PRELIMINARY QUALITY ASSESMENT OF WHEAT GRAIN PRODUCED IN THE REPUBLIC OF NORTH MACEDONIA

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Abstract: Wheat is one of the most important cereal crops and stapple food at a global level, also at a national level in the Republic of North Macedonia. It is due to several factors, mainly the large growing area of the wheat crop, the adaptability to various environmental conditions and the nutritional characteristics of the wheat grain. Only the wheat flour is able to form a dough with unique properties essential for production of high-quality bakery products, especially bread, which are prevalent in the diet of our population. For years now, Macedonian farmers have had a serious challenge in terms of the production of good quality wheat grain. The milling companies in the country often warn about the unsatisfactory level of the domestic wheat quality, which requires the necessary import of a high-quality wheat grain (or flour) from abroad. This negatively affects not only the milling and bakery industries, but furthermore the entire wheat production, the national economy and the end consumers. Therefore, an imperative task of the research institutions in the fields of agriculture and food processing is to analyze the current state of technological quality of wheat grown in our country, to investigate risks and limiting factors and to recommend the solutions and best practices. This is the aim of this preliminary quality assessment of wheat grains produced in different regions of the country. Ten wheat grain samples grown in the season 2022/2023 were collected from different fields located in the selected regions in North Macedonia: Skopje region (Petrovec), Kocani region (Bosevica and Sredorek) and Pelagonija region (the subregion near Prilep: Mazuciste and Senokos and the subregion near Bitola: Kravari and Egri). Each sample is of particular wheat variety; some of the them are domestic registered varieties (Radika, Milenka, Belica and Osatka), while others are foreign wheat varieties (Alkantara, Falado, Gabrio and Pibrac). The following grain quality parameters were examined: test weight, sedimentation value, moisture content, protein content and gluten content. Furthermore, in each sample, the determination of besatz was done and bug wheat analysis was performed to identify possible infestation by *Eurygaster* spp. and *Aelia* spp. Some of the analyses were conducted in the laboratories of Food Institute in Novi Sad, Serbia (FINS), while the others in the laboratories of two milling companies (VitaMill and Kokrra e Artë.) in the vicinity of Tetovo, North Macedonia. The test weight of the studied samples ranged from 60.54 kg/hL to 72.91 kg/hL, with the moisture content within the limits from 10.57 % to 12.87%. Based on the results obtained for protein content, gluten content, sedimentation value, and total besatz, most of the samples are classified in class III or one class below, according to the conditions for grading wheat intended for flour production. The parameters used for identifying bug wheat infestation detected bug infestation in 6 of total 10 observed wheat samples, while in two samples a strong presumption of contamination was indicated. The hardest bug infestation was found in the samples of Belica variety originating from two different field plots in Kocani region (location called Sredorek). In general, the already documented bug damage in the majority of the analyzed grain samples, followed with the assessed weak technological quality require further detailed studies. Among all, the focus has to be put on the effects of the wheat bugs on the grain quality parameters. Here, the multi-disciplinary approach with mutual participation and close collaboration of agricultural experts of different profiles and food processing technologists is essential.
Keywords: wheat, grains, varieties, quality characteristics, wheat bugs

1. INTRODUCTION

Wheat is one of the most widespread crops, with total harvested area of 220 407 070 ha and total production quantity of 798 975 306 t in 2023 at a global level (FAOSTAT). It is due to several factors, mainly to the adaptability of the wheat crop to various environmental conditions which enables production on large growing areas. Furthermore, wheat represents one of the most important stapple food in the world because of the exceptional nutritional characteristics of the wheat grain. Only the wheat flour is able to form a dough with unique properties essential for production of high-quality bakery products, especially bread (Rakita, 2017).

In North Macedonia, wheat represents the most important cereal at national level. Bread and bakery products traditionally dominate in the diet of our population, similarly to the neighboring countries in the region (Šarić et al., 2005; Hoxha et al., 2020). In the last three decades, wheat production in North Macedonia faces up with stagnation

and decrease; during the period 1993-2005, the growing area used to be over 100 000 ha with the production of 250 000 – 380 000 t. But, year by year, growing area dropped to 69 522 ha, with the production quantity of 215 165 t in 2023 (State Statistical Yearbooks of the Republic of Nort Macedonia, 1999, 2009, 2014, 2019 and 2024).

