UDC 633.112.9 DOI:10.30835/2413-7510.2018.152144
633.11:631.527:581.19

GRAIN QUALITY OF TETRAPLOID WHEAT TRITICUM TIMOPHEEVII (ZHUK.) ZHUK.

Relina L.I., Boguslavskyi R.L., Vecherska L.A., Didenko S.Yu., Golik O.V., Sheliakina T.A., Pozdniakov V.V.
Plant Production Institute nd. a. V.Ya. Yuriev of NAAS, Ukraine

The article is devoted to the comprehensive investigation of the quality parameters of tetraploid wheat (*Triticum timopheevii)* grain. Particular attention is paid to prospects of involving *T. timopheevii* in breeding programs as a resource of valuable quality and technology properties.

Key words: *Triticum timopheevii, grain quality, protein content, carotenoids, total antioxidant activity, zinc, iron, copper, vitreousness, grain hardness*

Introduction. *Triticum timopheevii* or Timopheev's wheat is a cultivated tetraploid wheat. It is an endemic crop of the piedmonts of western Georgia [1]. The species has probably been domesticated in Georgia. The domesticated form is restricted to western Georgia. Timopheev's wheat is believed to have evolved in isolation from the more common tetraploid wheat species *T. durum* Desf., *T. turgidum* L. as also from it putative wild ancestor *T. araraticum* Jakubz.

It is suitable for sandy, loamy and clay soils and prefers moist well-drained soil. Soil pH can be acidic, neutral of alkaline. It is a light-demanding plant [2].

T. timopheevii is highly resistant to head smut [3]. It is also immune to root rots, powdery mildew, leaf, stem, yellow rusts, Septoria blotch etc. [3, 4].

There have been successful attempts to involve *T. timopheevii*in breeding since the late 1800th [4, 5, 6, 7, 8, 9]. *T. timopheevii* was crossed with common wheat. The effect of *T. timopheevii* introgression fragments on resistance to leaf and stem rusts, powdery mildew and a number of quantitative traits was evaluated in introgressive lines of common wheat [7]. The lines with an introgressive fragment of the 5G chromosome were 100% resistant to Western Siberian populations of leaf rust and stem rust that was typical for Omsk region. Lines with a fragment of the 2G chromosome were resistant to Western Siberian populations of stem rust. No negative influence of alien material from *T. timopheevii* on the yield and other quantitative traits of common wheat was observed, indicating that *T. timopheevii* can be used in breeding as donors of resistance to fungal diseases, which was further confirmed by [8, 9, 10].

Y.A. Andreev et al. [11] discovered highly homologous wamp genes in *T. timopheevii*. These genes encode hevein-like plant defense peptides have antifungal activity and are accumulated in response to phytopathogen challenge. They also participate in plant response also to abiotic stress, since high salt concentrations enhanced their expression.

Thus, *T. timopheevii* is a promising object for breeding, though little studied in terms of grain quality, and these characteristics of wheat grain are drawing increasing attention nowadays. Grain quality is determined by many parameters such as protein and starch contents and compositions, vitamin and antioxidant contents, micronutrient amounts, etc. Augmentation in grain nutrient levels (biofortification), either agronomically (fertilization) or genetically (breeding), is thought to be a promising and cost-effective approach to alleviating malnutrition and related health problems [12, 13, 14, 15, 16]. This solution, however, requires a comprehensive exploration of potential genetic resources. Therefore, our objective was to

ISSN 1026-9959. Селекція і насінництво. 2018. Випуск 114.

evaluate the protein content, carotenoid level, antioxidant activity and trace mineral contents in *T. timopheevii* grain as well asperformance and processing parameters of *T. timopheevii* grain.

Materials and methods. The analyses were carried out on *T. timopheevii* from a collection of the National Center for Plant Genetic Resources of Ukraine. The plants were grown on typical black soil. The cultivars used for comparisons (emmer Holikovska and durum wheat Spadshchyna) were grown in plots located in the same field with *T. timopheevii* using identical agronomic techniques. Grain harvested in 2015, 2016 and 2017 (years with various weather conditions) was used in analyses.

The protein content was determined by Kjeldahl digestion [17]. The carotenoid level was spectrophotometrically assessed in acetone extracts as described in [18, 19]. The total antioxidant activity was investigated by DPPH• assay [20]. The contents of iron, zinc and copper were determined by atomic absorption spectrometry [21]. The test weight and vitreousness were evaluated in compliance with [22]. The grain hardness was determined on a YPD-300 hardness tester (Ltpm China) (measuring force applied to crush kernels) by the method developed by A.V. Yarosh et al [23] and expressed in newtons.

Results and discussion. The protein content in *T. timopheevii* grainwas within 18.2–16.5% (Table 1), depending on the year, which is rather high, as good durum wheat grain contains 15–18 % of protein (grade I grain has ≥14.0% of protein [24]. For example, the protein content in grain of reference durum wheat cv. Spadshchyna bred at the Plant Production Institute named after V.Ya. Yuriev of NAAS ranges within 14.5–16.5%. 2017 was the most favorable year for protein accumulation. The protein content variation can be attributed to weather fluctuations during crucial periods in the plant development. The grain accumulated 18.2% of protein, when the precipitations amounts were 26 and 39 mm during the phases of green mass development and grain filling, respectively. Increase in the precipitations amount was associated with a reduction in the protein content, though the species prefers moist conditions. This can be due to insufficient drainage of soil, as the soil in the cultivation site was moderately clayey with medium drainage, and *T. timopheevii* does well on well-drained soils [2]. There was no apparent relationship between the protein content and temperatures during the crucial phases of the plant development. Despite this variation, high protein content in grain seems to be a consistently expressed trait in *T. timopheevii*, and this speciesbelongs to high-protein wheats.

Table 1

Biochemical parameters of *Triticum timopheevii* grain, 2015–2017

Year	Protein content, %	Carotenoid content, mg/kg	TAOA, CGAE/ g of seeds	Earing date	Green mass development		Grain filling	
					Σ_p, mm	t_{av}, °C	Σ_p, mm	t_{av}, °C
2015	16.5	3.54	608.4	06.10.2015	58	16.3	102	20.3
2016	17.4	2.72	620.3	06.27.2016	123	19.6	96	23.1
2017	18.2	3.10	628.1	07.01.2017	26	19.1	39	22.6

Staples are not considered an important source of vitamins, antioxidants or minerals in the diet. However, there is an opinion [25] that because of high staple consumption, any increase in concentrations of these substances may have a significant effect on human nutrition and health. Wheat is the major staple food crop in many countries, contributing 28% of the world's edible dry matter [26].

