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Grain physical characteristics and bread-making quality of alternative cereals towards common and durum wheat

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Abstract

The present study is aimed at explaining the physical characteristics and bread-making quality of Khorasan wheat (BGR 40365, BGR 12389), einkorn (B2E0417) and emmer (B2000528). Here we will compare the aforementioned grains to both, common wheat (cv. Enola and Sadovo 1) and durum wheat (cv. Progres and Denitza). The physico-chemical characteristics (i.e thousand kernel weight, gluten content and Pelshenke value), are known to differ significantly among the wheat species, however, few studies have examined these characteristics in ancient grains. The highest thousand kernel weight and test weight were observed in BGR 40365. The highest wet gluten content was found in BGR 12389 (34.02%). One variety of einkorn (B2E0417) was determined to be 'gluten free'. Emmer (B2000528) was characterized by high content of wet gluten (30.13%). The best balance between gluten quantity and quality was observed in two varieties of Khorasan wheat (BGR12389, BGR 40365). PC-analysis was applied to group varieties according to their similarity on the basis of ten traits. Three sub-groups could be identified where the first one composed by the hexaploid wheat cultivar Sadovo 1 and cultivar Enola. The second sub-group included cultivar Progres and BGR 40365, while cultivar Denitza, BGR 12389 and B2000528 constituted the heterogeneous third sub-group.

Key words: Bread-making quality, Einkorn, Emmer, Khorasan, Physical characteristics of grain

Introduction

The consumer's interest in natural, unconventional and nutritional foods led to the development of new specialty foods based on grain blends. These components of foods are often termed 'ancient wheat' or 'primitive wheat', suggesting that the species were not the subject of modern plant breeding programs. Examples of these "ancient wheat" are einkorn (*Triticum monococcum* L.), emmer (*T. dicoccon* Schrank.) and Khorasan (syn. Oriental) wheat (*Triticum turgidum* L. *ssp. turanicum* (Jakub.) Mk.) are such neglected and underutilized wheat species, which probably survived over the centuries in subsistence farming systems in Europe, the Near East and Central Asia (Abdel-Aal et al., 1998; Grausgruber et al., 2004; Piergiovanni et al., 2009). These species are used for production of different cultural foods and breads based on religious and/or cultural; customs. Various types of breads are made in different cultures that are consumed as staple or at special festivals (Asghar, 2011). The attention towards these ancient species have also been renewed by the increasing demand for traditional products, the request for species suitable to be grown in marginal areas and the need to preserve genetic diversity (Stagnari et al., 2008).

In Bulgaria the interest in primitive wheat has increased during the past few years. Today the farmers practicing organic agriculture initiate the testing of various varieties of einkorn and emmer applicable to organic or low-input farming. A lot of practical questions originate because of difficulties with sowing norms and terms, unknown growth type, no possibilities and/or problems with threshing and de-hulling, or relatively low yield in relation to cultivated wheat. As presented by the Bulgarian Ministry of Agriculture and Foods the agricultural areas with einkorn and emmer amount 1,000 ha (www.limec-bgagro.bg). So called 'primitive wheat varieties' are cultivated in different country regions: Silistra, Vratsa, Plovdiv and village Rabevo- Eastern Rodopes.

The aim of this study was to illuminate the characteristics of Khorasan wheat, einkorn and emmer. Here we will compare the grain physical characteristics of these 'ancient wheat to the bread-

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making quality of common wheat and durum wheat.

Material and Methods

The study was conducted in the Institute of Plant Genetic Resources “Konstantin Malkov” - Sadovo, during 2013. As standards two cultivars of common winter wheat (Enola and Sadovo 1) and two cultivars of durum wheat (Progres and Denitza) are used. In parallel varieties of species einkorn (*Triticum monococcum* L.), emmer (*T. dicoccon* Schrank.) and Khorasan (syn. Oriental) wheat (*Triticum turgidum* L. *ssp. turanicum* (Jakub.) Mk.) were investigated (Table 1). The grain physical characteristics such as, thousand kernel weight, test weight and general vitreousness were determined according to the methods described in BDS ISO 520 (2003), BDS ISO 7971-2 (2000) and BDS 13378 (1976) . The moisture content of the flour samples was determined according to BDS ISO 712 (1997). Wet and dry gluten content in different flour samples was estimated by the hand washing method according to BDS 13375 (1988). The sedimentation value of whole wheat flour was determined using the method presented by Pumpyanskiy (1971). Bread making strength index and gluten weakness were defined according to BDS 13375 (1988). The whole wheat meal flour of each wheat variety was also tested for fermentation value (Pelchenke et al., 1953).

