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INVESTIGATION OF THE TECHNOLOGICAL PROPERTIES OF EMMER FLOUR

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Abstract. The article presents the results of studying the technological properties of emmer flour obtained from the grain of the variety *Golikovska*, in comparison with commercial patent wheat flour. It has been found that emmer flour contains 1.4 times as much crude gluten and 1.3 times as much dry gluten as wheat flour does. It has been shown that gluten of emmer flour is 1.2 times less strong and 1.3 times more elastic than gluten of wheat flour, and can be included in the 2nd group of quality. According to the results of farinographic tests, it has been established that the experimental emmer dough sample is formed 2 minutes earlier and is 3 times less stable than wheat dough. The results of the alveographic tests have shown that, compared to wheat dough, the tenacity of emmer dough is lower by 25.9%, the extensibility is higher by 26.3%, its alveogram configuration ratio is lower by 36.4%, and its baking strength is lower by 28.2%. It has been established that the starch of emmer flour starts being gelatinised (turning into paste) a little later and at a slightly higher temperature than wheat flour starch does. The maximum viscosity of wheat starch paste is by 58.3% higher than that of emmer starch paste. It has been established that the falling number of emmer flour is by 9.6% smaller in comparison with that of wheat flour. The dough-raising capacity of model yeast dough systems prepared from emmer flour is by 25.0% better than it is in model systems made from wheat flour. It has been found that in emmer yeast dough, fermentation processes are more intensive than in wheat yeast dough: at the end of fermentation, the emmer dough had by 13.3% higher titrated acidity and had formed by 12.5% more carbon dioxide. The volume of emmer dough was by 16.7% higher than that of wheat dough. The sensory evaluation of unleavened and yeasted puff pastries made from emmer flour has shown that they are not inferior in quality to baked products made from wheat flour, have a regular shape and a bright crust colour, and are large in volume.

Keywords: emmer flour, wheat flour, flour properties, fermentation, puff pastry.

Introduction. Formulation of the problem

An important issue of Ukraine's modern food industry is searching for alternative raw materials to be used for manufacture of high quality baked products and flour confectionery. Emmer wheat (Triticum dicoccum Schrank) can be considered one of these promising raw materials, because it contains a considerable amount of protein and other essential nutrients. Besides, emmer is adapted to be grown in organic farming. It has hard hulls on the surface of its grains that make emmer difficult to process and increase the cost of emmer flour.

To solve this problem, a team of researchers from the Plant Production Institute nd. a. V. Ya. Yuryev of the National Academy of Agricultural Sciences (Kharkiv) have created a new variety of emmer called Golikovska, which passed state variety testing and was included in the Plant Varieties Register of Ukraine (certificate of state registration of the plant variety No. 150209) [1]. It was the result of complex interspecific crossing of common emmer Triticum dicoccum and durum wheat Triticum durum. The emmer obtained has no hard hulls on the grain surface and therefore is easily threshed. It has higher yields compared to emmer of varieties known before. The new emmer variety is higher in proteins, dietary fibre, and other

essential nutrients than wheat is. Besides, emmer of the variety Golikovska is adapted to the agro-climatic conditions of Ukraine in general and of the Kharkiv Region in particular.

The chemical composition and technological properties of the Golikovska variety of emmer are studied quite well. A grain bread technology based on this emmer variety has been suggested [10]. However, there are but scarce studies of how emmer flour can be used to make flour confectionery. So, it is of scientific and practical interest to research the functional and technological properties of emmer flour obtained from the emmer variety Golikovska, and its application in flour confectionery production.

Analysis of recent research and publications

Modern scientific publications on grain selection and its processing pay quite a lot of attention to researching the properties of emmer. The results of studying the chemical composition of emmer grain of different varieties and lines, obtained by scientific teams of the Czech Republic [2,3], Italy [4], USA, Turkey [5], Poland, and other countries, show that the protein content in emmer of different varieties can vary 11.8–22.0%, and the dietary fibre content within 9.7–15.5% [2]. Emmer contains more phosphorus, sulphur, magnesium, zinc, and iron than soft wheat does [2,6-9].

The chemical composition of the emmer variety *Golikovska* is given in Table 1.

Table 1 – Chemical composition of emmer and wheat (per 100 g of DM) [10].