Carotenoid content is a determinant of wheat nutritional value and affects end-product quality. Wheat grain generally contains very low carotenoid amounts and in order to enrich wheat grain with carotenoids, new high-carotenoid sources are searched for. The carotenoid content in *T. timopheevii* grainwas medium: 2.72–3.54 mg/kg (Table 1). It is considered that high quality bright-yellow pasta can be made from grain containing not less than 5.5 mg/kg of carotenoids [27]. Hence, *T. timopheevii* cannot be referred to high-carotenoid ones.

Antioxidant content is another determinant of wheat nutritional value. The total antioxidant activity in *T. timopheevii* grain amounted to 618.2 chlorogenic acid equivalents (CGAE) /g of seeds in 2017, reducing in the other study years (see Table 1). The peak content of antioxidants in the years with the minimal precipitation during the wheat development may be accounted for by enhanced non-specific protection against stress. A positive correlation was observed between seed antioxidants and drought tolerance in other plant species [28]. The average antioxidant activity in *T. timopheevii* grain remains higher than that in reference durum wheat grain, cv. Spadshchyna (525.4±38.9 CGAE /g of seeds). Thus, *T. timopheevii* can be tested for using in wheat breeding for high antioxidant content.

Some minerals are essential in metabolism or for the synthesis of essential compounds. Bread and breakfast cereals are sometimes specifically fortified with iron [29], therefore, there is a chance to breed high-iron wheat cultivars. The iron content in commercial durum wheat varies within 25.7–40.5 mg/kg [30]. *T.timopheevii* grain contains 39.27–55.90 mg/kg of iron (see Table 2), which is considerably higher than the iron levels in commercial durum wheat cultivars and comparable to the iron content in Polish emmer grain (49 mg/kg, though such comparisons should be drawn with reservations, because growing conditions may vary a lot) [31] and in cv. Holikovska grain (around 40 mg/kg) bred at the Plant Production Institute named after V.Ya. Yuriev of NAAS). This variation can be attributed to weather fluctuations during crucial periods in the plant development: the grain accumulated 55.90 mg/kg of iron, when the precipitations amounts were 26 and 39 mm during the phases of green mass development and grain filling, respectively. Increase in the precipitations amount was associated with a reduction in the iron content. Thus, in general, the iron content changed in parallel with the protein content. This was expected, since the high grain protein content gene (*GPC-B1)* was also shown to confer higher concentrations of both Fe and Zn in grain [32, 33]. Despite this variation, high iron content in grain appears to be genetically intrinsic to *T. timopheevii*.

Table 2

Mineral contents in *Triticum timopheevii* grain in different years

Year	Minerals			Earing date	Green mass development		Grain filling	
	Zn	Fe	Cu		Σ_p, mm	t_{av}, °C	Σ_p, mm	t_{av}, °C
2015	36.334	40.040	4.455	06.10.2015	58	16.3	102	20.3
2016	36.524	39.270	2.790	06.27.2016	123	19.6	96	23.1
2017	41.041	55.900	1.860	07.01.2017	26	19.1	39	22.6

Note: Σ_p – precipitation amount, t_{av} – average temperature.

Zinc is also an essential trace element for humans. Wheat (especially germ and bran) is among the food plants that contain the most zinc [34]. For fortification, 2003 review recommended cereals as a cheap, stable source that is as easily absorbed [35]. The zinc content in commercial durum wheat varies within 24.8–48.8 mg/kg [30]. ContiME et al. [36] reported that Italian durum wheat contained 24 mg/kg of zinc. The maximum allowable concentration of zinc in grain is 50.0 mg/kg [37]. *T.timopheevii* grain contains 36.33-41.04 mg/kg of zinc (see Table 2), which is comparable to commercial durum wheat and our emmer, cv. Holikovska (around 31.0 mg/kg), and somewhat less than in Polish emmer grain (54 mg/kg, as Suchowilska et al reported [31]). The zinc content-weather conditions relationship was similar to the protein/iron content-weather conditions relationship (see the discussion above) Correlations between Zn and Fe contents were positive for wild emmer [32, 38, 39], and domesticated emmer [40].

Copper is another essential trace element. Italian durum wheat, for example, contains 3.5 mg/kg of copper [36]. The variations in this parameter can be wide: 1.8–39.7 mg/kg in durum wheatmilling products [41]. In Russian wheat grain the copper content ranged within 2.0–12.8 mg/kg, depending on the cultivation site[42]. Other Russian researchers report that the copper level in spring wheat grain averaged 5.15±0.40 mg/kg (throughout 10 years), with the maximum allowable concentration of 10 mg/kg [37]. Suchowilska et al [31] reported that grain of a related species, *Triticum dicoccum,* contained 4.4 mg/kg of copper. *T. timopheevii* grain contained of 1.86-4.46 mg/kg of copper in different years (see Table 2). Thus, such levels can satisfy the need of human body for copper, on the one hand, and are far below the maximum allowable concentration, on the other hand. The copper content was maximal in the years, when the average air temperature during the phases of green mass development and grain filling was relatively low: 16.3 and 20.3°C, respectively. Rise in temperature to 19.1–19.6°C and to 22.6–23.1°C, respectively, was associated with lower copper content. Unlike the iron and zinc contents, we observed no relationship between the copper content and the precipitation amount.

Concurrently with biochemical characterization, we measured performance and processing parameters of *T. timopheevii.* The 1000-seed weight was 34.29 g (see Table 3), meaning that *T.timopheevii* has medium-sized grain. The test weight and vitreousness are criteria for determining grain grade.The grain unit was around 846 g/L, which is sufficiently high, as the minimal grain unit for durum wheat is set on 700 g/L, and grade I grain has ≥750 g/L [24]. The vitreousness was markedly high – 100%, which is valuable for easy milling (grade I grain has ≥70% vitreousness [24]. The grain hardness is one of the key determinants of milling behavior and has a great influence on flour and dough quality [43, 44, 45]. For example, the grain hardness was shown to correlate with bread-making quality [46, 47]. The *T. timopheevii* grain hardness was 286N. It is difficult to compare different researchers' data, as they use different techniques and devices to measure the grain hardness. However, Veha et al. [48] cross-checked the Hardness Index (HI) produced Perten SKCS 4100 equipment against maximum breaking force in Newtons produced by Lloyd 1000R Testing Machines. Using their data, we can assume that 286 N measured on a YPD-300 hardness tester corresponds approximately HI 68. Using Szabó et al's data [49], we obtain a similar result. This means that *T.timopheevii* is likely to belong to hard wheats according to Haraszi et al's classification [50, 51].

Table 3

Technological parameters of *Triticum timopheevii* grain, 2015–2017

Year	Grain hardness, N	Test weight, g/L	Vitreous-ness, %	1000-grain weight, g	Earling date	Green mass development		Grain filling	
						Σp, mm	t_{av}, °C	Σp, mm	t_{av}, °C
2015	283	842	99	34.1	06.10.2015	58	16.3	102	20.3
2016	279	850	100	34.6	06.27.2016	123	19.6	96	23.1
2017	296	846	100	34.3	07.01.2017	26	19.1	39	22.6

Conclusions. Thus, our results have demonstrated that

1) *T.timopheevii* has medium-sized grain;

2) *T. timopheevii* is noticeable for a high antioxidant activity, sufficient iron and zinc contents, balanced copper content, exclusively high vitreousness and high grain harness;

3) *T. timopheevii* cannot be referred to high-carotenoid species.

