each other.

Results obtained from the sedimentation test had significant differences among varieties in both sessions. The sedimenatation value of the varieties had a range of 32,0 mL to 64,0 mL. The sedimentation value was highest in Altana and significant to other varieties used in this study in both years (53,0 mL and 64 mL, respectively). The lowest sedimentation value was Obtained in Radika in both sessions (32,0 mL and 34,0 mL, respectively).

Farinograph dough stability time is important index for classifying wheat, and it often indicates the most appropriate end use for the wheat cultivars (Tian *et al*., 2007). Water-absorption gives an indication of the potential of the protein molecules to absorb the added water, and therefore is an indicator of baking quality (MacRitchie, 1984). Van Lill and Smith (1997) reported that grain with higher protein content tended to be harder and give higher ash-content flour, which then results in higher water-absorption.

Stability is an indication of the flour tolerance to mixing and stronger flour tends to be more stable (Miralbés, 2004). Miralbés (2004) also reported a linear relationship between stability and protein content. There is positive correlation between the globulin protein fraction and dough development time. Gliadin and glutenin are significantly correlated with flour protein content, dough development time, stability, and water-absorption as well as loaf volume. There exist several rheological tests to evaluate dough characteristics during mixing and fermentation processes. Among them, water absorption capacity of the flour is important to obtain acceptable dough consistency during the mixing time. In general, waterabsorption increases as protein content increases, although water-absorption is a function of protein quantity and protein quality (Finney *et al*., 1987). Zounis and Quail (1997) reported significant correlations between farinograph water-absorption (FABS) and mixogram peak height as well as between FABS and maximum mixograph bandwidth.

Comparison of some rheological parameters of examined wheat varieties is presented in Table 3. According to the presented values, farinograph water absorption was significant among varieties in both years of study. In 2008, Milenka (58,0%) and Altana (58,0%) were with slightly significant differences in comparison with Radika (57,0%), Bistra (56,0%) and Treska (53,0%). In 2009, Bistra (63,0%) and Treska (63,0%) have the the highest water absorption capacity. Dough stability time was highest in Altana in both years (4,0 min and 6,5 min, respectively). Treska has shown the same dough development time with Altana in 2009. From the values presented in Table 3, it is remarkable that the average value for dough stability in 2009 (4,8 min) was two times higher in comparison to 2008 (2,4 min). According to farinograf results the highest quality class has Altana (A1/A2), following Treska and Milenka (A2/B1) and Radika and Bistra (B1). The extensograph determines the resistance and extensibility of a dough by measuring the force required to stretch the dough with a hook until it breaks. Extensograph results include resistance to extension, extensibility, and area under the curve. Resistance to extension is a measure of dough strength. A higher resistance to extension requires more force to stretch the dough. Extensibility indicates the amount of elasticity in the dough and its ability to stretch without breaking. Extensograph is employed to predict the dough characteristics during the fermentation process. Flours with high protein contents and high gluten strength result in doughs with a nearly perfect gluten matrix. The breads made of such doughs could benefit from near to perfect texture and bread volume (Bloksma and Bushuk, 1988). Therefore, accurate prediction of dough rheology could provide many benefits to the baking industry for satisfying consumer demands.

The results from extensograph evaluation showed that the high protein content variety Altana (85 cm^2 and 102 cm^2) possessed highest dough energy, significant among varieties in both years (Table 3). The extensogrph resistance and extensibility were significantly different among varieties in both years. Treska (290,0) owned significantly higher dough resistance in 2008, but not in the 2009 (250,0), having with Bistra (240,0) the lowest dough resistance. Dough extensibility was significantly higher in Altana (157,0 mm and 180,0 mm) in two years of study, except to Milenka (157,0 mm) in 2008 where no significant difference was found.

Conclusions

Presented two-year trial showed that differential results were obtained for grain yield and quality of the bread wheat varieties evaluated. It can be concluded that wheat variety Bistra performed significant high grain yield over two years of study carried out. Obtained results for grain yield demonstrate strong influence from the environment and climate conditions showing increased grain yield of 10% in 2009 due to the total rainfall and distribution of rainfall.

Since there are, generally, negative correlations between yield and protein content in wheat, the typical negative correlations between grain yield and protein content was found in this experiment in high yielding variety Bistra. Beside high yield obtained, variety Bistra is ranked among varieties with lowest to moderate protein content.

Sedimentation values of flour above 36 mL are characterized as very good and also there is positive correlation between sedimentation value and baking. The sedimentation values of the varieties had a range of 32,0 – 64,0 mL which was included in very good category, except variety Radika (32,0 mL and 34,0 mL) owning low sedimentation value in both sessions. Wheat variety Bistra (32,0 mL) although has sedimentation value under the range in 2008, but not in 2009 (38,0 mL) which is influenced from the climatic conditions.

The high flour protein content variety Altana, also possessed high hectoliter mass, sedimentation value, water absorption capacity, dough stability time, dough energy, dough resistance and dough extensibility, that in general are positively correlated parameters with high protein content and mainly with protein structure. Most rheological properties obtained from farinograph curves in accordance to extensograph dough properties were also affected by climatic conditions. In accordance to farinograph and extensograph parameters Altana is wheat variety with good technological properties having quality level A1/A2 depending of the year of study. It can be concluded that wheat grain yield and technological quality are strongly influenced by the environment and climatic condition. It may be concluded that wheat variety Bistra is high yielding variety and Altana is variety whit good quality (A1/A2 quality level) preferable for bread-making industry.

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ПРИНОС И ТЕХНОЛОШКИ КВАЛИТЕТ КАЈ НЕКОИ МАКЕДОНСКИ СОРТИ МЕКА ПЧЕНИЦА

Маријана Спирковска, Љупчо Јанкуловски, Милисав Иваноски, Даниела Димовска

Апстракт
Пченицата (*Triticum aestivum L.*) претставува најважното лебно жито. Освен одгледување на високопродуктивни сорти, многу е значајно и одгледувањето на високо квалитетни сорти пченица, особено за потребите на пекарската индустрија и производството на леб. Квалитетот на пченицата се оценува врз основа на физички, хемиски и тестови за технолошкиот квалитет. Преку емпириски испитувања од ваков вид, се овозможува предвидување на квалитетот на лебот. За да се следи стабилноста на квалитетот на некои сорти пченица, испитуван е технолошкиот квалитет на пчениците од производните 2007/08 и 2008/09 год. кај сортите *Миленка, Радика,Бистра,Треска и Алтана*, селекции на Земјоделски институт, Скопје.Сортата *Бистра* покажа статистички највисок принос на семе во однос на останатите сорти, текот на двегодишното истражување.Сортата *Алтана* се одликува со највисока содржина на протеини, седиментациона вредност, енергија на тестото, отпорност на растегливост и растегливост. Според технолошкиот квалитет, сортата *Алтана* покажа највисок квалитет и припаѓа на А1-А2 класа на квалитет, потоа следат сортите *Треска и Миленка* (А2-Б1) и сортите *Радика и Бистра* (Б1).
Клучни зборови: пченица, сорта, принос, технолошкиот квалитет.