The experimental data of evaluated parameters were analyzed using the statistical program SPSS 13.0. The analysis of variance was applied to determine the following descriptive characteristics: mean value, standard error of means, standard deviation and coefficient of variation. Principal Component Analysis (PCA) for similarity was applied to wheat varieties on the basis of ten characteristics: thousand kernel weight, test weigh, vitreousness, moisture content, wet and dry gluten contents, sedimentation values, Pelshenke value, bread making strength index and gluten weakness. PCA was implemented in three components in the factor plane.

Results and Discussion

Physical characteristics of grain

The physical characteristics thousand kernel weight, test weight and vitreousness showed significant variation among different wheat species (Table 2). The thousand kernel weight ranged from 22.67 to 57 g. The highest thousand kernel weight confirmed statistically was observed in BGR 40365 (Khorasan wheat), followed by cultivar Progres (56.60 g). The other Khorasan wheat (BGR12389) and cultivar Denitza were found statistically at par with respect to their thousand kernel weight as recorded 31.67, 36 g, respectively. In comparison with the cultivars Sadovo1, Enola, Pobeda and Denitza significantly the lowest thousand kernel weights were found in the grains of covered wheat’s of *Triticum monococcum* L. - B2E0417 (22.67 g) and *Triticum dicoccon* Schrank. - B2000528 (25.73 g), but both of these possessed non-significant differences among each other. The thousand kernel weight is a useful tool for the assessment of the potential milling yield. The kernel size contributes directly towards the improvement of grain yield as well as milling yield. Khan et al. (2009) indicated that the wheat varieties possessing a higher grain weight present a better potential for grinding and flour extraction. That is why the wide variation of grain weight could be used for improvement of this trait for creation of genotypes appropriate for maximum flour outputs. In our investigation BGR 40365 can be used as a donor of gene by this trait into the common winter wheat.

Table 1. List of wheat species and varieties.

No.	Genus/species	Subtaxa	Name of variety	Origin
1	*Triticum aestivum* L.	var. lutescens	Sadovo 1	Bulgaria
2	*Triticum aestivum* L.	var. erythrospermum	Enola	Bulgaria
3	*Triticum durum* Defs.	var.leucurum	Progres	Bulgaria
4	*Triticum durum* Defs.	var.alexandrinum	Denica	Bulgaria
5	*Triticum turgidum* L. ssp. turanicum (Jakubz.) Mk.	var. notabile	BGR 12389	Russia
6	*Triticum turgidum* L. *ssp. turanicum* (Jakubz.) Mk.		BGR 40365	Germany
7	*Triticum monococcum* L.	var.vulgare	B2E0417	Bulgaria
8	*Triticum dicoccon* Schrank	var.farum	B2000528	Italy

The highest test weight was recorded of BGR 40365, respectively 83 kg/hl and the lowest of durum wheat cultivar Denitza (78.10 kg/hl). The wheat cultivars Enola, Sadovo 1 and Progres are designed with very closely values (resp. 80.10; 80.30 and 80.60 kg/hl). There should be pointed that variety BGR 40365 was large seeded with well-filled grains which contain relatively more endosperm and less coats.

The grain vitreousness is important as a character for kernel grading and bread-making properties (Popov, 1965; Wang et al., 2002). The vitreousness of the evaluated varieties ranged from 62 to 99.67%. The highest value was recorded from Khorasan varieties where 99.67% for BGR 12389 and 97.67% for BGR 40365. The wheat with the lowest vitreousness 62% was eincorn (B2E041) and durum wheat cultivar Progres.

As presented the highest values of the physical grain characters were observed of Khorasan wheat (BGR 40365) in comparison with other varieties included in the study. This finding confirms the reported before by other researchers regarding hundred kernels weigh and test weigh of different wheat species (Grausgruber et al., 2005; Stagnari et al., 2008; Abdel-Haleem et al., 2012).

