Emmer wheat (Triticum dicoccum (schrank.) schuebl.) in the technology of whole-wheat bread production

E Khmeleva, N Berezina, A Khmelev, V Rumyantseva, T Kunitsyna and Yu Rogacheva

Orel State University named after I.S. Turgenev, 95, Komsomolskaya st., Orel region, 302026, Russian Federation

E-mail: hmelevaev@bk.ru

Abstract. Worldwide interest in healthy food is promoting the production of non-traditional bakery products. Whole-wheat bread refers to such kind of products. Emmer as a crop with a valuable chemical composition is a promising source of raw materials for developing grain bakery products of increased nutritional value and giving them functional properties. The high content of proteins in emmer wheat characterized by a balanced amino acid composition, food fibers, and minerals is indicated. The possibility of using emmer wheat grain (Triticum dicoccum (Schrank.) Schuebl.) in bread making for the production of whole-wheat bread is analyzed. The chemical composition and quality indicators of emmer wheat grain of Runo variety grown in the Orel region are established. The conducted analysis of the content, wet gluten quality and autolytic activity changes (in terms of falling-number) in emmer wheat grain at steeping stage shows the necessity to develop technological methods that allow providing the production of high-quality whole-wheat bread. Methods for steeping emmer wheat grain have been developed that neutralize the deterioration of the technological properties of emmer wheat grain at the steeping stage and allow producing whole-wheat bread with high organoleptic and physicochemical characteristics.

1. Introduction

Emmer wheat (Triticum dicoccum (Schrank.) Schuebl.) is a wide-spread type of wheat in ancient times. It should be noted that there are discrepancies regarding the designation of this crop in the scientific Russian and foreign publications: “The term spelt is used both for Triticum Spelta L. and Triticum Dicoccum Schrank, which is very controversial”. According to [1, 2] only Triticum dicoccum is cultivated in our country, i.e. “amelcorn, emmer”, but spelt Triticum Spelta is not cultivated in Russia. However, the term “spelt” is commonly applied to Triticum dicoccum” [1, 2].

This crop is well-known since prehistoric times. Grains of hulled spelt were found during archaeological excavations in Egypt. Spelt is mentioned in ancient manuscripts in Babylonia. Archaeologists found grains dating back to the VII century B.C. in Iraq, matching the description of spelt in a mixture with an einkorn wheat grain [1].

Spelt appeared in Russia in the Stone Age. It became known in the V century B.C. in the Krasnodar region. Slavic tribes brought spelt from Asia into the western part of Russia in the 1st millennium A.D. Increased interest in spelt appears in the XVIII century, which is explained by the rooting of French cuisine in Russia, which recommends spelt porridge, “as easily digested by the stomach”, as well as the introduction of Western European literature on Agriculture. At this time, spelt was widely cultivated in the Kazan, the Orenburg provinces, and Bashkiria [2]. In the XIX century there is a sharp reduction in the area for growing spelt, it was considered economically unprofitable in comparison with other crops. The main reasons for that were the difficulties of threshing, storing and blocking spelt grain, as well as the development of higher-yielding varieties of soft wheat. By the beginning of the XX century, only some regions cultivated spelt (along the Volga and the Kama, Transcaucasia). At this time, spelt was
extensively used to develop many well-known varieties of soft and durum wheat (Tulun 197, Cesium 94, Saratovskaya 29, etc.) [3, 4].

Currently, the cultivation of spelt, the ancient crop, in Russia and abroad has increased. The interest in spelt is not accidental: farmers, having realized the huge potential of this crop, which is expressed in adaptability and resistance to diseases and pests, unpretentiousness to the conditions of cultivation, adaptability to overcome adverse environmental factors, cultivate spelt using environmentally friendly technologies without the use of fertilizers and pesticides, which make it possible to obtain organic products that are in great demand nowadays [5, 6]. Earlier, hull content of this crop was considered to be a negative factor, but today it is an advantage in comparison with standard hulless wheat, allowing producing demanded environmentally friendly raw materials of plant origin.