In order to stop these negative trends, a lot of measures have to be undertaken for improving the wheat production at national level. Among all, it is urgent to pay attention to an issue that has been insufficiently observed so far - the technological quality of the wheat grain produced in Nort Macedonia.

For years now, Macedonian farmers have had a serious challenge in terms of the production of good quality wheat grain. The milling companies in the country often warn about the unsatisfactory level of the domestic wheat quality, which requires the necessary import of a high-quality wheat grain (or flour) from abroad. This negatively affects not only the milling and bakery industries, but furthermore the entire wheat production, the national economy and the end consumers.

Several studies in the country (Ivanoski et al., 2001; Menkovska, 2003; Ilievski et al., 2011; Spirkovska et al., 2013) assessed the grain quality parameters of mainly Macedonian wheat varieties and genotypes under the local conditions. The most of the obtained values show, in general, average to good technological quality. But these results relate to samples taken out from variety trials set up in a limited surface area, with the best agricultural practices applied, mostly in order to determine the genetic potential for grain quality. They cannot be always representative for the large fields in the entire wheat farming throughout the country. Therefore, such kind of investigations have to be intensified and extended at many levels.

Protein composition is a key component of the end-use value for wheat grain. Although the qualitative composition of the grain is genetically determined, the quantitative composition is significantly modified by the growing conditions (Jamieson et al., 2004, cit. by Torbica et al., 2008). The quality of wheat grain is determined by its genetic potential, the applied production technology and environmental conditions. The influence of these factors is complex and the wheat quality is the result of their interaction (Šarić et al., 2005; Rakita, 2017; Živančev et al., 2022). Their deficit or surplus might deteriorate the wheat grain quality in smaller or greater degree. The most influencing abiotic factors are macro-elements (nitrogen, sulfur), high temperature, drought, heat stress, rainfalls before and during the harvest, while the biotic are the attack of field molds and insects, especially wheat bugs (Torbica et al., 2008).

Wheat bugs or sunn pests (several species of *Eurygaster* spp. and *Aelia* spp.) are some of the most harmful pests on wheat, which cause very severe decrease of the wheat grain quality. The area of their distribution is wherever the wheat is grown, but mostly in semi-arid regions around the world – South and Eastern Europe, North Africa, Middle East, Russia, Ukraine, Serbia, Romania, Bulgaria, Turkey, Italy, Greece, Spain etc. (Torbica et al., 2014; Đurić et al., 2014; Dizlek, 2018; Salis et al., 2010; Sakka et al., 2022). Numerous studies on different aspects of this topic were conducted in the appointed regions, countries and worldwide. The North Macedonia belongs to the same region with the similar climate conditions and the presence of sunn pests was registered on the wheat seed plots (Spasov et al., 2010). But at national level, there is a lack of studies and data available on how wheat bugs influence the wheat technological quality.

Therefore, an imperative task of the research institutions in the fields of agriculture and food processing is to analyze the current state of technological quality of wheat grown in our country, to investigate risks and limiting factors and to recommend the solutions and best practices. The aim of this study is to perform the preliminary quality assessment of wheat grains produced in different regions of the country.

2. MATERIALS AND METHODS

Ten wheat grain samples grown in the season 2022/2023 were analyzed, all of them winter wheat varieties: Radika, Milenka, Belica and Osatka (domestic registered varieties) and Alkantara, Falado, Gabrio and Pibrac (foreign introduced varieties). Belica is the variety with white grains, while the other varieties are all with red grains.

The samples were collected from different wheat farms, fields located in the selected regions in North Macedonia:

Skopje region: location Petrovec (Osatka);

Kocani region: location Bosevica (Radika) and location Sredorek, from 3 different plots (Milenka, Belica BP and Belica BS) and

Pelagonija region: the subregion near Prilep: location Mazuciste, from 2 different plots (Alkantara 1 and Alkantara 2) and location Senokos (Falado) and the subregion near Bitola: Kravari and Egri (Pibrac and Gabrio).