References

1. Zhukovskiy PM. Domestic plants and their relatives.Leningrad: Kolos, 1971. P. 27.
2. Plants for future *Triticum timopheevii* Zhuk. Plants for a Future (1995-2010) [cited 2018 Aug 18] Available from: https://www.pfaf.org/user/Plant.aspx? LatinName =Triticum+timopheevii
3. Wheats of the world. In: Dorofeev VF, editor. Leningrad: Agropromizdat. 1987, P. 413.

4. Tingting Chen, Jin Xiao, Jun Xu, Wentao Wan, Bi Qin, Aizhong Cao, Wei Chen, Liping Xing, Chen Du, Xiquan Gao,Shouzhong Zhang, Ruiqi Zhang, Wenbiao Shen, Haiyan Wang, and Xiue Wang. Two members of TaRLK family confer powdery mildew resistance in common wheat. BMC Plant Biol.2016; 16: 27.
5. Australian Agriculture: Its history and challenges. In: T Henzell, editor. Csiro Publishing, 2007 P. 30.
6. Laikova LI, Belan IA, Badaeva ED, Posseeva LP, Shepelev SS, Shumny VK, Pershina LA. Development and study of spring bread wheat variety Pamyati Maystrenko with introgression of genetic material from synthetic hexaploid *Triticum timopheevii* Zhuk. x *Aegilops tauschii* Coss. Genetika.2013; 49(1): 103–120.
7. Timonova EM, Leonova IN, Belan IA, Rosseeva LP, Salina EA. The influence of particular chromosome regions of *Triticum timopheevii* on the formation of resistance to diseases and quantitative traits in common wheat. Russian Journal of Genetics: Applied Research. 2012; 2(4): 330–343.
8. Brown-Guedira GL, Singh S, Fritz AK. Performance and mapping of leaf rust resistance transferred to wheat from *Triticum timopheevii* subsp. *armeniacum.* Phytopathology. 2003; 93(7): 784–789.
9. Singh AK, Sharma JB, Vinod, Singh PK, Singh A, Mallick N. Genetics and mapping of a new leaf rust resistance gene in *Triticum aestivum L.* × *Triticum timopheevi* Zhuk. derivative 'Selection G12'. J Genet.2017; 6(2): 291–297.
10. Zhang D, Bowden RL, Yu J, Carver BF, Bai G. Association analysis of stem rust resistance in U.S. winter wheat. PLoS One. 2014; 9(7): e103747.
11. Andreev YA, Korostyleva TV, Slavokhotova AA, Rogozhin EA, Utkina LL, Vassilevski AA, Grishin EV, Egorov TA, Odintsova TI. Genes encoding hevein-like defense peptides in wheat: distribution, evolution, and role in stress response. Biochimie. 2012; 94(4): 1009–16.
12. Garg M, Sharma N, Sharma S, Kapoor P, Kumar A, Chunduri V, Arora P. Biofortified crops generated by breeding, agronomy, and transgenic approaches are improving lives of millions of people around the world. J. Front Nutr. 2018; 5: 12.
13. Welch RM, Graham RD. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany. 2004; 55: 353–364.
14. Bouis HE. The potential of genetically modified food crops to improve human nutrition in developing countries. Journal of Developmental Studies 2007; 43: 79–96.
15. Cakmak I. Enrichment of cereal grains with zinc: agronomic or genetic biofortification? Plant and Soil. 2008; 302: 1–17.
16. Peleg Z, Cakmak I, Ozturk L, et al. Quantitative trait loci conferring grain mineral nutrient concentrations in durum wheat B wild emmer wheat RIL population. Theoretical and Applied Genetics; 2009: 119: 353–369.
17. Kjeldahl J. "Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern" (New method for the determination of nitrogen in organic substances). Zeitschrift für analytische Chemie. 1983; 22(1): 366–383.
18. Yermakov AI, Arasimovich VV, Smirnova-Ikonnikova MI, Yarosh NP, Lukovnikova GA. Methods of biochemical studies on plants. Leningrad: Kolos, 1972. P. 456.
19. Murri IK. Millet biochemistry. In Biochemistry of domestic plants, Vol. 1. 2nd edition, Moscow-Leningrad: Selkhozgiz, 1958, P. 512–588.
20. Arabshahi S, Urooj A. Antioxidant properties of various solvent extracts of Mulberry *Morus indica* L. Leaves. Food Chem. 2007; 102: 1233–1240.
21. Krupskiy NK, Aleksandrova AM. On determination of mobile forms of microelements. Trace elements in the lives of plants, animals, and man: Meeting of the Task Group of the Academy of Sciences of UkrSSR (Feb. 22–23.1963). Kyiv: Naukova Dumka, 1964. 325 p.
22. Evaluation of grain quality. In: II Vasilenko, VI Komarov. M, editor. Moscow: Agropromizdat, 1987. 208 p.