According to literary sources, spelt wheat is known to be a genetically high-protein variety with a protein content of up to 20 % or more [1, 6-11], high content of vitamins [12, 13], minerals [13-16], dietary fibers [12,16, 17] and polyunsaturated fatty acids [16-18]. It is also known that spelt contains mucopolysaccharides that contribute to the strengthening of the immune system of the human body [16], and polyphenolic compounds that have anti-mutagenic and anti-carcinogenic effects [15,19].

One of the directions for manufacturing functional food products, in addition to eliminating the deficit of food substances, is to reduce the risk of disease development. The problem of dietary nutrition is currently gaining more and more relevance due to the increase of genetic and allergic diseases. According to scientific publications, spelt is recommended as alternative raw materials for producing food for people suffering from celiac disease [20]. This issue remains controversial, since the opinions of some researchers differ in their scientific works. According to Udachin R. A. [21] spelt lacks some gliadin fraction, which allows it to be used as an alternative to wheat in the diet of people suffering from celiac disease. Konarev V. G. [22] believes that only spelt samples from Ethiopia and Yugoslavia which, in his opinion, do not contain the toxic α-6 component in gliadin, can be recommended for dietary nutrition of patients with gluten enteropathy. Bazhenova I. A. [16] recommends the use of spelt grown in the Karachayevo-Cherkessian Republic in the diet of patients, since the reduced content of gliadin is determined, in the fraction of which the α-6 component is poorly represented.

The purpose of the research was to determine the ultimate composition and technological properties of spelt grain in order to justify its application and develop technological solutions for the production of whole-wheat bread.

2. Materials and methods of research

The object of research is emmer wheat grain Triticum dicoccum (Schrank.) Schuebl., of Runo variety cultivated in the Orel region. This variety was selected by individual selection from a sample of VIR k17560 collection by specialists of the SSI of the Krasnodar Research Institute of Agriculture n.a. P.P. Lukyanenko, successfully passed state crop variety testing and was included in the register of selection achievements since 2009. The following specifications of emmer wheat of Runo variety were declared: drought-resistant, mid ripening, resistant to all types of rust, powdery mildew, smut; the grain is red, glassy, and has a high content of protein (17-20.5 %) and lysine (0.46-0.51 % in absolute dry matter) [1];

The methods of research of the chemical composition and quality indicators of grain: moisture index was determined by drying method using the moisture-testing oven (MTEO-3M), reducing substances - according to Federal Standard (GOST) 8756.13-87, starch was determined by volume method based on obtaining a complex compound with iodine, subsequent oxidation of starch with bichromate and iodometric register of the latter, total protein was determined by Kjeldahl method, lipids - by a method based on determining the refractive indices of lipids and α-naphthalene bromide, cellulose - by Kürschner-Hanak method, ash - according to GOST 32933-2014, gluten content and properties - according to GOST 54478-2011, falling number - according to GOST 27676-88.

Methods for evaluating the quality of whole-wheat bread: organoleptic (appearance, crumb condition, taste, flavor) and physicochemical parameters (moisture, grain, acidity, specific volume, crumb structural and mechanical properties) in the products were determined in (5±1) hours after baking according to the methods specified in [23].

3. Results of research

The chemical composition of emmer wheat grain Triticum dicoccum (Schrank.) Schuebl. of Runo variety grown in the Orel region (table 1) was studied in the article, since it is known that the chemical composition of the grain varies greatly depending on the grain variety, growing area, climatic conditions of cultivation and harvesting.
Table 1. Chemical composition of Triticum dicoccum (Schrank.) Schuebl. grain