The following grain quality parameters: test weight or hectoliter weight, sedimentation value, moisture content, protein content and gluten content) were determined in the laboratories of two milling companies VitaMill and Kokrra e Arte, in the vicinity of Tetovo, North Macedonia. Near Infrared technology was used (Infraneo NIRT Chopin Technologies and FOS Infratec TM 1241 Grain Analyzer, respectively). In the laboratories of Food Institute in Novi Sad, Serbia (FINS) in each sample, the determination of besatz was done (gravimetric method). Bug wheat

analysis was performed (Mixolab Chopin Technologies, Protoco1: WheatBug1) to identify possible infestation by *Eurygaster* spp.

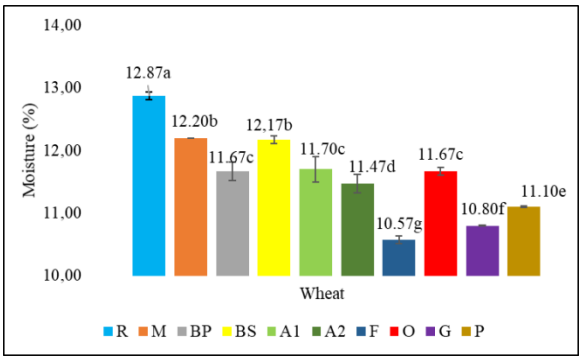
The obtained results are presented, analyzed, and statistically processed using Microsoft Excel and the statistical package XLSTAT 2019. Statistical processing includes analysis of variance (ANOVA) and Fisher's Least Significant Difference test with a significance factor of 95% ($p<0.05$).

3. RESULTS AND DISCUSSIONS

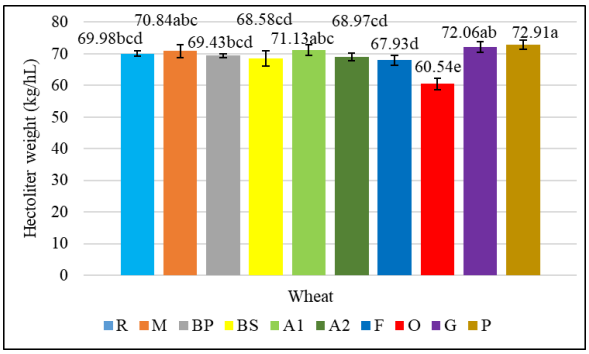
The results of the analyses conducted on 10 wheat samples (mean values out of three repetitive measurements ± standard deviation (SD)) are presented in graphs and table. Means followed with distinct letters in the graphs indicate significant differences according to Fisher's LSD test ($P\leq0.05$).

The Graph 1. presents the results for moisture content of the analyzed wheat varieties, revealing significant differences among the samples ($p < 0.05$). The domestic wheat variety Radika (R) characterized with significantly highest moisture content ((12.87±0.06%) while the foreign variety Falado with significantly lowest moisture content (10.57±0.06%). The moisture content of wheat typically ranges from 7.8 to 14.8% (Szuba-Trznadel et al., 2024), which is consistent with the results shown in Graph 1.

Graph 1. Moisture content



Graph 2. Hectoliter weight



*Radika (R), Milenka (M), Belica (BP), Belica (BS), Osatka (O), Alkantara 1 (A1), Alkantara 2 (A2), Falado (F), Gabrio (G), Pibrac (P)

Source: Authors research

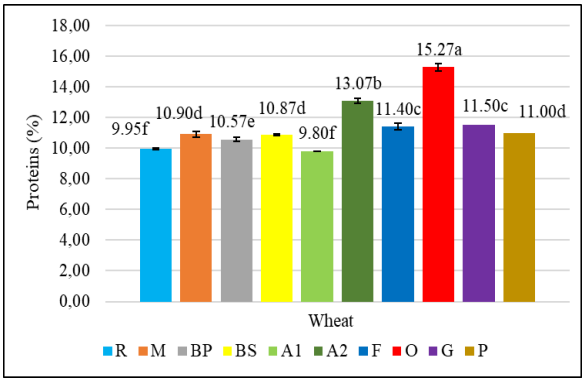
Hectoliter weight is accepted as one of the main quality factors by the milling industry. Millers commonly use hectoliter weight (test weight) as an indicator of the expected flour yield (Boz et al., 2012). Numerous factors influence a grain's hectoliter weight, some of which represent the characteristics of the grain itself, including size, shape, surface, presence of damaged and broken grains, various impurities, etc., but also the variety, applied agricultural techniques, agro-ecological conditions, and even the measurement method and measuring instruments used (Crljenković, 2021). Hectoliter weight is a measure of the volume of grain per unit. It is usually expressed as kilograms per hectoliter and is a good indicator of the soundness of the grain (Masih et al., 2020).