Nutrients and biologically active substances	Emmer	Weat
Proteins, g	19.0±0.5	13.9±0.7
Fats, g	2.5±0.1	2.3±0.1
Carbohydrates, g	75.9±1.8	81.5±1.5
incl. mono- and disacharides	3.5±0.1	3.0±0.1
starch	57.4±1.2	66.5±1.8
Dietary fibre, g	15.5±0.7	12.5±0.4
incl. cellulose	3.4±0.1	3.1±0.1
hemicellulose	11.0±0.5	8.5±0.3
Vitamins, mg		
B_1	0.41±0.01	0.35±0.01
B_2	0.12±0.01	0.09±0.01
PP	3.8±0.1	3.3±0.1
Minerals, mg		
iron	4.9±0.2	4.6±0.2
zinc	2.7±0.1	2.4±0.1
phosphorus	310±12	254±9
potassium	280±10	262±8
magnesium	154±7	103±4
calcium	43±1.2	36±1.2
Ash, %	2.15±0.10	1.73±0.08

The data presented in Table 1 make it clear that emmer of the variety *Golikovska* contains by 36.7 and 8.7% more protein and fat, respectively, than wheat does. The total amount of carbohydrates in emmer is smaller, mainly due to the 13.7% lower starch content. However, emmer contains by 24.0% more dietary fibre compared to wheat. It is worth noting that a high protein and dietary fibre content is typical of the chemical compositions of the known varieties of emmer *Triticum diccocum* [2,11,12].

Different emmer varieties contain 24.2-44.3% of gluten, which is often too strong [2,5,13]. As a result, emmer flour is not recommended for manufacture of baked goods [3,14]. However, it can be used to produce flour confectionery [15,16] and as an improver of weak wheat flour [17]. There are also some varieties of emmer high in weak gluten [11]. One of these is emmer of the variety *Golikovska* [10].

The decreased quality of emmer gluten could be explained by its increased autolytic activity (Table 2).

Table 2 – Activity of grain enzymes [10]

Parameter	Emmer	Wheat
Activity of proteolytic enzymes, mg of nitrogen per DM	18.0±0.3	14.8±0.3
Total activity of amylolytic enzymes, mg of starch at $\tau \times 60^{-2}$, s	92.8±1.4	82.2±1.1
incl. α-amylase	14.2±0.1	10.5±0.2
β-amylase	78.6±0.5	71.7±0.9

Indeed, according to the data presented in Table 2, the activity of proteolytic and amylolytic enzymes of emmer is, respectively, by 21.6 and 12.9% higher than that in wheat. Besides, according to the data [10,18], the increased activity of amylolytic enzymes of emmer results in its 8.8% higher sugar-forming ability compared to wheat. This can tell on the gas formation rate in yeast dough prepared from emmer flour.

R. Cubbada and E. Marconi's results of farinographic tests indicate a higher water absorption of emmer flour compared to wheat flour, its lower stability of emmer dough, and its thinner consistency [19]. However, their test baking results show that baked goods made from emmer flour have a high specific volume due to a high content of gluten. Besides, these products have a pleasant aroma. On the other hand, C. Longin *et al.* note that products obtained from flour of another emmer variety have a grey crumb colour and an uneven porosity structure [13].

The developers of emmer of the variety *Golikovska* together with the scientists of Kharkiv State University of Food Technology and Trade have found that the new emmer variety contains more than 30% of gluten, and bread made from fine emmer flour has high organoleptical and physicochemical quality parameters. This is described in utility model patent of Ukraine No. u201105683 "Method of manufacturing baked goods" [20]. However, in recent research and publications, there is still lack of consistent

information on the technological properties of flour made from emmer of the variety *Golikovska*. So, studying how emmer flour can be used in flour confectionery production, in particular, to manufacture puff pastry, is of scientific and practical interest.

The purpose of the research presented in this article is to investigate the functional and technological properties of emmer flour for its further application in puff pastry production. To achieve this purpose, the following **objectives** were set:

– to investigate the content and properties of gluten in emmer flour in comparison with wheat flour, its water-holding capacity, and the physical properties of the dough;

– to study the specific features of the properties of starch obtained from emmer flour;

– to study the microbiological processes that take place during fermentation of emmer dough;

– to investigate experimentally how emmer flour can be used to produce unleavened and yeasted puff pastry.