23. Yarosh AV, Riabchun VK, Leonov OYu, Didenko SYu, Kopytina LP, Sakhno TV, Sheliakina TA. Method for evaluating grain hardness in winter bread wheat. Henetychni Resursy Roslyn. 2014; 15: 120–131.
24. State Standard of Ukraine 3768:2010. National Standard of Ukraine. Wheat. Specifications Valid from 01. 04.2010.
25. Glenn B Gregorio. Progress in breeding for trace minerals in staple crops. The Journal of Nutrition. 2002; 132(3): 500S–502S.
26. FAOSTAT. 2008. [cited 2018 Aug 18] Available from: http://www.fao.org/faostat/en/#home.
27. Vasilchuk NS. Spring durum wheat breeding. Saratov, 2001. 123p.
28. Lakshmi SU, Krishna MSR, Deepthi RS, Prasad GS, Kasim DP. Seed Antioxidants interplay with drought stress tolerance indices in Chilli (*Capsicum annuum* L.) Seedlings. BioMed Research International. 2018; 2018: 1605096.
29. Food Standards agency – eat well, be well – iron deficiency. Eatwell.gov.uk. Retrieved on 27 June 2012.
30. Magallanes-López AM, Hernandez-Espinosa N, Velu G, Posadas-Romano G, Ordoñez-Villegas VMG, Crossa J, Ammar K, Guzmán C. Variability in iron, zinc and phytic acid content in a worldwide collection of commercial durum wheat cultivars and the effect of reduced irrigation on these traits. Food Chem. 2017; 237: 499–505
31. Suchowilska E, Wiwart M, Kandler W, Krska R. A comparison of macro- and microelement concentrations in the whole grain of four Triticum species. Plant Soil Environ. 2012; 58(3): 141–147.
32. Cakmak I, Torun A, Özkan H, Millet E, Feldman M, Fahima T, Korol AB, Nevo E, Braun HJ. *Triticum dicoccoides*: an important genetic resource for increasing zinc and iron concentration in modern cultivated wheat. Soil Sci Plant Nut. 2004; 50:1047–1054.
33. Distelfeld A, Cakmak I, Peleg Z, Ozturk L, Yazici AM, Budak H, Saranga Y, Fahima T. Multiple QTL-effects of wheat Gpc-B1 locus on grain protein and micronutrient concentrations. Physiol. Plantarum. 2006; 129: 635-643.
34. Audrey H Ensminger, James E Konlande. Foods & Nutrition Encyclopedia (2nd ed.). Boca Raton, Florida: CRC Press. 1993. P. 2368–2369.
35. Rosado JL. Zinc and copper: proposed fortification levels and recommended zinc compounds. Journal of Nutrition. 2003; 133(9): 2985S–9S.
36. Conti ME, Cubadda F, Carcea M. Trace metals in soft and durum wheat from Italy. Food Addit Contam. 2000; 17(1): 45–53.
37. Feschenko VP. The ecological state of cereals in the Novosibirsk region by contents of heavy metals. Sovremennyye Problemy Nauki i Obrazovaniya. 2014; 5. Available from: http://www.science-education. Ru/ ru/article/view?id=15088.
38. Peleg Z, Saranga Y, Yazici A, Fahima T, Ozturk L, Cakmak I. Grain zinc, iron and protein concentrations and zinc-efficiency in wild emmer wheat under contrasting irrigation regimes. Plant Soil. 2008; 306: 57–67.
39. Chatzav M, Peleg Z, Ozturk L, Yazici A, Fahima T, Cakmak I, Saranga Y. Genetic diversity for grain nutrients in wild emmer wheat: potential for wheat improvement. Annals of Botany. 2010; 105(7): 1211–1220.
40. Gregorio GB. Progress in breeding for trace minerals in staple crops. J Nutr. 2002; 132(3): 500S–502S.
41. Micco C, Onori R, Miraglia M, Gambelli L, Brera C. Evaluation of lead, cadmium, chromium, copper and zinc by atomic absorption spectroscopy in durum wheat milling products in relation to the percentage of extraction. Food Addit Contam; 1987; 4(4): 429–35.
42. Pugaev SV. Contents of heavy metals in grain of winter and spring wheat grown in different environmental conditions. Vestnik Mordovskogo Universiteta. 2013; 3–4: 89–93.
43. Symes K. Classification of Australian wheat varieties based on the granularity of their wholemeal. Australian Journal of Experimental Agriculture and Animal husbandry. 1961; 1: 18–23
44. Hoseney RC. Wheat hardness. Cereal Foods World. 1987; 32: 320–322.

45. Pomeranz Y, Williams PC. Wheat hardness: its genetic, structure and biochemical background, measurement and significance. In: Advances in Cereal Science and Technology (edited by Y Pomeranz). St Paul, MN: AACC. 1990. P. 471–557.
46. Fedotov VA. Factors of formation of consumer properties of grain/flour products. Vestnik OGU. 2011; 4(123). Available from: https://cyberleninka.ru/article/v/faktory-formirovaniya-potrebitelskih-svoystv-zernomuchnyh-tovarov.
47. Medvedev PV, Fedotov PV, Bochkaryova IA. Comprehensive assessment of consumer properties of grain and its products. Mezhdunarodnyy Nauchno-Issledovatelskiy Zhurnal. 2015; 7-1(38): 77–80.
48. Veha A, Szabó PB, Gyimes E. Different method to determine the kernel hardness of Hungarian winter wheat varieties, 7th International Conference Integrated Systems for Agri-Food Production, Sipa. Nyíregyháza, Hungary. 2011. P. 10–12.
49. Szabó BP, Véha A, Gyimes E.: Measuring the wheat kernel hardness. Review of Faculty of Engineering, Analecta Technica Szegedinensia. 2007; 1: 97–100.
50. Haraszi R, Sissons M, Juhasz A, Kadkol G, Tamas L, Anderssen RS. Using rheological phenotype phases to predict rheological features of wheat hardness and milling potential of durum wheat. Cereal Chemistry. 2016; 93(4): 369–376.
51. Haraszi R, Juhasz A, Sissons M, Rakszegi M, Tamas L, Anderssen RS. Rheological hardness index for assessing hardness of hexaploids and durums. J. Cereal Chemistry. 2013; 90(5): 430–438.

Список використаних джерел

1. Жуковский П.М. Культурные растения и их сородичи. Л.: Колос, 1971. С. 27.
2. Plants for future *Triticum timopheevii* Zhuk. Plants for a Future (1995–2010). URL: www.pfaf.org/user/Plant.aspx? LatinName=Triticum+timopheevii.
3. Пшеницы мира / под ред. Дорофеева В.Ф.; сост. Удачин Р.А. Ленинград ВО Агропромиздат. 1987. С. 413.
4. Chen T., Xiao J., Xu J., Wan W., Qin B., Cao A., Chen W., Xing L., Du Ch., Gao X., Zhang Sh., Zhang R., Shen W., Wang H., Wang X. Two members of TaRLK family confer powdery mildew resistance in common wheat. BMC Plant Biol. 2016. № 16. P. 27.
5. Australian Agriculture: Its History and Challenges Ed. by Henzell T. Csiro Publishing 2007. P. 30.
6. Laikova L.I., Belan I.A., Badaeva E.D., Posseeva L.P., Shepelev S.S., Shumny V.K., Pershina L.A. Development and study of spring bread wheat variety Pamyati Maystrenko with introgression of genetic material from synthetic hexaploid Triticum timopheevii zhuk. x Aegilops tauschii Coss. Genetika. 2013. № 49(1). P. 103–12.
7. Timonova E.M., Leonova I.N., Belan I.A., Rosseeva L.P., Salina E.A. The influence of particular chromosome regions of *Triticum timopheevii* on the formation of resistance to diseases and quantitative traits in common wheat. Russian Journal of Genetics: Applied Research. 2012. № 2(4). P. 330–343.
8. Brown-Guedira G.L., Singh S., Fritz A.K. Performance and mapping of leaf rust resistance transferred to wheat from *Triticum timopheevii* subsp. *armeniacum*. Phytopathology. 2003. № 93(7). P. 784–789.
9. Singh A.K., Sharma J.B., Vinod, Singh P.K., Singh A., Mallick N. Genetics and mapping of a new leaf rust resistance gene in *Triticum aestivum* L. × *Triticum timopheevii* Zhuk. derivative 'Selection G12'. J Genet. 2017. № 96(2). P. 291–297.
10. Zhang D., Bowden R.L., Yu J., Carver B.F., Bai G. Association analysis of stem rust resistance in U.S. winter wheat. PLoS One. 2014. № 9(7). e103747.
11. Andreev Y.A., Korostyleva T.V., Slavokhotova A.A., Rogozhin E.A., Utkina L.L., Vassilevski A.A., Grishin E.V., Egorov T.A., Odintsova T.I. Genes encoding hevein-like defense peptides in wheat: distribution, and role in stress response. Biochimie. 2012. № 94(4). P. 1009–1016.