In this research, the hectoliter weight in the evaluated varieties was low in general; the average values ranged from 60.54±1.82 kg/hL to 72.91±1.39 kg/hL (Graph 2). Only the sample of the variety Osatka (O), with the lowest mean value of 60.54±1.82 kg/hL, significantly differs from all the assessed samples at level of $p < 0.05$. This wheat sample cannot be used for flour milling, being beyond the required minimum test weight level of 67 kg/ hL. Not any of the analyzed samples reached the requirements of I and II class (over 78 kg/ hL and over 76 kg/ hL respectively). Two of ten wheat samples fulfill the requirements for III class (over 72 kg/ hL) - Gabrio (G, 72.06±1.70 kg/hL) and Pibrac (P, 72.91±1.39 kg/hL) (PE Official Gazette of the Republic of Macedonia, No. 104/2011).

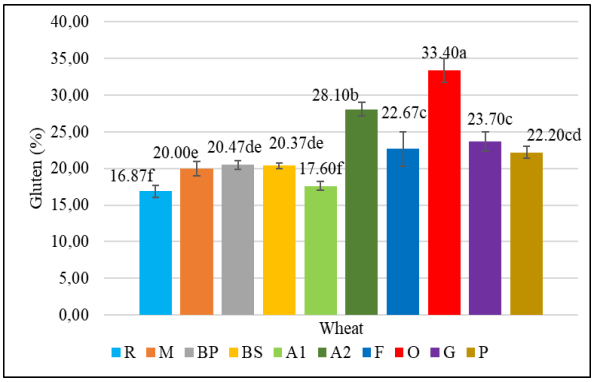
The average values for the protein content and gluten content are presented in Graph 3. and Graph 4 respectively. Most often, the grain protein content varies between 7% and 18% (Guzmán et al., 2022). The protein content of the studied wheat samples (Graph 3) varied from 9.80±0.01% to 15.27±0.25%. The highest protein content was determined in the sample of the variety Osatka (O) - (15.27±0.25%), significantly higher ($p < 0.05$) in comparison with all other samples. This value is also higher than the required level of 14% protein content for the I class, according to the national Rulebook on minimum requirements for quality, characteristics and classification of cereals and rice (PE Official Gazette of the Republic of Macedonia, No. 104/2011). The same Rulebook requires minimum 12% protein content for the II class (assessed in the sample Alkantara 2 (A2) - 13.07±0.15%) and at least 10.5% for the III class (determined in Milenka (M) - 10.90±0.20%, Belica P (BP) 10.57±0.15%; Belica S (BS) - 10.87±0.06%, Falado (F) - 11.40±0.20%, Gabrio (G) - 11.50±0.00% and Pibrac (P) - 11.00±0.00%. The samples

with protein content below 10.5% were Radika (R) with 9.95±0.05% and Alkantara 1 (A1) - 9.80±0.01%. According to Punia et al. (2019), the investigated varieties can be classified as low-protein (R, A1), mid-protein (M, BP, BS, F, G, P) and high-protein varieties (O, A2). Alomari et al. (2023) suggest that wheat with moderate to high protein content (>12%) are convenient for bread making, while those with lower proteins can be used for cookies, pasta and animal feeding. However, the quality standards might slightly varry in different countries.

Graph 3. Protein content



Graph 4. Gluten content



*Radika (R), Milenka (M), Belica (BP), Belica (BS), Osatka (O), Alkantara 1 (A1), Alkantara 2 (A2), Falado (F), Gabrio (G), Pibrac (P)
Source: Authors research

Gluten is the protein viscoelastic network that develops when wheat flour is mechanically mixed with water. This protein network gives wheat dough its unique properties that allow it to be processed into a variety of flour-based products such as breads, cakes, biscuits, cookies, and pasta (Guzmán et al., 2022). Among the quality components of wheat, gluten plays the most important role in determining industrial use (Yıldırım & Deger, 2021).