| Component                        | Emmer wheat grain (Triticum dicoccum (Schrank.) Schuebl.) | Soft wheat grain (Triticum aestivum L.) |
|----------------------------------|----------------------------------------------------------|---------------------------------------|
| Water, %                         | 11.00                                                    | 14.00                                  |
| Proteins, %                      | 14.50                                                    | 11.80                                  |
| Fats, %, among them:             |                                                          |                                        |
| polyunsaturated fatty acids, %   |                                                          |                                        |
| Carbonhydrates, among them:      |                                                          |                                        |
| starch, %                        | 70.0                                                     | 59.50                                  |
| reducing sugar, %                | 53.90                                                    | 55.50                                  |
| cellulose, %                     | 3.02                                                     | 1.09                                   |
| Vitamins, mg:                    |                                                          |                                        |
| В₁                                | 0.36                                                     | 0.44                                   |
| В₂                                | 0.113                                                    | 0.15                                   |
| В₅                                | 1.19                                                     | 1.15                                   |
| В₆                                | 0.23                                                     | 0.53                                   |
| В₉, µgr                          | 45.00                                                    | 37.50                                  |
| H                                | 9.30                                                     | 10.40                                  |
| Ash, %                           | 2.10                                                     | 1.70                                   |
| Mineral substances, mg:          |                                                          |                                        |
| Mg                               | 136.00                                                   | 108.00                                 |
| P                                | 401.00                                                   | 370.00                                 |
| Fe                               | 4.40                                                     | 5.40                                   |
| K                                | 338.00                                                   | 337.00                                 |
| Zn                               | 3.28                                                     | 2.79                                   |
| Mn                               | 115.00                                                   | 108.00                                 |
| Se, µgr                          | 11.70                                                    | 29.00                                  |

The results obtained show that emmer wheat grain of Runo variety grown in the territory of the Orel region (2015) contains 14.5 % of protein, which is lower than that stated in the documentation for this grain variety and presented in the thesis [1]. But, still, superior to soft wheat, which has 11.8 % of protein. Probably, this discrepancy in the amount of protein in emmer wheat can be explained by the soil and climatic conditions of cultivation in the Orel region, since it is known that Runo variety is recommended for cultivation in the Krasnodar region ("forms a protein content not lower than 16.3 %") [1].

It was determined that emmer, in comparison to soft wheat, contains more important functional ingredients such as:
- polyunsaturated fatty acids involved in the regulation of cellular metabolism, increasing vascular wall elasticity, contributing to cholesterol reduction, thereby reducing the risk of atherosclerosis;
- dietary fibers, cellulose in particular, which have a positive effect on the digestive processes, stabilize the blood sugar content, reduce the risk of developing cardiovascular diseases and circulatory disorders;
- vitamins (В₅ and В₉) involved in the processes of metabolism, maintaining the activity of the cardiovascular and nervous systems that reinforce the human immune system;
- mineral elements (magnesium, phosphorus, zinc, manganese) involved in bone tissues construction contributing to nerve cells and enzymes activity.

Evaluation of the technological advantage of Triticum dicoccum (Schrank.) Schuebl as raw materials for bakery production was carried out according to the content and quality of wet gluten, falling-number value. Harvests 2015 and 2017 of emmer wheat grain were analyzed. Different weather conditions affected emmer grain quality indicators [25]; they differed significantly in the content of gluten, values of which ranged from 21 % in the grain of harvest 2015 to 30 % in the grain of harvest 2017. The quality of gluten in all the studied samples was characterized as satisfactory poor (77.5-85 FDM units). Gluten in the process of washing adhered to hands heavily, had a smearing consistency, and quickly blurred during subsequent sweating, which indicates the low baking properties of flour from such grains. The indicated significant difference in the content of wet gluten in emmer grain of different harvests, taking into account its low quality, requires the development of various technological solutions for the use of this kind of grain for the production of whole-wheat bread.
The level of falling-number value of emmer grain was high enough (350-380 sec), which allows its use in the “traditional” technology of whole-wheat bread with the stage of grain hydrothermal processing (steeping), in which there is an increase in the activity of all the corn seed enzymes.

Based on the water absorption pattern by emmer grain until obtaining moisture needed for grain refinement (42-44 %), optimal parameters of steeping emmer grains were experimentally determined, i.e. in water at a ratio of 1:1 at a temperature of 20±2 °C for three hours. The short duration of the process is associated with the partial removal of hulls when emmer grain blocking.

