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COMPARATIVE BIOCHEMICAL AND TECHNOLOGICAL STUDIES OF BULGARIAN DURUM WHEAT GRAIN

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Abstract

During the period 2015-2018 in the Educational Experimental and Implementation Base of the Department of Plant Breeding at the Agricultural University - Plovdiv a comparative study of the biochemical and technological properties of the grain of the Bulgarian varieties of durum wheat Progress (standard), Beloslava, Vazhod and Yavor was conducted. The field experiment is based on the rapeseed predecessor by the block method in four repetitions with the size of the harvest plot - 15m^2. As a result of the experiment, the following was found: Durum wheat variety Yavor is characterized by the highest content of crude protein (14.8%) in the grain, as well as common (13.5%) and essential (3.61%) amino acids in % to absolute dry matter compared to the standard. The highest yield of wet gluten was reported in the varieties Beloslava (42.9%) and Vazhod (40.3%), as well as the highest number of chebobacterial strength and sedimentation number compared to the variety Progress.

Key words*: durum wheat, varieties, biochemical and technological properties.*

INTRODUCTION

Durum wheat is the main raw material for the production of pasta, due to its valuable biochemical and technological properties of grain, which allow to obtain high quality products. The main quality indicators of durum wheat varieties - protein content and gluten strength are factors for the quality of prepared pasta. Pasta with a bright yellow colour and good cooking quality (Marti et al., 2016; Sayaslan et al., 2012; Kolev et al., 2008) is obtained from varieties that combine high yellow pigments (over 7 ppm), protein concentration (over 15-16% dm), and strong gluten.

The interaction of a complex of factors, including variety, ecological conditions, and cultivation technology, is crucial for improving the quality of durum wheat grain (Haile et al., 2018; Delibaltova & Kirchev, 2010; Kirchev, 2011; Kolev et al., 2008). Optimizing these factors leads to high results in durum wheat production (Yanev & Kolev, 2008). Each variety with its genetic capacity is an effective means of increasing grain yield and quality (Kolev et al., 2004; Yanev, 2006; Yanev et al., 2008; Kolev et al., 2011). By growing varieties suitable for a particular region, we can reduce the negative impact of environmental conditions (Clarke, 2000; Mangova and Petrova, 2007; Kolev et al., 2012).

The aim of the present study is to establish the biochemical and technological properties of grain of Bulgarian durum wheat varieties.

MATERIALS AND METHODS

During the period 2015-2018 we conducted a field experiment in the Educational, Experimental and Implementation Base of the Agricultural University Plovdiv, using the block method, in four repetitions with the size of the harvest plot of 15 m^2.

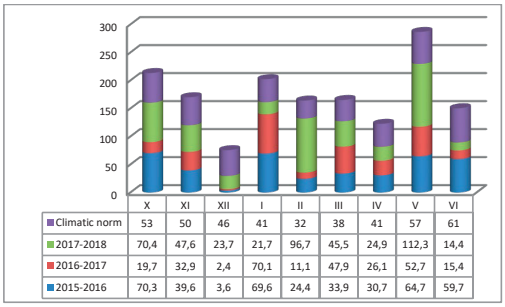
The varieties Progress (standard), Beloslava, Vazhod, and Yavor were tested.

The durum wheat varieties were grown in a crop rotation with rapeseed. Depending on the climatic conditions, immediately after harvesting the predecessor, the plant remains were removed, and the soil was disc-processed two or three times with disc harrows at a depth of 8-12 cm. The sowing of the studied varieties of durum wheat was carried out in the optimal period for Southern Bulgaria from 20th October to 5th November with a sowing rate of 500 germinating seeds of m^2.