The gluten content of the analyzed varieties ranged from 16.87±0.85% to 33.40±1.60% (Graph 4). The lowest gluten content was found in the samples of Radika (R) - 16.87±0.85% and Alkantara 1 (A1) - 17.60±0.60%, with no significant differences between them ($p > 0.05$), but significantly differing with other samples ($p < 0.05$). The variety with the highest protein content – Osatka (O), also had significantly highest ($p < 0.05$) gluten content - 33.40±1.60%

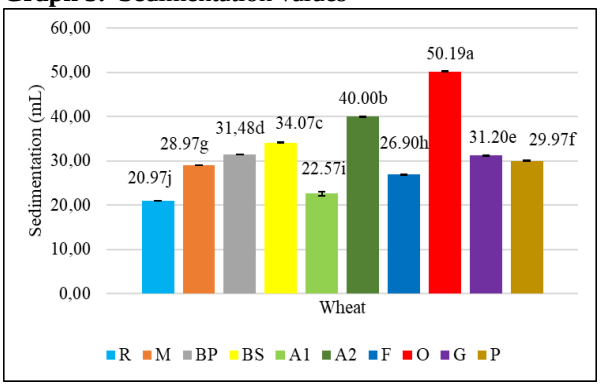
Wheat with gluten values less than 20% is not suitable for the production of wheat flour (Polat & Yagdi, 2019). According to this, it can be seen that wheat varieties R and A1 are not suitable for the production of wheat flour.

The Zeleny sedimentation test is used to predict the quantity and quality of gluten and to estimate the protein content of wheat with the same gluten quality (Dizlek & İslamoğlu, 2015). It has proved to be a reliable, highly reproducible quality test that generally gives a good indication of the end-use quality of wheat (Akyürek &, Başer, 2016). Graph 5 shows the obtained Zeleny sedimentation values of the analyzed wheat varieties. The variations in Zeleny sedimentation values of wheat varieties were found significant levels ($p < 0.05$) and ranged from 20.97±0.06 mL (sample O) to 50.19±0.01 mL (sample R).

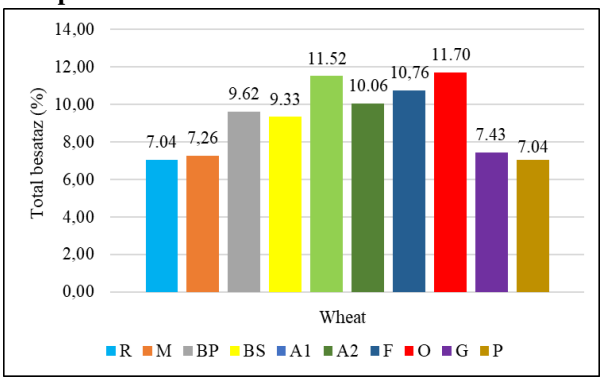
According to the national Rulebook on minimum requirements for quality, characteristics and classification of cereals and rice (PE Official Gazette of the Republic of Macedonia, No. 104/2011), not any of the analyzed varieties reached the minimum requirement for I class (60 mL sedimentation value). The samples A2 and O had values over 40 mL (minimum requirement for II class), while the samples BP, BS и G over 30 mL (minimum requirement for III class). The sedimentation value in rest of the samples (R, M, A1, F and P) was below 30 mL.

Yıldırım,& Deger (2021) reported that wheat varieties with a sedimentation value of 15 mL or less are weak gluten quality, between 15-24 mL are medium gluten quality, between 25-36 mL are good gluten quality, and with 36 mL and above have very good gluten quality. According to this classification, it can be seen that wheat varieties R (20.97±0.06 mL) and A1 (22.57±0.45 mL) have poor gluten quality, while other wheat varieties have good and very good gluten quality.