At the stage of grain steeping, changes in its protein-proteinase and carbohydrate-amylose complexes are inevitable, which may affect the rheological properties of the dough and the quality of final bakery products. In this regard, it is necessary to evaluate the change in the content, gluten quality and autolytic activity (by falling-number) in emmer grain in the process of steeping. The results obtained are shown in table 2.

Table 2. Indicators of protein-proteinase and carbohydrate-amylose complexes of emmer grain in the process of steeping

| Harvest 2015: | Wet gluten weight fraction, % | Gluten quality, un. FDM | falling-number value, sec |
|--------------|-------------------------------|-------------------------|--------------------------|
| Dry          | 21.0                          | 77.5                    | 406                      |
| In 1 h of steeping | 21.0                          | 97.5                    | 387                      |
| In 2 h of steeping | 21.0                          | 105.0                  | 375                      |
| In 3 h of steeping | 20.0                          | 110.0                  | 353                      |
| Harvest 2017: |                               |                         |                          |
| Dry          | 31.0                          | 80.0                    | 380                      |
| In 1 h of steeping | 31.0                          | 95.0                    | 365                      |
| In 2 h of steeping | 31.0                          | 102.5                  | 352                      |
| In 3 h of steeping | 30.0                          | 105.0                  | 339                      |

The analysis of experimental data allowed concluding the following: during steeping in all the studied emmer grain samples, there is a significant gluten quality deterioration, while its content does not change. At the end of the steeping process (after 3 hours), the gluten passes into the quality group III “unsatisfactory poor” (FDM readings are 102.5 un. or more). Probably, with long-term hydration, protein molecules swell, their structure is loosened due to the rupture of disulfide bonds, causing a significant weakening of the protein.

Despite the low level of enzyme activity in the native (dry) grain (falling-number is 380-406 sec.), it is advisable to control its value when grain moistening in order to avoid getting bread with sticky and crushed crumb. It was found that in the process of emmer grain steeping, the activity of amylases increases (falling-number decreases), but its value at the end of the process is 339-353 sec, not exceeding the established standards.

Table 3. Quantity and quality of emmer wheat grain gluten Triticum dicoccum (Schrank.) Schuebl in the process of steeping in different conditions

| emmer wheat grain Triticum dicoccum (Schrank.) Schuebl in the process of steeping in different conditions | Wet gluten weight fraction, % | Gluten quality, un. FDM |
|-------------------------------------------------|-----------------------------|-------------------------|
| Dry                                             | 21.0                        | 77.5                    |
| Steeping in water (control)                     | 20.0                        | 110.0                   |
| Variant 1                                       | 20.0                        | 65.0                    |
| Variant 2                                       | 20.0                        | 72.5                    |
| Variant 3                                       | 20.0                        | 60.0                    |

A significant deterioration of gluten quality in the steeping process, especially in the case of its initially low content in the grain (emmer grain of harvest 2015) will not allow producing bread with high consumer properties. To solve this problem, technological methods were suggested for influencing emmer grain gluten at the moistening stage: steeping in milk whey (variant 1), in a solution of sodium chloride (variant 2), and adding ascorbic acid (variant 3). Taking into account the fact that during the steeping process, all the liquid is completely absorbed by the grain, salt was used to prepare a solution for
steeping in the standard dosage for bakery products - 1.5% on grain weight. The concentration of ascorbic acid used to prepare a solution for grain steeping is taken according to the recommendations of technological instructions collected book for the production of bakery products, as well as of a number of researchers.

As a result of the conducted research, a positive technological effect was obtained on the protein-protease complex of emmer grain in the steeping process. In all experimental samples, the effect of grain gluten strengthening is observed in comparison with the control sample (steeping in water). Probably, protein proteolysis slows down, and gluten is also strengthened by the action of acids (lactic and ascorbic).