The total amount of phosphorus P_8 kg/da is applied with the main tillage, and nitrogen fertilizer (ammonium nitrate) N_{12} - 1/3 before sowing, and the remaining amount 2/3 in early spring as fertilizer.
Weed, disease and pest control is carried out according to the established technology of growing durum wheat (Yanev et al., 2008).
Harvesting is done in full maturity, by direct harvesting with a small experimental Wintersteiger seedmaster universal combine harvester.
The chemical and technological analyses were performed at the Laboratory Testing Complex at Agricultural University Plovdiv.
The grain samples from the tested varieties of durum wheat are qualified according to the indicators: mass per 1000 grains under BDS ISO 520: 2003; hectolitre mass under BDS ISO 7971-2: 2000; grain vitreousness under BDS EN 15585: 2008; sedimentation number of the flour by the method of Pumpyansky; extraction of wet and dry gluten; gluten loosening; baking value (BV) according to BDS EN ISO 21415-2: 2008, and fermentation index according to the Pelshenke method.
The determination of the total nitrogen in the grain was performed in ground samples of wheat grain after wet burning (Gorbanov, 1990) with concentrated sulfuric acid and hydrogen peroxide. We calculated the crude protein based on the fact that the nitrogen content in the wheat grain protein is 17.5%. The percentage of nitrogen determined by the described method was multiplied by a factor of 5.7.
We carried out the quality and quantity determination of the total amino acids in the grain after acid hydrolysis with 6 and HCL for 24 hours at 105°C in a thermostat. The reading was done on an automatic amino analyser, manufactured in the Czech Republic.
The statistical processing of the data obtained on the studied indicators was performed with the software BIOSTAT (Penchev, 1998).

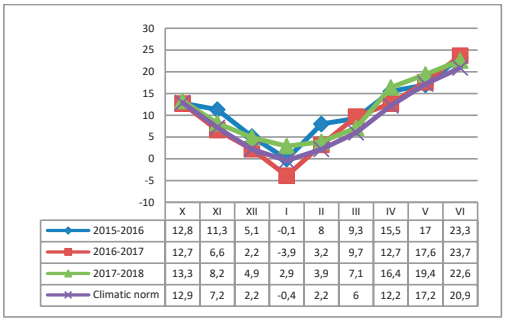
RESULTS AND DISCUSSIONS

The amount of precipitation during the vegetation of durum wheat during the years of the experiment is as follows: 2015/2016 - 396.5 mm/m^2, 2016/2017 - 278.3 mm/m^2, 2017/2018 - 457.2 mm/m^2, with a climatic norm of 419.6 mm/m^2. The amount of precipitation in the second experimental year is less than the climatic norm, but due to their better distribution during the critical stages of plant development, the harvest year of 2016/2017 is more favourable for the growth and development of durum wheat.
Unfavourable for the development of plants is the harvest year 2015-2016 due to the lower rainfall in the period from February to June compared to the climatic norm, which had a negative impact on the productivity of durum wheat (Figures 1 and 2).



	X	XI	XII	I	II	III	IV	V	VI
Climatic norm	53	50	46	41	32	38	41	57	61
2017-2018	70,4	47,6	23,7	21,7	96,7	45,5	24,9	112,3	14,4
2016-2017	19,7	32,9	2,4	70,1	11,1	47,9	26,1	52,7	15,4
2015-2016	70,3	39,6	3,6	69,6	24,4	33,9	30,7	64,7	59,7

Figure 1. Precipitation by months, sum mm/m^2



	X	XI	XII	I	II	III	IV	V	VI
2015-2016	12,8	11,3	5,1	-0,1	8	9,3	15,5	17	23,3
2016-2017	12,7	6,6	2,2	-3,9	3,2	9,7	12,7	17,6	23,7
2017-2018	13,3	8,2	4,9	2,9	3,9	7,1	16,4	19,4	22,6
Climatic norm	12,9	7,2	2,2	-0,4	2,2	6	12,2	17,2	20,9

Figure 2. Monthly temperatures (average)

Influence of the variety on some physical indicators and wheat grain yield

The physical properties of durum wheat grain are determined by the variety and the growing conditions. These properties are significantly influenced by meteorological and soil conditions. Agrotechnical factors do not affect equally. Stronger changes are caused by nitrogen fertilization and irrigation, which improve some and worsen other physical properties.