Research materials and methods

The emmer flour used in the research was of 70% extraction. It was obtained on a Bühler laboratory mill from spring emmer of the variety Golikovska harvested in 2017. The properties of the emmer flour under study and of products made from it were compared with those of commercial patent wheat flour produced of the TM Khutorok (LLC Zovnishtorgproduct, Dnipro). Strong flour was chosen as a reference sample, because it is recommended for puff pastry manufacturing. The main research was carried out in the laboratories of the Kharkiv Institute of Trade and Economics of the Kyiv National University of Trade and Economics (the Innovative Food and Catering Technologies Department) and in the Grain Quality Laboratory of the Plant Production Institute nd. a. V. Ya. Yuryev of the National Academy of Agricultural Sciences (Kharkiv).

The moisture content of the flour was determined by the accelerated drying method in accordance with the State Standard of Ukraine GOST 5900-2014. The content and properties of gluten were determined by the well-known methods described in [21]. The physical properties of emmer and wheat dough were determined using a Brabender farinograph and a Chopin alveograph. The water holding capacity of the flour was determined as follows. 1.0 g of the flour was mixed with 30 cm^3 of distilled water and stirred for 1 min with an electronic stirrer at 1000 rpm. The mixture was then rested for 30 min and centrifuged for 15 min at 4000 rpm. Non-adsorbed water was drained, and the tube was left tilted for 10 min to remove the residual water. The water holding capacity was calculated by the formula:

$$X = ((a–b) / c) \cdot 100, \quad (1)$$

where a is the mass of the test tube with the sample and bound water, g;

b is the mass of the test tube with the dry sample, g;

c is the mass of the sample, g.

The properties of the starch of emmer and wheat flour were studied with a Brabender amylograph. The autolytic activity of the flour was determined by Falling Number method.

The dough-raising capacity of the yeast and the titrated acidity of the dough were determined by the methods described in [21]. The active acidity of the dough was determined potentiometrically using a pH-meter 150-M. The intensity of alcohol fermentation and the rate of gas formation in the model dough systems were assessed by the amount of the carbon dioxide generated [21]. The gas-holding capacity of the dough was investigated indirectly by measuring the change in the dough volume during fermentation, for which 50 g of dough was placed in a 250-cm^3 graduated cylinder and kept in a thermostat at 30°C throughout the experiment.

Puff pastry was made according to the recipes and technologies given in [22,23]. The quality of the flour confectionery was assessed by organoleptic parameters in accordance with the requirements for the quality of unleavened puff pastry and with State Standard of Ukraine DSTU 8709: 2017.

The findings were statistically processed with MS Office Excel software.

Results of the research and their discussion

The content and properties of gluten largely determine the technological properties of flour and the range of using it to manufacture baked goods and pastry. That is why at the first stage of the study, it was important to compare these parameters for emmer and wheat flour (Table 3).

Table 3 – Content and properties of gluten of emmer and wheat flour

Parameter	Emmer flour	Wheat flour
Crude gluten, %	40.3±0.6	28.8±0.5
Dry gluten, %	13.2±0.2	9.9±0.2
Hydration capacity, %	198±5	185±2
Tenacity of gluten, units	89±2	76±1
Extensibility of gluten, cm	17±1	13±1
Quality group	II	I

It has been found that emmer flour contains 1.4 and 1.3 times more crude and dry gluten, respectively, than wheat flour does. This is consistent with the data of other researchers who studied the properties of known emmer varieties [2,5,13]. However, emmer gluten is inferior in quality to wheat gluten: it is 1.2 times less strong and 1.3 times more elastic, and can be classified as belonging to the 2nd quality group (whereas wheat gluten belongs to the 1st group of quality). It is worth noting that this feature is specific of the emmer variety *Golikovska*, which differs in its gluten tenacity from emmer of previous varieties. The

significant difference in the content of crude and dry gluten for the samples of emmer and wheat flour is probably explained by the more pronounced hydrophilic properties of emmer flour due to its higher protein content. This is consistent with the results of studying the hydratation capacity of gluten in both flour samples, with the results of studying the water holding capacity of flour (Fig. 1), and with the results of the farinographic test (Table 4).