To evaluate the quality of whole-wheat bread made from emmer wheat, the swollen grain was subjected to refinement on a disperser and the dough was kneaded on a laboratory dough mixer to a homogenous consistency with moisture of 46-47% with the addition of all of the recipe ingredients: pressed yeast, food salt, sugar and vegetable oil. The dough fermentation process was carried out at a temperature of 29-31 °C to a final acidity of 4.5-5.0 deg. It should be noted that during the dough sample fermentation obtained from grain steeped in milk whey, the acidity increased faster, the duration of dough fermentation was reduced by an average of 30 minutes compared to other samples. The obtained result confirms the well-known fact about the effect of whey on the production process of bakery products and its use for accelerated production technologies. The prepared dough was cut into pieces weighing 0.35 kg, placed in the bakery molds and sent to the proofing cabinet for 30-40 min. (proofing temperature (34±2) °C, relative moisture 76-80 %). The products were baked at a temperature of 210 °C for 30-35 minutes.

Organoleptic and physicochemical quality indicators of whole-wheat bread produced from emmer wheat are shown in Table 4.

Table 4. Quality indicators of whole-wheat bread produced from emmer wheat

| Indicator | control sample | variant 1 | variant 2 | variant 3 |
|-----------|----------------|-----------|-----------|-----------|
| Bread appearance: | Similar to the baking mold, with a flat top crust | Similar to the baking mold, with a convex top crust | |
| shape | | | |
| surface | Grainy, with small cracks, with inclusions of crushed grain | Grainy, without cracks and ruptures, with inclusions of crushed grain | |
| colour | Brown | Light brown | |
| Crumb condition: | Unpronounced, without cavings interspersed with whole grain | Pronounced, without cavings interspersed with particles of crushed grain | |
| vesiculation | | | |
| Degree of product availability | Slightly wet by touch | Slightly wet by touch | |
| Taste, favour | Typical of whole-wheat bread | Pronounced, typical of whole-wheat bread | |
| Moisture, % | 46.0 | 46.5 | 46.0 | 46.0 |
| Acidity, degree | 4.0 | 5.5 | 4.6 | 5.0 |
| Visculation, % | 45.0 | 59.0 | 60.0 | 62.0 |
| Specific volume, cm$^3$/g | 1.6 | 2.3 | 2.38 | 2.41 |
| Structural and mechanical characteristics of crumb, mm: | | | |
| $\Delta H_{gen}$ | 14.9 | 18.5 | 19.6 | 21.0 |
| $\Delta H_{pl}$ | 2.5 | 3.0 | 3.0 | 3.7 |
| $\Delta H_{el}$ | 12.4 | 15.5 | 16.6 | 17.3 |

The results of laboratory baking show that experimental samples of emmer grain bread using whey, sodium chloride solution or ascorbic acid for steeping grain had the best organoleptic and physicochemical parameters. The chosen methods of preparing emmer grain confirmed the technological effect of grain gluten strengthening at the steeping stage, which led to the production of whole-wheat bread with the correct shape, a large specific volume with a convex crust without ruptures and cracks, a pronounced thin-walled vesiculation of the crumb, more pronounced taste and flavor in contrast to the control sample.
4. Conclusion and recommendations
Emmer wheat grain Triticum dicoccum (Schrank.) Schuebl of Runo variety, cultivated in the Orel region, has a rich chemical composition and is of interest for expanding the range of grain bakery products that meet the modern requirements of a healthy diet. The low technological properties of the studied grain are revealed, requiring the development of technological solutions for its use in the production of whole-wheat bread. The parameters for emmer grain steeping were experimentally established to ensure high quality of whole-wheat bread.