The mass of 1000 grains characterizes the well-nutrition and grain size, and is an indirect milling indicator of the output of the obtained flour when milling the grain.
From the studied varieties of durum wheat the standard Progress variety has the highest mass per 1000 grains (Table 1) with an absolute weight of 59.6 g. The other varieties have lower values of mass per 1000 grains compared to the standard.
Another indirect indicator of the milling properties is grain hectolitre mass. When buying wheat, the milling properties are evaluated per hectolitre mass. It is determined by the quality and condition of the grain - moisture, culture and inert impurities, size and shape. It is positively influenced by agro technical factors such as fertilization and predecessor.

Table 1. The influence of variety on the physical properties and grain yield of durum wheat

Varieties	The physical properties						Grain yield	
	Mass per 1000 grains		Hectolitre mass		Vitreousness			
	g	%	kg	%	%	% to st.	kg/da	%
1. Progress	59.6	100.0	81.6	100.0	92.1	100.0	383.5	100.0
2. Beloslava	55.4	93.0	82.7	101.3	98.6	107.1	423.7	110.5
3. Vuzhod	58.1	97.5	82.9	101.6	97.9	106.3	458.0	119.4
4. Yavor	57.9	97.1	82.0	100.5	94.1	102.2	395.8	103.2
GD 5%	4.12	6.9	4.12	5.1	5.7	6.1	35.1	9.1

All tested varieties have a mathematically unproven higher grain hectolitre mass compared to the Progress variety.
Vitreousness is also an important milling indicator and its high values determine the production of white flours with high yield. This indicator strongly correlates with the content of protein and starch. It is influenced by many factors, but the varietal characteristics, fertilization and meteorological conditions during the formation and ripening of the grain are decisive. For the studied varieties vitreousness varies from 92.1% for Progress variety to 98.6% for Beloslava variety and the value of this indicator is by 7.1% higher than the standard.
According to Filipov (Filipov & Mangova, 1992), in dry years vitreousness of wheat grain is most affected by nitrogen fertilization, followed by the varietal characteristics.
The yields of durum wheat grain depend on many factors, but the most important of them are the position of the crop in the crop rotation, the stocks of the available to the plants forms of nitrogen, phosphorus and potassium, the fertilization rates, the times of fertilizer application, the climatic conditions during vegetation, etc.
The highest grain yield during the study period was obtained from the Vazhod variety. The grain obtained from this variety is by 74.5 kg/da (19.4%) more than the standard Progress variety. Beloslava variety follows by 40.2 kg/da (10.5%) more than the standard. Third, in terms of yield is Yavor variety with grain addition of 12.3 kg/da (3.2%).
The increase in yield is mathematically proven for varieties Vazhod and Beloslava, while in Yavor variety higher productivity than the standard is mathematically unproven.

Influence of the variety on some chemical parameters of wheat grain

Nitrogen and variety are among the main factors that, in addition to the yield, have a strong influence on the quality of wheat.
Protein content is one of the most important indicators characterizing the quality of wheat grain. According to a number of authors, grain yield and protein concentration cannot be improved simultaneously. Achieving a high protein content in the grain can indirectly affect the yield, i.e. there is an inverse relationship between grain yield and protein concentration. The importance of protein content for the technological qualities of wheat is direct and indirect. Gluten production is closely correlated with it.
The analysis of the obtained results for the content of crude protein in the grain shows that Yavor variety is characterized with the highest protein content, and this increase is by 3.5% for Yavor compared to Progress variety standard. In varieties Beloslava and Vazhod it is by 15.4% to 19% lower (Table 2).
The results obtained confirm the established inverse relationship between grain yield andprotein concentration in it.