Chemical characteristics
Moisture content

The moisture content ranged from 7.83% to 9.47% (Table 3). The highest moisture content was determined in the common wheat varieties (Enola and Sadovo 1), 9.0% and 9.47%, respectively. The group of tetraploid wheat varieties (Progres, Denitza, BGR 12389, BGR 40365 and B2000528) showed close values of this character. The lowest moisture content was determined in the diploid wheat (B2E0417) -7.83%. The variation of moisture content in different wheat varieties might due to their different chemical components – proteins and starch as well to the shape of seeds and seed covering structures. Practically all components of the environment that influence the equilibration seed moisture could affect the water content in seeds. In another studies this effect is also confirmed taking attention both to the genetic characters of each variety and the environment including climate and agro-factors during vegetation (Mahmood, 2004; Khan et al., 2009).

Table 2. Physical characteristics of grain of different wheat species.

	Triticum aestivum L.		*Triticum durum* Defs.		*Triticum turgidum ssp. turanicum* (Jakubz.) Mk.		*Triticum monococcum* L.	*Triticum dicoccon* Schrank
	Sadovo 1	Enola	Progres	Denitza	BGR 12389	BGR 40365	B2E0417	B2000528
Vitreousness, %								
Mean	64.00	70.00	62.00	81.67	99.67	97.67	62.00	93.67
Std. Error of Mean	1.15	0.58	0.58	0.33	0.33	0.33	1.15	0.33
Std. Deviation	2.00	1.00	1.00	0.58	0.58	0.58	2.00	0.58
CV,%	3.13	1.43	1.61	0.71	0.58	0.59	3.23	0.62
Thousand kernel weight, g								
Mean	49.40	44.40	56.60	36.00	31.67	57.00	22.67	25.73
Std. Error of Mean	0.12	0.58	0.35	0.29	0.33	0.69	0.33	0.47
Std. Deviation	0.20	1.00	0.60	0.50	0.58	1.20	0.58	0.81
CV,%	0.40	2.25	1.06	1.39	1.82	2.11	2.55	3.14
Test weight, kg/hl								
Mean	80.10	80.30	80.60	78.10	81.60	83.00	-	-
Std. Error of Mean	0.17	0.10	0.35	0.06	0.40	0.58	-	-
Std. Deviation	0.30	0.17	0.60	0.10	0.69	1.00	-	-
CV,%	0.37	0.22	0.74	0.13	0.85	1.20	-	-

Table 3. Chemical characteristics of whole wheat flour of different wheat species.

	Triticum aestivum L.		*Triticum durum* Defs.		*Triticum turgidum ssp. turanicum* (Jakubz.) Mk.		*Triticum monococcum* L.	*Triticum dicoccon* Schrank
	Sadovo 1	Enola	Progres	Denitza	BGR 12389	BGR 40365	B2E0417	B2000528
mousture content, %								
Mean	9.47	9.00	8.00	8.60	7.87	8.20	7.83	8.00
Std. Error of Mean	0.03	0.06	0.06	0.06	0.03	0.06	0.03	0.06
Std. Deviation	0.06	0.10	0.10	0.10	0.06	0.10	0.06	0.10
CV,%	0.61	1.11	1.25	1.16	0.73	1.22	0.74	1.25
wet gluten content, %								
Mean	31.92	32.08	23.10	36.70	34.02	26.30	-	30.13
Std. Error of Mean	0.08	0.08	0.10	0.10	0.02	0.30	-	0.03
Std. Deviation	0.11	0.11	0.14	0.14	0.03	0.42	-	0.04
CV,%	0.35	0.35	0.61	0.39	0.08	1.61		0.14
dry gluten content, %								
Mean	10.40	10.69	8.16	12.62	11.48	9.24	-	10.32
Std. Error of Mean	0.23	0.18	0.10	0.04	0.24	0.09	-	0.18
Std. Deviation	0.40	0.32	0.18	0.07	0.41	0.16	-	0.32
CV,%	3.85	2.95	2.21	0.55	3.57	1.73	-	3.10
bread-making strength index								
Mean	55.00	78.00	40.00	67.00	76.00	71.00	-	51.00
Std. Error of Mean	1.73	0.58	2.89	1.15	2.89	1.15	-	1.73
Std. Deviation	3.00	1.00	5.00	2.00	5.00	2.00	-	3.00
CV,%	5.45	1.28	12.50	2.99	6.58	2.82	-	5.88
gluten weakness, mm								
Mean	10.51	6.03	13.03	7.98	6.50	4.50	-	12.01
Std. Error of Mean	0.20	0.09	0.04	0.07	0.23	0.12	-	0.14
Std. Deviation	0.34	0.15	0.06	0.13	0.40	0.20	-	0.24
CV,%	3.24	2.53	0.47	1.58	6.15	4.44	-	2.00
sedimentation value, cm3								
Mean	52.00	55.00	19.67	26.00	25.33	22.33	14.67	30.00
Std. Error of Mean	0.58	0.58	0.33	0.58	0.33	0.33	0.33	0.58
Std. Deviation	1.00	1.00	0.58	1.00	0.58	0.58	0.58	1.00
CV,%	1.92	1.82	2.94	3.85	2.28	2.59	3.94	3.33
Pelshenki test, min								
Mean	47.00	171.00	32.67	38.00	108.00	58.00	29.67	28.67
Std. Error of Mean	1.73	2.89	0.33	0.58	1.15	0.58	0.33	0.33
Std. Deviation	3.00	5.00	0.58	1.00	2.00	1.00	0.58	0.58
CV,%	6.38	2.92	1.77	2.63	1.85	1.72	1.95	2.01