12. Garg M., Sharma N., Sharma S., Kapoor P., Kumar A., Chunduri V., Arora P. Biofortified crops generated by breeding, agronomy, and transgenic approaches are improving lives of millions of people around the world. J. Front Nutr. 2018. № 5. P. 12.
13. Welch R.M., Graham R.D. Breeding for micronutrients in staple food crops from a human nutrition perspective. Journal of Experimental Botany. 2004. № 55. P. 353–364.
14. Bouis H.E. The potential of genetically modified food crops to improve human nutrition in developing countries. Journal of Developmental Studies. 2007. № 43. P. 79–96.
15. Cakmak I. Enrichment of cereal grains with zinc: agronomic or genetic biofortification? Plant and Soil. 2008. № 302. P. 1–17.
16. Peleg Z., Cakmak I., Ozturk L. et al. Quantitative trait loci conferring grain mineral nutrient concentrations in durum wheat B wild emmer wheat RIL population. Theoretical and Applied Genetics. 2009. № 119. P. 353–369.
17. Kjeldahl J. Neue Methode zur Bestimmung des Stickstoffs in organischen Körpern (New method for the determination of nitrogen in organic substances). Zeitschrift für analytische Chemie. 1983. № 22(1). P. 366–383.
18. Ермаков А.И., Арасимович В.В., Смирнова-Иконникова М.И., Ярош Н.П., Луковникова Г.А. Методы биохимического исследования растений. Л.: Колос, 1972. 45 с.
19. Мурри И.К. Биохимия проса. / В кн.: Биохимия культ, растений, т. 1. Изд. 2, М.-Л.: Сельхозгиз, 1958. С. 512–588.
20. Arabshahi S., Urooj A. Antioxidant properties of various solvent extracts of mulberry *Morus indica* L. Leaves. Food Chem. 2007. № 102. P. 1233–1240.
21. Крупский Н.К., Александрова А.М. К вопросу об определении подвижных форм микроэлементов // В сб.: Микроэлементы в жизни растений, животных и человека. Киев: Наукова Думка, 1964. С. 29–30.
22. Оценка качества зерна / Сост.: Василенко И.И., Комаров В.И. М.: Агропромиздат, 1987. 208 с.
23. Ярош А.В., Рябчун В.К., Леонов О.Ю., Діденко С.Ю., Копитіна Л.П., Сахно Т.В., Шелякіна Т.А. Методологія оцінки твердості зерна у пшениці м'якої озимої. Генетичні ресурси рослин. 2014. № 15. С. 120–131.
24. ДСТУ 3768:2010 Національний стандарт України. Пшениця. Технічні умови Пшеница. Технические условия. WHEAT Specifications. Чинний від 2010-04-01.
25. Gregorio G.B. Progress in breeding for trace minerals in staple crops. The Journal of Nutrition. 2002. № 132(3). P. 500–502.
26. FAOSTAT. 2008. [cited 2018 Aug 18]. URL: www.fao.org/faostat/en/#home.
27. Васильчук Н.С. Селекция яровой твердой пшеницы. Саратов, 2001. 123 с.
28. Lakshmi S.U., Krishna M.S.R., Deepthi R.S., Prasad G.S., Kasim D.P. Seed antioxidants interplay with drought stress tolerance indices in chilli (*Capsicum annuum* L) seedlings. BioMed Research International. 2018. № 14. URL: doi: 10.1155/2018/1605096.
29. Food Standards Agency. Eat well, be well – Iron deficiency. Food Standards Agency: London, 2012. URL: www. Eatwell.food.gov.uk.
30. Magallanes-López A.M., Hernandez-Espinosa N., Velu G., Posadas-Romano G., Ordoñez-Villegas V.M.G., Crossa J., Ammar K., Guzmán C. Variability in iron, zinc and phytic acid content in a worldwide collection of commercial durum wheat cultivars and the effect of reduced irrigation on these traits. Food Chem. 2017. № 237. P. 499–505.
31. Suchowilska E., Wiwart M., Kandler W., Krska R. A comparison of macro- and microelement concentrations in the whole grain of four Triticum species. Plant Soil Environ. 2012. № 58(3). P. 141–147.
32. Cakmak I., Torun A., Özkan H., Millet E., Feldman M., Fahima T., Korol A.B., Nevo E., Braun H.J. *Triticum dicoccoides*: an important genetic resource for increasing zinc and iron concentration in modern cultivated wheat. Soil Sci Plant Nut. 2004. № 50. P. 1047–1054.
33. Distelfeld A., Cakmak ., Peleg Z., Ozturk L., Yazici A.M., Budak H., Saranga Y., Fahima T. Multiple QTL-effects of wheat Gpc-B1 locus on grain protein and micronutrient concentrations. Physiol. Plantarum. 2006. № 129. P. 635–643.