Table 2. Content of total nitrogen and crude protein in durum wheat grain

Varieties	Absolute dry matter	Content of total nitrogen	Crude protein	
	%	%	N.5,7	%
1. Progress	90.05	2.51	14.3	100.0
2. Beloslava	88.2	2.14	12.1	84.6
3. Vuzhod	88.1	2.03	11.6	81.1
4. Yavor	87.9	2.60	14.8	103.5

A similar pattern is observed in the analysis of data on the amount of total amino acids in the grain of the studied varieties (Table 3).

Table 3. Content of total amino acids in durum wheat grain

Varieties	In % to absolute dry matter			
Amino acids	Progress	Beloslava	Vuzhod	Yavor
Monoaminocarbonates				
Glycine	0.54	0.41	0.43	0.50
Alanine	0.55	0.44	0.43	0.52
Valin	0.50	0.44	0.45	0.53
Dicarbonate				
Aspartic acid	0.78	0.58	0.72	0.90
Glutamic acid	4.22	4.21	3.82	4.54
Oxyaminocarbons				
Serine	0.63	0.58	0.64	0.61
Threonine	0.39	0.35	0.32	0.39
Basic				
Lysine	0.51	0.36	0.43	0.47
Histidine	0.35	0.26	0.32	0.34
Arginine	0.75	0.63	0.65	0.71
Sulfur-containing				
Methionine	0.13	0.14	0.09	0.14
Cystine	0.12	0.11	0.14	0.14
Aromatic				
Phenylalanine	0.65	0.62	0.58	0.73
Tyrosine	0.28	0.27	0.25	0.31
Proline	1.41	1.45	1.32	1.51
Leucine				
Leucine	0.84	0.80	0.80	0.92
Isoleucine	0.41	0.37	0.37	0.43
Total:	13.06	12.12	11.62	13.50
%	100.0	92.8	89.0	103.3

In the case of Yavor variety the concentration of total amino acids in the grain is 3.3% higher than in the standard, while in the case of Beloslava and Vazhod varieties the decrease of this indicator is 7.2% for Beloslava and 11.0% for Vazhod, where this decrease is in all groups of amino acids. A similar trend is observed in the amount of essential amino acids in the grain of the studied varieties (Table 4).

Table 4. Content of essential amino acids in durum wheat grain

Varieties	In % to absolute dry matter			
Amino acids	Progress	Beloslava	Vuzhod	Yavor
Lysine	0.51	0.36	0.43	0.47
Threonine	0.39	0.35	0.32	0.39
Valine	0.50	0.44	0.45	0.53
Methionine	0.13	0.14	0.09	0.14
Leucine	0.84	0.80	0.80	0.92
Isoleucine	0.41	0.37	0.37	0.43
Phenylalanine	0.65	0.62	0.58	0.73
Общо:	3.43	3.08	3.04	3.61
%	100.0	89.8	88.6	105.2

Influence of the variety on the technological properties of wheat grain

One of the most important indicators of wheat quality is the quantity and quality of gluten. According to a number of authors, the quality of wheat depends not so much on the amount of crude protein, but above all on the quality of gluten, which is closely related to the type, variety, etc.

Wet gluten is an extremely important indicator for both wheat grain and its products - flour, dough, bread, etc. It is a known fact from literature resources that it is positively correlated with crude protein.

Gluten is a mixture of proteins. It is an elastic, tough and water-insoluble substance. It contains gliadin (44%), glutenins (41%), and other protein substances (15%). On its physical properties - elasticity and extensibility, depend the elasticity, porosity, gas retention when baking bread, the volume and duration of its storage.

Wet gluten is a complex colloidal system of two main protein substances: gliadins (soluble in alcohol) and glutenins (insoluble). It is obtained after prolonged washing of the dough with water or saline solution. It is done with the help of a gluten washer until a yielding-elastic substance is obtained, which is no longer washed away. The main indicators of the physical condition of wet gluten are its toughness, extensibility, and cohesion.

It is found that the amount of protein and gluten depends on 70% of the ecological conditions and the cultivation technology and 30% on the variety.