Gluten content

As known the wet gluten is a visco-elastic proteinaceous substance obtained after washing out the starch granules from wheat flour dough (Mis, 2000; Yanchev and Ivanov, 2012). Quality of the resulting gluten is a considerable index of the wheat baking potential. Gluten quality is characterized by the degree of extensibility and the elasticity (Curic et al., 2001).

The variation of gluten content between examined varieties was in a large scale (Table 3). In our study was found out that from eincorn (B2E0417) the wet gluten is not washing out. This sample was assigned as 'zero gluten' from all evaluated wheat varieties. The highest wet gluten content was found in *T. durum* Defs. cv. Denitza

(36.70%) and *Triticum turgidum* L. *ssp. turanicum* (Jakub.) Mk. BGR 12389 (34.02%). In BGR 40365 was determined that the wet gluten content was relatively low but it was tight, stiff and with the minimum allocation of gluten ball (4.6 mm). Emmer (B2000528) and bread wheat cv. Sadovo 1 were characterized by high wet gluten content (resp. 30.13% and 31.92%), but with lower gluten quality indicated by gluten weakness (10.5 and 13.0 mm). Similar results were reported by Grausgruber et al. (2004). In their study was shown that emmer varieties possess high protein and wet gluten contents but low gluten quality. The best combination of grain gluten properties was observed in wheat cv. Enola and in varieties of Khorasan wheat (BGR12389, BGR 40365). The bread-making strength index of above samples was very high as an indication for good gluten quality.

Dry gluten content correlates positively with the wet gluten content (Zaidel et al., 2009; Baslar and Ertugay, 2011). In our study it varied from 8.16% for cv. Progers to 12.62% for cv. Denitza.

Sedimentation values (SV)

The highest rate of sedimentation value was described of bread wheat cultivars Sadovo 1 and Enola, respectively 52 cm^3 and 55 cm^3. Contrariwise the lowest value of SV (14.67 cm^3) was detected for einkorn (B2E0417). The tetraploid wheat in this study (Progres, Denitza, BGR 12389, BGR 40365 and B2000528) was described with sedimentation value between 19.67 to 30 cm^3 (Table 3).

As other authors indicated SV is in a positive relation to the crude protein content and wet gluten content (Yanchev and Ivanov, 2012). Our results confirm this suggestion comparing gluten content and sedimentation value of evaluated varieties.

Pelshenke test (PT)

The Pelshenke test is one of the most important tests for assessment of the gluten strength (Khan et al., 2009). The variation of this character between evaluated samples of wheat species ranged from 28.67 to 171 min (Table 3). The highest value of PT was observed for bread wheat cv. Enola (171 min), followed by Khorasan wheat BGR 12389 (108 min). The lowest value was determined of coated wheat varieties: B2000528 (*T. dicoccon* Schrank.) and B2E0417 (*T. monoccocum* L.), respectively 29.67 and 28.67 min.

Principal component analysis (PC)

PC-analysis was applied to arrange varieties by their similarity. The analysis was carried out on the basis of presented above ten traits by three components in the factor plane. The values of the three components to each of the studied parameters were calculated empirically (Table 4). The analysis showed that the first component explains 38.536% of the total variation, the second – 28.007% and the third – 20.133%. The all three components explain total **86.68**% of the variation in the experiment. The most effective by the first component were four characters: test weight, Pelshenki test, gluten weakness, and bread-making strength index. The second component correlated to thousand kernel weight and wet and dry gluten content. The third component was influenced by moisture content, vitreousness and sedimentation value. Three-dimensional scatter plot presented the distribution of varieties according to factor's scales (Figure 1). Three sub-groups could be identified where the first one composed by the hexaploid wheat cultivar Sadovo 1 and cultivar Enola. The second sub-group included cultivar Progres and BGR 40365, while cultivar Denitza, BGR 12389 and B2000528 constituted the heterogeneous third sub-group.