34. Ensminger A.H., Konlande J.E. Foods & Nutrition Encyclopedia (2nd ed.). Boca Raton, Florida: CRC Press. 1993. P. 2368–2369.
35. Rosado J.L. Zinc and copper: proposed fortification levels and recommended zinc compounds. Journal of Nutrition. 2003. № 133(9). P. 2985–2989.
36. Conti M.E., Cubadda F., Carcea M. Trace metals in soft and durum wheat from Italy. Food Addit Contam. 2000. № 17(1). P. 45–53.
37. Фещенко В.П. Экологическое состояние зерновых культур Новосибирской области по содержанию тяжёлых металлов. Современные проблемы науки и образования. 2014. № 5. URL: www.science-education. Ru/ ru/article/view?id=15088.
38. Peleg Z., Saranga Y., Yazici A., Fahima T., Ozturk L., Cakmak I. Grain zinc, iron and protein concentrations and zinc-efficiency in wild emmer wheat under contrasting irrigation regimes. Plant Soil. 2008. № 306. P. 57–67.
39. Chatzav M., Peleg Z., Ozturk L., Yazici A., Fahima T., Cakmak I., Saranga Y. Genetic diversity for grain nutrients in wild emmer wheat: potential for wheat improvement. Annals of Botany. 2010. № 105(7). P. 1211–1220.
40. Gregorio G.B. Progress in breeding for trace minerals in staple crops. J Nutr. 2002. № 132(3). P. 500–502.
41. Micco C., Onori R., Miraglia M., Gambelli L., Brera C. Evaluation of lead, cadmium, chromium, copper and zinc by atomic absorption spectroscopy in durum wheat milling products in relation to the percentage of extraction. Food Addit Contam. 1987. № 4(4). P. 429–435.
42. Пугаев В. Содержание тяжелых металлов в зерне озимой и яровой пшеницы, произрастающей в разных экологических условиях. Вестник Мордовского университета. 2013. № 3–4. С. 89–93.
43. Symes K. Classification of Australian wheat varieties based on the granularity of their wholemeal. Australian Journal of Experimental Agriculture and Animal husbandry. 1961. № 1. P. 18–23.
44. Hoseney R.C. Wheat hardness. Cereal Foods World. 1987. № 32. P. 320–322.
45. Pomeranz Y., Williams P.C. Wheat hardness: its genetic, structure and biochemical background, measurement and significance. In: Advances in Cereal Science and Technology (edited by Y. Pomeranz). St Paul, MN: AACC. 1990. P. 471–557.
46. Федотов В.А. Факторы формирования потребительских свойств зерномучных товаров. ВЕСТНИК ОГУ. 2011; 4 (123). URL: cyberleninka.ru/article/v/faktory-formirovaniya-potrebitelskih-svoystv-zernomuchnyh-tovarov.
47. Медведев П.В., Федотов В.А., Бочкарева И.А. Комплексная оценка потребительских свойств зерна и продуктов его переработки. Международный научно-исследовательский журнал. 2015. № 7-1(38). С. 77–78.
48. Veha A., Szabó P.B., Gyimes E. Different method to determine the kernel hardness of Hungarian winter wheat varieties, 7th International Conference Integrated Systems for Agri-Food Production, Sipa. Nyíregyháza, Hungary. 2011. P. 10–12.
49. Szabó B.P., Véha A., Gyimes E. Measuring the wheat kernel hardness. Review of Faculty of Engineering, Analecta Technica Szegedinensia. 2007. № 1. P. 97–100.
50. Haraszi R., Sissons M., Juhasz A., Kadkol G., Tamas L., Anderssen R.S. Using rheological phenotype phases to predict rheological features of wheat hardness and milling potential of durum wheat. Cereal Chemistry. 2016. № 93(4). P. 369–376.
51. Haraszi R., Juhasz A., Sissons M., Rakszegi M., Tamas L., Anderssen R.S. Rheological hardness index for assessing hardness of hexaploids and durums. J. Cereal Chemistry. 2013. № 90(5). P. 430–438.

ЯКІСТЬ ЗЕРНА ТЕТРАПЛОЇДНОЇ ПШЕНИЦІ TRITICUM TIMOPHEEVII (ZHUK.) ZHUK

Реліна Л.І., Богуславський Р.Л., Вечерська Л.А., Діденко С.Ю., Голік О.В., Шелякіна Т.А., Поздняков В.В.
Інститут рослинництва ім. В.Я. Юр‘єва НААН, Україна

Мета досліджень. Визначення вмісту білка та каротиноїдних пігментів, загальної антиоксидантної активності, рівня мікроелементів в зерні *T. timopheevii* та продуктивності і технологічних показників зерна *T. timopheevii*.

Матеріали та методи. Зразки *T. timopheevii* длядосліджень було отримано з колекції Національного центру генетичних ресурсів рослин України.. Грунт – типовий чорнозем. Сорти, які було використано для порівняння, вирощувались на одному полі з *T. timopheevii* із застосуванням однакових агротехнологій.Для вивчення було використано зерно, зібране в 2015, 2016 та 2017 (роки з різними погодними умовами). Вміст білка визначали за методом Кьельдаля. Рівень каротиноїдних пігментів оцінювали в екстрагованих ацетоном фракціях методом спектрофотометрії. Загальну антиоксидантну активність досліджували за допомогою аналізу з використанням стабільного вільного радикалу DPPH. Вміст заліза, цинку та міді визначали методом атомно-абсорбційної спектрометрії. Натура та склоподібність оцінювалися відповідно до затверджених методик. Твердість зерна визначалась на твердометрі *YPD-300* (який вимірює силу, що необхідно докласти для руйнування зернівки, в ньютонах) методом, розробленим А.В. Ярошем та ін.

Результати і обговорення. Вміст білка в зерні *T. timopheevii* склав 18,2–16,5 %, в залежності від року, що є досить високим, оскільки якісне зерно твердої пшениці містить 15–18 % білка. Зерно *T. timopheevii* накопичувало 18,2 % білка, коли сума опадів була 26 і 39 мм під час фаз розвитку зеленої маси та наливу зерна відповідно. Підвищення суми опадів було пов’язано із зниженням вмісту білка, хоча цей вид надає перевагу вологим умовам. Це можна пояснити недостатнім дренуванням грунту, оскільки грунт в місці вирощування помірно глинистий з середнім дренуванням, а *T. timopheevii* добре почувається на добре дренованих грунтах. Загальна антиоксидантна активність в зерні *T. timopheevii* складала 618,2 екв. хлорогенової кислоти в 2017 р., знижуючись в інші роки дослідження, що вище, ніж в зерні сорту твердої пшениці Спадщина, створеному в Інституті рослинництва ім. В.Я. Юр`єва НААС (525,4±38,9 екв. хлорогенової кислоти/г насіння). Максимальний вміст каротиноїдів в роки з мінімальною сумою опадів під час розвитку пшениці може бути обумовлено посиленням неспецифічного захисту від стресу. Вміст каротиноїдних пігментівв зерні *T. timopheevii* був середнім: 2,72–3,54мг/кг. Оскільки вважається, що високоякісні макарони яскраво-жовтого кольору можна виготовляти з зерна, що містить не менше 5,5 мг/кг каротиноїдів, цей вид не можна вважати висококаротиноїдним. Зерно досліджуваних зразків *T. timopheevii* містить 39,27–55,90 мг/кг заліза, що значно перевищує рівень заліза в комерційних сортах твердої пшениці та порівнянне з вмістом заліза в зерні польської полби (49 мг/кг) та близько в зерні сорту Голіковська, створеному в Інституті рослинництва ім. В.Я. Юр`єва НААН (40 мг/кг). В цілому вміст заліза змінюється паралельно з вмістом білка, що було очікувано, оскільки дані літератури свідчать про те, що ген *grainproteincontent (GPC-B1)* також контролює накопичення *Fe* та *Zn* в зерні. Зерно *T. timopheevii* містить 36,33-41,04 мг/кг цинку, що можна порівняти з комерційною твердою пшеницею і нашим сортом полби Голіковська (близько 31,0 мг/кг) і є дещо нижчим, ніж у зерні полби в інших роботах. Варіації в рівнях білка, заліза і цинку можуть бути обумовлені змінами в погодних умовах під час ключових періодів розвитку рослин. Зв’язок вмісту цинку з погодними умовами був подібним до ситуації з вмістом білка і заліза та погодними умовами. Зерно *T. timopheevii* містить 1,86–4,46 мг/кг міді в різні роки. Такий рівень, з одного боку, може задовольнити потребу організму людини, а, з іншого боку, є значно нижчим від гранично допустимої концентрації. Вміст міді був максимальним у роки, коли середня температура повітря на етапах розвитку зеленої маси та наливу зерна була відносно низькою: 16,3 та 20,3 °C відповідно. Підвищення температури до 19,1–19,6 °C та до 22,6–23,1 °C, відповідно, було пов'язано з меншим вмістом міді. На відміну від вмісту заліза та цинку, ми не спостерігали взаємозв'язку між вмістом міді та кількістю опадів.