Graph 5. Sedimentation values



Graph 6. Total besatz



*Radika (R), Milenka (M), Belica (BP), Belica (BS), Osatka (O), Alkantara 1 (A1), Alkantara 2 (A2), Falado (F), Gabrio (G), Pibrac (P)Source: Authors research

The values for total besatz in the tested samples ranged from 7.4% (samples R and P) to 11.7% (sample O). According to the national Rulebook, where I class requires maximum 2.00% total besatz, II class maximum 4.00% and III class maximum 6.00% total besatz, due to higher % of total besatz, not any of the analyzed samples can reach the requirements for classification.

One of the most important forms of preharvest damage to wheat is caused by wheat bugs (Eurygaster spp. and Aelia spp.). The insects insert their mouth parts into the immature grain and while injecting their saliva suck the milky juices. Flour from damaged wheat leads to sticky and weak doughs formation and loaves with low volume and unacceptable texture due to the bug proteolytic enzymes' injected which cause the breakdown of gluten structure in the doug (Allameha et al. 2015). Two new parameters are used to identify if the wheat is bug-infested: change in Mixolab Consistency (CMC) and Slope Index Value (SIV) (Table 1). The lower the CMC value, the greater the bug infestation. The highest percent of CMC (-24.31%), and therefore the lowest bug damage was registered in the sample Alkantara 1; the nearest low CMC values were determined in Pibrac and Gabrio (-29.65 % and -33.64% respectively). In opposite, the lowest CMC values were found in the two samples of Belica variety, Belica S (-57.31%) and Belica P (-52.64%), followed by Milenka (-49.69%) and Falado (-47.31%). In parallel, the SIV value will be considered. An SIV value less than 0.1 indicates that wheat is not bug-infested. An SIV value between 0.1 and 0.15 indicates a strong presumption of contamination. An SIV value greater than 0.15 indicates that wheat is bug-infested (Chopin Technologies, 2012).

Table 1. Identification of possible bug infestation

Parameters	**Wheat samples**									
	R	M	BP	BS	A1	A2	F	O	G	P
CMC [%]	-42.86	-49.69	-52.64	-57.31	-24.31	-38.37	-47.31	-43.8	-33.64	-29.65
SIV[Nm/min]	0.12	0.19	0.28	0.26	0.08	0.16	0.22	0.31	0.1	0.08

* CMC- Change in Mixolab Consistency; SIV- Slope Index Value*Radika (R), Milenka (M), Belica (BP), Belica (BS), Osatka (O), Alkantara 1 (A1), Alkantara 2 (A2), Falado (F), Gabrio (G), Pibrac (P)

Source: Authors research

The SIV values of samples Alkantara 1 and Pibrac (0.08 Nm/min) are less than 0.1 indicating that these wheat varieties are not bug-infested. The SIV values of samples Radika (0.12 Nm/min) and Gabrio (0.1 Nm/min) are between 0.1 and 0.15 indicating a strong suspicion of bug-infestation. The values of the rest seven samples are greater than 0.15 indicating that these wheat varieties are bug-infested, with samples Belica P and Belica S having the highest bug infestation.

However, based on these two parameters CMC and SIV, Alkantara 1 and Pibrac were not bug damaged, Radika and Gabrio under suspicion of bug damage; Falado, Alkantara 2, Belica BP, Belica BS, Osatka and Milenka were bug damaged. Two samples of Belica have white grains and white grained varieties are found as more susceptible to Sunn pests infestation with more severe attacks (Sanaey et al., 2012; Kinaci et al. 2007).

4. CONCLUSIONS

This preliminary assessment of wheat samples from different regions in North Macedonia reveals the weak technological quality, that confirms the current state in the entire wheat production and milling industry in the country. Serious attention has to be paid to the technological quality at national level. Quality analyses have to be intensified including larger extent of grain, flour and dough quality parameters. The already documented bug damage in the majority of the analyzed grain samples require further detailed studies. There is an urgent necessity of Sunn pests monitoring and managing at national level. The focus has to be put on the effects of the wheat bugs on the grain quality parameters. Furthermore, all the factors influencing the wheat grain quality in North Macedonia have to be considered: environmental conditions, applied production technology (selection of high-quality wheat varieties, optimizing mineral nutrition, pest management etc.). Here, the multi-disciplinary approach with mutual participation and close collaboration of agricultural experts of different profiles and food processing technologists is essential.

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