Table 4. Weighted factors (PC1, PC2 and PC3) of descriptive characteristics on the rotated matrix with tree factors.

Characters	Component		
	1	2	3
Moisture content, %	0.148	0,064	0.935
Vitreousness, %	0.287	0.413	-0.803
Thousand kernel weight, g	0.178	-0.929	0.231
Test weight, kg/hl	0.652	-0.461	0.276
Sedimentation value, cm3	0.184	0.205	0.876
Pelshenki test, min	0.742	0.123	0.283
Wet gluten, %	0.307	0.871	0.246
Gluten weakness, mm	-0.956	-0.098	0.149
Bread-making strenght index, or	0.922	0.371	-0.034
Dry gluten, %	0.306	0.873	0.121
% of total variance explained	38.536	28.007	20.133
Cumulative variation, %	38.536	66.543	86.676

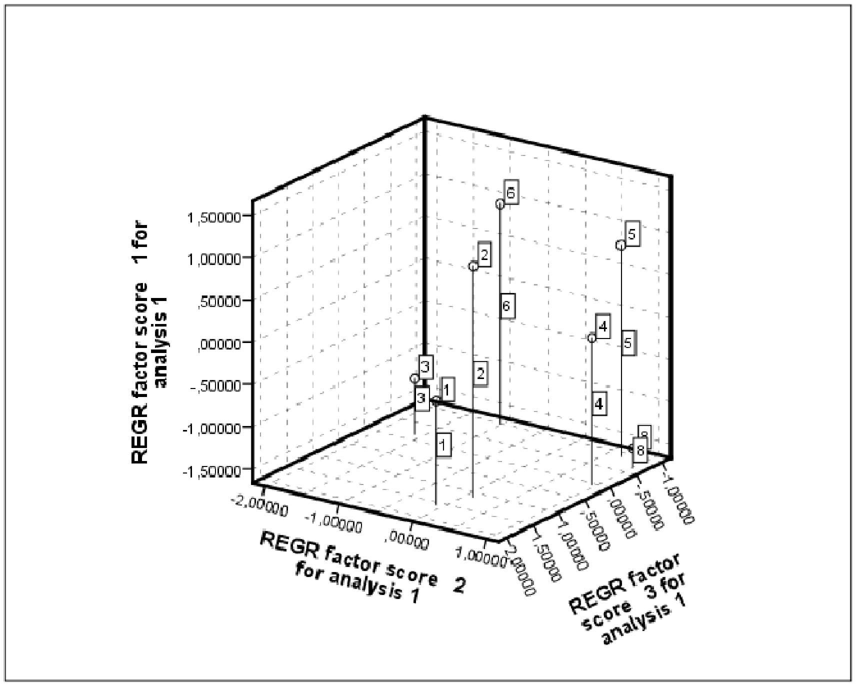

Figure 1. Three-dimensional scatter plot of the first three principal components. The varieties presented with the conditional numbers 1-8 of the graph correspond to the description in Table 1.

Conclusion

The physical characteristics of grain such as thousand kernel weight, test weight and vitreousness showed significant variation among evaluated wheat species. In this comparative study the highest physical properties of grain were described for Khorasan wheat, BGR 40365. This indicates that, Khorasan wheat has the potential to become high yield flour in grain. It is important to note that wet gluten was not washed out from einkorn, B2E0417. This means that einkorn is good selection for people requiring 'gluten free' diets. However emmer (B2000528) is characterized with high gluten content its gluten has lower quality because the gluten weakness. The most adequate balance between gluten quality and quantity traits were observed for cv. Enola (*T. aestivum* L.) and two varieties of Khorasan wheat (BGR12389, BGR 40365). So indicated three varieties possessed the highest bread-making strength index. Principal Component analysis illustrates the grouping of accessions by three components in the factor plane, where they explain total **86.68**% of the variation in the experiment. The effectiveness of evaluated characters was illustrated by their correlation to components. The most effective by the first component were four characters: test weight, Pelshenki test, gluten weakness, and bread-making strength index. The second component correlated to thousand kernel weight and gluten content. The third component was influenced by moisture content, vitreousness and sedimentation value.