Ми також вивчали елементи продуктивності та технологічні параметри *T. timopheevii*. Маса 1000 зерен склала 34,29 г, що означає, що *T. timopheevii* має зерно середнього розміру. Натура становила 846 г/л, що є досить високим показником, оскільки зерно I класу має натуру ≥750 г/л. Склоподібність була високою – 100 %, що є цінною ознакою для більш якісного помелу зерна. Твердість зерна *T. timopheevii* становила 286 N. Ми можемо вважати, що 286 N, визначена на твердометрі *YPD-300,* відповідає приблизно HI 68. Це означає, що *T. timopheevii*, ймовірно, належить до твердих пшениць відповідно до класифікації Haraszi та ін.

Висновки. Наші результати продемонстрували, що 1) *T. timopheevii* має зерно середнього розміру; 2) *T. timopheevii* характеризується високою антиоксидантною активністю, достатнім вмістом заліза та цинку, збалансованим вмістом міді, а також виключно високою склоподібностю та високою твердістю зерна; 3) *T. timopheevii* не можна віднести до високо каротиноїдних видів.

***Ключові слова**: Triticum timipheevii, якість зерна, вміст білка, каротиноїдні пігменти, загальна антиоксидантна активність, цинк, залізо, мідь, склоподібність, твердість зерна*

КАЧЕСТВО ЗЕРНА ТЕТРАПЛОИДНОЙ ПШЕНИЦЫ TRITICUM TIMOPHEEVII (ZHUK.) ZHUK.

Релина Л. И., Богуславский Р. Л., Вечерская Л. А., Диденко С. Ю., Голик О. В., Шелякина Т. А., Поздняков В. В.
Институт растениеводства им. В. Я. Юрьева НААН, Украина

Цель исследований. Определение содержания белка и каротиноидных пигментов, общей антиоксидантной активности, уровня микроэлементов в зерне *T. timopheevii* и производительности и технологических показателей зерна *T. timopheevii*.

Материалы и методы. Образцы *T. timopheevii* для исследований были получены из коллекции Национального центра генетических ресурсов растений Украины. Почва - типичный чернозем. Сорта, которые были использованы для сравнения, выращивались на одном поле с *T. timopheevii* с применением одинаковых агротехнологий. Для изучения было использовано зерно, собранное в 2015, 2016 и 2017 (годы с различными погодными условиями). Содержание белка определяли по методу Кьельдаля. Уровень каротиноидных пигментов оценивали в экстрагированных ацетоном фракциях методом спектрофотометрии. Общую антиоксидантную активность исследовали с помощью анализа с использованием стабильного свободного радикала DPPH. Содержание железа, цинка и меди определяли методом атомно-абсорбционной спектрометрии. Натура и стекловидность оценивались в соответствии с утвержденными методиками. Твердость зерна определялась на твердомере YPD-300 (измеряет силу, которую необходимо приложить для разрушения зерновки, в Ньютонах) методом, разработанным А.В. Ярошем и др.

Результаты и обсуждение. Содержание белка в зерне *T. timopheevii* составил 18,2–16,5 %, в зависимости от года, что является достаточно высоким, поскольку качественное зерно твердой пшеницы содержит 15–18 % белка. Зерно *T. timopheevii* накапливало 18,2 % белка, когда сумма осадков была 26 и 39 мм в период развития зеленой массы и налива зерна соответственно. Повышение суммы осадков было связано со снижением содержания белка, хотя этот вид предпочитает влажные условия. Это можно объяснить недостаточным дренированием почвы, поскольку почва в месте выращивания умеренно глинистая со средним дренированием, а *T. timopheevii* хорошо чувствует себя на хорошо дренированных почвах. Общая антиоксидантная активность в зерне *T. timopheevii* составляла 618,2 экв. хлорогеновой кислоты в 2017 г., снижаясь в другие годы исследования, что выше, чем в зерне сорта пшеницы твердой Спадщина, созданном в Институте растениеводства им. В.Я. Юрьева НААН (525,4±38,9 экв. хлорогеновой кислоты / г семян). Максимальное содержание каротиноидов в годы с минимальной суммой осадков во время развития пшеницы может быть обусловлено усилением неспецифической защиты от стресса. Содержание каротиноидных пигментов в зерне *T. timopheevii* был средним: 2,72–3,54мг/кг. Поскольку считается, что высококачественные макароны ярко-желтого цвета можно изготавливать из зерна, содержащего не менее 5,5 мг/кг каротиноидов, этот вид нельзя считать висококаротиноидним. Зерно исследуемых образцов *T. timopheevii* содержит 39,27–55,90 мг/кг железа, что значительно превышает уровень железа в коммерческих сортах твердой пшеницы и сравнимо с содержанием железа в зерне польской полбы (49 мг/кг) и примерно в зерне сорта Голиковська, созданном в Институте растениеводства им. В.Я. Юрьева НААН (40 мг/кг). В целом содержание железа меняется параллельно с содержанием белка, что было ожидаемо, поскольку данные литературы свидетельствуют о том, что ген *grainproteincontent* (GPC-B1) также контролирует накопление Fe и Zn в зерне. Зерно *T. timopheevii* содержит 36,33–41,04 мг / кг цинка, что можно сравнить с коммерческой твердой пшеницей и нашим сортом полбы Голиковська (около 31,0 мг/кг) и несколько ниже, чем в зерне полбы в других работах. Вариации в уровнях белка, железа и цинка могут быть обусловлены изменениями в погодных условиях во время ключевых периодов развития растений. Связь содержания цинка с погодными условиями была подобной ситуации с содержанием белка и железа и погодными условиями. Зерно *T. timopheevii* содержит 1,86–4,46 мг / кг меди в разные годы. Такой уровень, с одной стороны, может удовлетворить потребность организма человека, а с другой стороны, значительно ниже предельно допустимой концентрации. Содержание меди было максимальным в годы, когда средняя температура воздуха на этапах развития зеленой массы и налива зерна была относительно низкой: 16,3 и 20,3 С соответственно. Повышение температуры до 19,1–19,6 С и к 22,6–923,1 С соответственно, было связано с меньшим содержанием меди. В отличие от содержания железа и цинка, мы не наблюдали взаимосвязи между содержанием меди и количеством осадков.