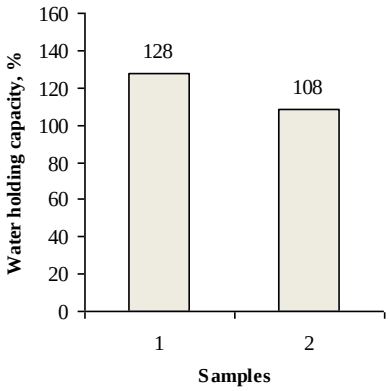


Fig. 1. Water holding capacity of emmer flour (1) and wheat flour (2)

Analysis of the data presented in Table 4 has revealed the difference in the properties of emmer and wheat dough: emmer dough is formed 2 min earlier, and is 3 times less stable than wheat dough. This agrees with the results obtained earlier by R. Cubbada and E. Marconi [19]. There is, though, some discrepancy between these data and the information that emmer flour is significantly higher in gluten-forming proteins than wheat flour is, and has a higher content of non-starch polysaccharides (Table 1) that would make dough preparation longer and keep it stable. On the other hand, the data obtained may result from the increased autolytic activity of emmer flour compared to that of wheat flour (as shown in Fig. 2). Besides, it agrees with the data presented in Table 2 and with the results of the research [10,18] on the activity of enzymes in emmer grain of the variety *Golikovska*. At the same time, the two flour samples do not differ in dough rarefication, which may be due to the peculiarities of the structure of their protein-proteinase and carbohydrate-amylase complexes and requires further research. Thus, the increased hydrophilic properties of emmer flour compared to wheat flour can be the preconditions to increase the part of liquid components in the recipes of pastry with the use of emmer flour. The reduced time of dough formation from flour of the emmer variety *Golikovska* can also be taken into account when developing confectionery technologies involving the use of this type of flour, in particular when substantiating the dough making parameters.

The differences in the physical properties of emmer and wheat dough are confirmed by the results of interpreting alveograms of emmer and wheat flour (Table 5).

Table 4 – Results of interpreting the farinograms of emmer and wheat flour

Parameters	Emmer flour	Wheat flour
Water absorption, %	67.0±1.0	60.0±1.0
Dough formation time, min	6.5±0.5	8.5±0.5
Stability of dough, min	5.0±0.5	15.0±1.0
Degree of rarefication, units	50±10	50±10

Table 5 – Results of interpreting alveograms of emmer and wheat flour

Parameters	Emmer flour	Wheat flour
Tenacity (P), mm	63±2	85±2
Extensibility (L), mm	96±3	76±3
Configuration ratio (P/L)	0.7	1.1
Baking strength (W), 10^{-4} J	268±6	373±5

It has been found that emmer dough is less resilient by 25.9% and more extensible by 26.3% than wheat dough. As a result, the alveogram configuration ratio for emmer dough is lower by 36.4%, and its baking strength is lower by 28.2%. That confirms that emmer flour is less suitable for baked goods production than wheat flour, as was previously reported by other researchers [3,14]. On the other hand, emmer flour contains a significant amount of weak gluten with increased extensibility, which opens opportunities of using this flour type for puff pastry production.

Starch is as important as gluten in the formation of unleavened and yeasted puff pastry dough. To predict the properties of emmer dough in the technological process, the starch gelatination parameters have been studied by an amylographic test (Table 6), and the Harberg-Perten Falling Number of the flour has been determined (Fig. 2).

Table 6 – Gelatination parameters of flour starch

Parameters	Emmer flour	Wheat flour
Gelatination point, °C	63±1	60±1
Time before gelation starts, min	22±1	20±1
Peak viscosity, cP	480±10	760±10

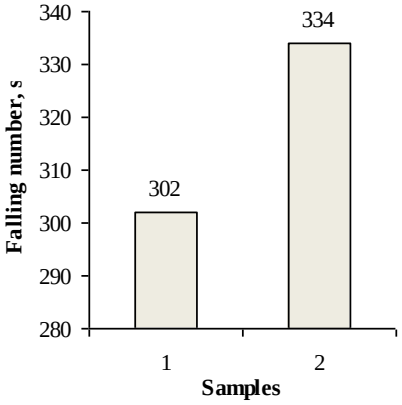


Fig. 2. Falling number of emmer flour (1) and wheat flour (2)

It has been found that emmer starch begins to gelatinise a little later and at a slightly higher temperature than wheat starch. This may be due to the peculiarities of the structure of starch granules. The peak viscosity of the starch paste of wheat flour is by 58.3% higher than that of emmer flour. That, too, indicates differences in the structure of starch granules of wheat and emmer flour and the high activity of amylolytic enzymes in emmer flour. Also, it may be due to the peculiarities of the agro-climatic conditions for the grain both flour samples were based on. The data obtained correlate with the results of determining the falling number of the flour samples tested (Fig. 2). According to the results of the experimental studies, it has been established that the falling number value of emmer flour is by 9.6% lower than that of wheat flour.