References
[1] Borovik AN 2016 Selection and re-entry to the culture of endangered and rare crops of wheat: shot wheat (triticum spheerococcum perc.), emmer wheat (triticum dicoccum (schrank.) schuebl.), durum wheat (triticum durumdesf.) and the development of triticale shot wheat (triticale spheerococcum) to diversify the production of high-quality grain Diss. Dr.sc.agr
[2] Stoletova E A 1925 Emmer. Triticum dicoccum Schrank Works on applied botany and selection 14 27-111
[3] Ianchenko V I 2002 Selection and genetic evaluation of spelt for use in spring wheat breeding Improving the efficiency of selection and seed production of agricultural plants (Novosibirsk: Novosibirsk State Agricultural University) 112–120
[4] Krupnova O V 2010 Quality of spring soft wheat grain with translocations from relatives Synopsis of a thesis.... Dr.sc.biol.
[5] Khmeleva E V, Belokobylyskaya E V, Frolova A Yu and Hmelev A S 2020 Prospects for using emmer (Triticum dicoccum) in organic farming and developing organic products Technology and merchandising of innovative food products 1 (60) p 97-102
[6] Konvalina P, Capouchova I and Stehno Z 2013 Baking quality of hulled wheat species in organic farming International Journal of Nutrition and Food Engineering 7 370-373
[7] Malchikov P N, Zotikov V I, Sidorenko V S, Shablokina E N and Myasnikova N G 2016 Prospects for improving the cereal qualities of durum wheat in the selection process Legumes and cereals 3 101-108
[8] Popova NM 2017 Ecological breeding evaluation of samples of the spelt wheat Vestnik KrasSAU 5 15-20
[9] Lachman J, Orsak M, Pivec V and Jiru K 2012 Antioxidant activity of grain of einkorn (Triticum mono-coccum l.), emmer (Triticum dicoccum schuebl) and spring wheat (Triticum aestivum l.) varieties Plant Soil and Environment 9 15-21
[10] Stehno Z 2007 Emmer wheat Rudico can extend the spectra of cultivated plants Czech Journal of Genetics and Plant Breeding 43 113-115
[11] Mangova M 2014 Aestivum, spelt, einkorn and emmer – differences and similarities in morphological and technological aspects National Scientific Conference “60 years of Fruit Growing Institute – Plovdiv”(Bulgaria: Plovdiv) 129-132
[12] Chugunova O V and Kryukova E V 2015 Agronomic properties of spelt as unconventional raw materials for the production of flour confectionery products Scientific vestnik 3 90-100
[13] Kryukova E V 2014 Forming the quality of flour confectionery products using spelt flour Synopsis of a thesis Ph.D. in Engineering Science
[14] Suchowińska E, Wiwatt M and Kandler W 2012 A comparison of macro- and microelement concentrations in the whole grain of four Triticum species Plant soil environment 58 141-147
[15] Lachman J, Miholova D and Pivec V 2011 Content of phenolic antioxidants and selenium in grain of einkorn (Triticum monococcum), emmer (Triticum ducoccum) and spring wheat (Triticum aestivum) varieties Plant soil environment 57 235-243
[16] Bazhenova I A 2004 Research of technological properties of emmer grain (Triticum dicoccum shrank.) and its use in the development of culinary products Diss. Ph.D. in Engineering Science
[17] Yukov VV 2005 Volga spelt and products of its processing Izvestia of high schools. Food technology 1 23-25
[18] Marconi E, Panfili G, Iafelice G and Fratianni A 2001 Qualitative and quantitative evaluation of lipidic fraction in T. dicoccon Schrank and T. spelta L. Tec Molitoria 52 826–838
[19] Lachman J, Miholova D and Pivec V 2012 Antioxidant activity of grain of einkorn (Triticum monococcum), emmer (Triticum ducoccum) and spring wheat (Triticum aestivum) varieties Plant
soil environment 58 15-21

[20] Tiunov V M, Chugunova O V and Grashchenkov D V 2018 Features of the development of diets for preschool children in celiac patients Proceedings of the Voronezh State University of Engineering Technologies 80 (2) 211-219

[21] Udachin R A 2002 Spelt-forgotten grain culture in Russia Russian Land 2 p.8-15.

[22] Konarev V G 1980 Wheat proteins (Moscow: Kolos)

[23] Koryachkina S IA, Labutina N V, Berezina N A and Khmeleva E V 2012 Quality control of raw materials, semi-finished products and bakery products (Moscow: DeLi plus)

[24] Skurikhin I M and Tutelyan V A 2002 Chemical composition of Russian food products (Moscow: DeLi print)

[25] Shaimerdenova D A 2018 Comparative characteristics of grain classifications of soft wheat of Kazakhstan and major grain-producing countries Proceedings of the Voronezh State University of Engineering Technologies 80 (1) 40-145