Мы также изучали элементы производительности и технологические параметры *T. timopheevii*. Масса 1000 зерен составила 34,29 г, что означает, что *T. timopheevii* имеет зерно среднего размера. Натура составляла 846 г/л, что является достаточно высоким показателем, поскольку зерно I класса имеет натуру ≥750 г/л. Стекловидность была высокой – 100 %, что является ценным признаком для более качественного помола зерна. Твердость зерна *T. timopheevii* составляла 286 N. Мы можем считать, что 286 N, определенная на твердомере YPD-300, соответствует примерно HI 68. Это означает, что *T. timopheevii*, вероятно, относится к твердым пшеницам в соответствии с классификацией Haraszi и др.

Выводы. Наши результаты показали, что 1) *T. Timopheevii* имеет зерно среднего размера; 2) *T. timopheevii* характеризуется высокой антиоксидантной активностью, достаточным содержанием железа и цинка, сбалансированным содержанием меди, а также исключительно высокой стекловидностью и высокой твердостью зерна; 3) *T. timopheevii* нельзя отнести к высококаротиноидным видам.

***Ключевые слова**: Triticum timopheevii, качество зерна, содержание белка, каротиноидные пигменты, общая антиоксидантная активность, цинк, железо, медь, стекловидность, твердость зерна*

GRAIN QUALITY OF TETRAPLOID WHEAT TRITICUM TIMOPHEEVII (ZHUK.)ZHUK.

Relina L.I., Boguslavskyi R.L., Vecherska L.A., Didenko S.Yu., Golik O.V., Sheliakina T.A., Pozdniakov V.V.
Plant Production Institute nd. a. V.Ya. Yuriev of NAAS, Ukraine

Purpose and objectives. To evaluate the protein content, carotenoid level, antioxidant activity and trace mineral contents in *T. timopheevii* grain and to measure performance and processing parameters of *T. timopheevii* grain.

Materials and methods. The analyses were carried out on *T. timopheevii* from a collection of the National Center for Plant Genetic Resources of Ukraine. Plants were grown on typical black soil. The cultivars used for comparisons (emmer Holikovska and durum wheat Spadshchyna) were grown in plots located in the same field with *T. timopheevii* using identical agronomic techniques. Grain harvested in 2015, 2016 and 2017 (years with various weather conditions) was used in analyses. The protein content was determined by Kjeldahl digestion The carotenoid level was spectrophotometrically assessed in acetone extracts. The total antioxidant activity was investigated by DPPH assay. The contents of iron, zinc and copper were determined by atomic absorption spectrometry. The grain unit and vitreousness were evaluated in compliance with conventional techniques. The grain hardness was determined on a YPD-300 hardness tester (Ltpm China) (measuring force applied to crush kernels) by the method developed by AV Yarosh et al. expressed in newtons.

Results and discussion. The protein content in *T. timopheevii* grainwas within 18.2–16.5%, depending on the year, which is rather high as good durum wheat grain contains 15-18 % of protein. The grain of *T. timopheevii* accumulated 18.2% of protein, when the precipitations amounts were 26 and 39 mm during the phases of green mass development and grain filling, respectively. Increase in the precipitations amount was associated with a reduction in the protein content, though the species prefers moist conditions. This can be due to insufficient drainage of soil, as the soil in the cultivation site was moderately clayey with medium drainage, and *T. timopheevii* does well on well-drained soils. The total antioxidant activity in *T. timopheevii* grain amounted to 618.2 chlorogenic acid equivalents (CGAE) /g of seeds in 2017, reducing in the other study years, which is higher than in durum wheat grain, cv. Spadshchyna, bred at the Plant Production Institute named after VYa Yuriev of NAAS (525.4±38.9 CGAE /g of seeds). The peak content of antioxidants in the years with the minimal precipitation during the wheat development may be accounted for by enhanced non-specific protection against stress. The carotenoid content in *T. timopheevii* grainwas medium: 2.72–3.54 mg/kg. Since high-quality bright-yellow pasta is considered to be made from grain containing not less than 5.5 mg/kg of carotenoids, this species cannot be referred to high-carotenoid ones. *T. timopheevii* grain contains 39.27–55.90 mg/kg of iron, which is considerably higher than the iron levels in commercial durum wheat cultivars and comparable to the iron content in Polish emmer grain (49 mg/kg) and in cv. Holikovska grain (around 40 mg/kg) bred at the Plant Production Institute named after V.Ya. Yuriev of NAAS). In general, the iron content changed in parallel with the protein content, which was expected, since literature data indicate that the high grain protein content gene (*GPC-B1)* confers higher concentrations of both Fe and Zn in grain. *T. timopheevii* grain contains 36.33–41.04 mg/kg of zinc, which is comparable to commercial durum wheat and our emmer, cv. Holikovska (around 31.0 mg/kg), and somewhat less than in emmer grain in other investigations. The variations in the protein, iron and zinc contents can be attributed to weather fluctuations during crucial periods in the plant development. The zinc content-weather conditions relationship was similar to the protein/iron content-weather conditions relationship. *T. timopheevii* grain contained of 1.86–4.46 mg/kg of copper in different years. Such levels can satisfy the need of human body for copper, on the one hand, and are far below the maximum allowable concentration, on the other hand. The copper content was maximal in the years, when the average air temperature during the phases of green mass development and grain filling was relatively low: 16.3 and 20.3 °C, respectively. Rise in temperature to 19.1–19.6 °C and to 22.6–23.1 °C, respectively, was associated with lower copper content. Unlike the iron and zinc contents, we observed no relationship between the copper content and the precipitation amount.

We also measured performance and processing parameters of *T. timopheevii*. The 1000-seed weight was 34.29 g, meaning that *T. timopheevii* has medium-sized grain. Thetest weight was around 846 g/L, which is sufficiently high, as grade I grain has ≥750 g/L. The vitreousness was markedly high 100%, which is valuable for easy milling. The *T. timopheevii* grain hardness was 286 N. We can assume that 286 N measured on a YPD-300 hardness tester corresponds approximately HI 68. This means that *T. timopheevii* is likely to belong to hard wheats according to Haraszi et all's classification.

Conclusions. Our results have demonstrated that 1) *T. timopheevii* has medium-sized grain; 2) *T. timopheevii* is noticeable for a high antioxidant activity, sufficient iron and zinc contents, balanced copper content, exclusively high vitreousness and high grain harness; 3) *T. timopheevii* cannot be referred to high-carotenoid species.

Key words: *Triticum timopheevii, grain quality, protein content, carotenoids, total antioxidant activity, zinc, iron, copper, vitreousness, grain hardness*