References

Abdel-Aal, E. S. M., F. W. Sosulski and P. Hucl. 1998. Origins characteristics and potentials of ancient wheat. Cereal Foods World 43:708-715.

Abdel-Haleem, A. M. H., H. A. Seleem and W. K. Galal. 2012. Assessment of Kamut® wheat quality. World J. Sci. Tech. Sust. Dev. 9(3):194-203.

Asghar, A., S. Rauf, Sh. Nazir, A. Naveed and Aziz-ur-Rahman. 2011. Utilization of Wheat species as Cultural Food, In: Wheat: Genetics, Crops and Food Production. Chapter 5, pp. 1-31.

Başlar, M. and M. F. Ertugay. 2011. Determination of protein and gluten quality-related parameters of wheat flour using near-infrared reflectance spectroscopy (NIRS). Turk J. Agric. For. 35:139-144.

BDS 13375. 1988. The methods for determination of quality and quantity of gluten in the wheat. Sofia. Bulgaria.

BDS 13378. 1976. The methods for determination of vitreousness. Sofia. Bulgaria.

BDS ISO 520. 2003. Cereals and pulses - Determination of 1000 kernel weigh. Sofia. Bulgaria.

BDS ISO 712. 1997. Cereals and cereal products - Determination of moisture content (Routine reference method). Sofia. Bulgaria.

BDS ISO 7971-2. 2000. Cereals - Determination of bulk density, called "mass per hectolitre" Routine method. Sofia. Bulgaria.

Curic, D., D. Karlovic, D. Tusak, B. Petrovic and J. Dugum. 2001. Gluten as a standard of wheat flour quality. Food Technol. Biotechnol. 39(4):353–361.

Grausgruber, H., M. Oberforster, G. Ghambashidze and P. Ruckenbauer. 2005. Yield and agronomic traits of Khorasan wheat (*Triticum turanicum* Jakubz.). Field Crop Res. 91(2-3):319-327.

Grausgruber, H., C. Sailer, G. Ghambashidze, L. Bolyos and P. Ruckenbauer. 2004. Genetic variation in agronomic and qualitative traits of ancient wheats. Genetic variation for plant breeding. Proceedings of the 17th EUCARPIA General Congress, Tulln, Austria, 8-11 September 2004, pp. 19-22.

Khan, M. R., F. M. Anjum, T. Zahoor and H. Nawaz. 2009. Biochemical and technological characterization of pakistani spring wheats. Pak. J. Agri. Sci. 46(4):271-279.

Mahmood, A. 2004. Acid-PAGE gliadin composition and cluster analysis for quality traits of different wheat varieties. Ph.D. dissertation, Inst. Food Sci. Technol. Univ. Agric. Faisalabad, Pakistan.

Mis, A. 2000. Some methodological aspects of determining wet gluten quality by the glutomatic method. Int. Agrophysics 14:263-267.

Pelchenke, P., G. Hampel, W. Schafet, W. Kleber, H. Ludecke and E. Heuer. 1953. Methodenbuch, Band, XV.

Piergiovanni, A., R. Simeone and A. Pasqualone. 2009. Composition of whole and refined meals of Kamut under South Italian conditions. Chem. Eng. Transact. 17:891-896.

Popov, P. 1979. Wheat in Bulgaria. Zemizdat, Sofia. Bulgaria.

Pumpianskiy, A. 1971. Mikrometod opredeleniia nabuhaemosti muki v uskusnы kislote, V kn. Tehnologicheskie svojstva miagkih pshenic, Kolos, Leningrad, 37-40.

Stagnari, F., P. Codianni and M. Pisante. 2008. Agronomic and kernel quality of ancient wheats grownin central and southern italy. Cereal Res. Commun. 36(2):313–326.

Wang, N., F. Dowel, and N. Zhang. 2002. Determining wheat vitreousness using image processing and a neural network. Transaction of the ASAE. 46(4):1143–1150.

Yanchev, I. and U. Ivanov. 2012. Comparative study of physical, chemical and technological properties of the Greek and Bulgarian common wheat varieties. Field Crop Sci. 8(2):219-226.

Zaidel, A. D. N., N. L. Chin, Y. A. Yusof and R. Abd Rahman. 2009. Analysis and Correlation Studies on Gluten Quantity and Quality during Production. J. App. Sci. 9(9):1686-1694.