One of the important indicators for the quality of wheat is the quantity and quality of gluten - wet and dry (%). The baking and pasta qualities of wheat largely depend on the physico-chemical properties of gluten, its quality - on the variety, ecological conditions and technology of wheat cultivation, and especially on fertilization, and late leaf nutrition after ear formation of the crop, the timing and method of harvesting, drying, preparation and storage and is of particular importance for the production of bread, pasta and confectionery.

According to BDS, the content of wet gluten in the grain of strong and durum wheat must be over 28%. Its quantity depends more on the consistency than on the grain size. Only with the same consistency does the larger grain contain more gluten. To a large extent the quality of gluten depends on the temperature and humidity of the air in the filling and ripening phase of the grain. At lower temperatures and higher humidity, grain with a lower content and quality of protein and gluten is obtained.

The content of wet gluten is higher in the varieties Beloslava by 15.3%, and Vazhod by 8.3% compared to Progress variety, but gluten in these varieties is of poorer quality, for which we judge by the loosening of gluten (Table 5).

Table 5. Influence of the variety on some technological properties of grain

Varieties	Wet gluten		Dry gluten		Sedimentation number (sm^3)	Gluten release (mm)	Number of baking power usl. ed
	%	% към st	%	% to st,			
1.Progress	37.2	100.0	13.8	100.0	51	2.1	66
2.Beloslava	42.9	115.3	14.9	108.0	56	2.9	78
3.Vuzhod	40.3	108.3	14.4	104.3	55	2.6	75
4.Yavor	36.9	99.2	14.0	101.4	49	2.3	64
GD 5%	2.94	7.9	0.98	7.1			

Progress and Yavor varieties have a relatively lower gluten content, but their gluten is firm, inelastic, with minimal loosening of the gluten ball (2.1 and 2.3 mm), which is an indication of strong gluten. The best combination between quantity and quality of gluten is observed in Beloslava and Vazhod varieties. The high baking value (78 and 75) conditional units is an indication of good gluten quality.

The baking value is a set of indicators for the quantity and quality of gluten. All studied varieties are characterized by high baking values. A similar trend is observed with regard to the amount of dry gluten in the grain of the tested varieties of durum wheat. Beloslava variety is characterized by the highest content of dry gluten - 14.9% or by 8.0% higher than Progress variety. In other varieties, an increase in dry gluten is also observed, but it is mathematically unproven.

Sedimentation is a method for determining the puffiness of flour. The sedimentation number of common wheat has a positive correlation with its physical, chemical-technological, and baking properties. It gives an indirect assessment of the baking value. The sedimentation number is positively related to crude protein and wet gluten and is a swelling of gluten proteins in a dilute acid solution. In our studies Beloslava and Vazhod varieties are distinguished by a high sedimentation number.

CONCLUSIONS

For the first time comparative studies have been made on the influence of varietal characteristics on the chemical composition and technological properties of the grain of four varieties of durum wheat grown in Southern Bulgaria.

Of the studied varieties of durum wheat Progress variety has the highest mass per 1000 grains, while the other varieties have lower values of this indicator. All tested varieties have a mathematically unproven higher hectolitre grain mass compared to the Progress variety standard.

Under the ecological conditions of Plovdiv region, the highest grain yield is obtained from Vazhod variety durum wheat. The grain obtained from this variety is by 74.5 kg/da (19.4%) more than the standard Progress variety.

The grains of Yavor variety are characterized by the highest protein content, as this increase is 3.5% more than the standard, while the amount of protein in the other two varieties is lower.

The highest concentration of total and essential amino acids is in the grain of Yavor variety, while in the other two varieties it is significantly lower than the standard.

The highest yield of gluten was reported in the varieties Beloslava and Vazhod, as well as the highest baking value and sedimentation number compared to Progress variety.

The tested varieties of durum wheat have good physicochemical indicators and productive possibilities and can be successfully grown under the ecological conditions of Southern Bulgaria.

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