To study the possible effect of emmer flour on the technological properties of yeast, their dough-raising capacity has been determined. The research results are presented in Fig. 3.

The analysis of the data presented in Fig. 3 has shown that in the sample made from emmer flour, the dough-raising capacity of yeast is by 25.0% better than in the one made from wheat flour. This may be because emmer flour, compared to wheat flour, is higher in sugars and nitrogenous compounds (Table 1), which are a growth medium for yeast and lactic acid bacteria. The results obtained may also indirectly indicate better maturation behaviour of emmer yeast dough compared to wheat dough, which needs further research.

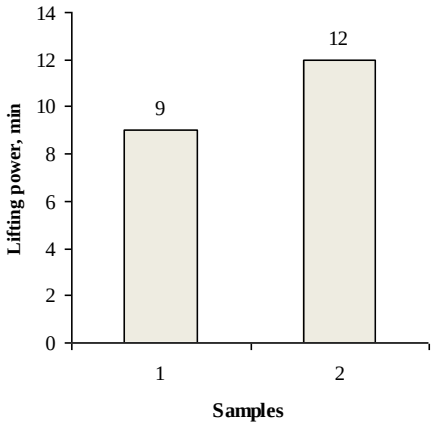
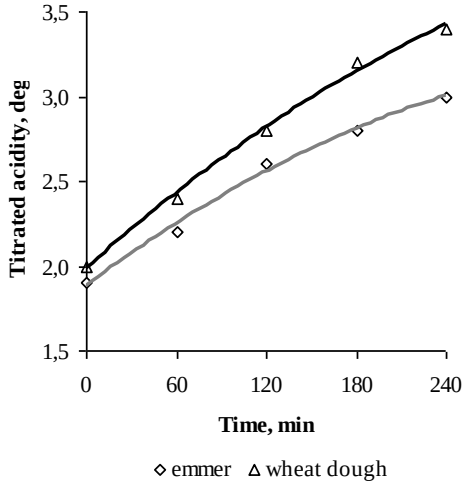
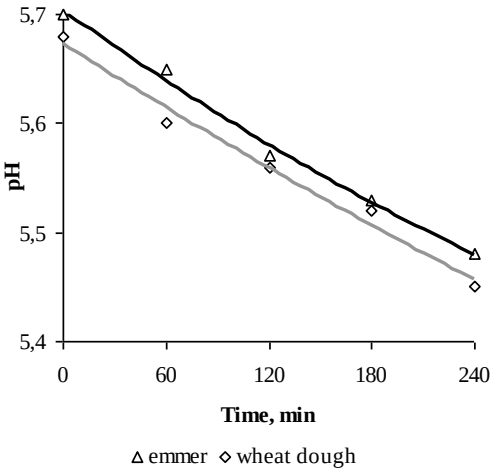


Fig. 3. Dough-raising capacity of yeast in model systems made from emmer flour (1) and wheat flour (2)

To study the peculiarities of maturation of yeast dough made from emmer flour, a series of experiments was carried out to determine the acidity of the dough during fermentation, the intensity of its fermentation, and the changes in the dough volume during maturation. The research results are presented in Fig. 4-7.



a)



b)

Fig. 4. Titrated (a) and active (b) acidity during fermentation of emmer (1) and wheat (2) dough

Analysis of the data presented in Fig. 4 (a, b) has allowed establishing that fermentation processes in emmer dough are more intensive than in wheat dough. It should be noted that the initial acidity (both active and titrated) differ within the measurement error. However, after 60 minutes of fermentation and beyond, throughout the observation period, acidity accumulation in emmer dough is more intensive than in wheat dough. So at the end of fermentation, the titrated acidity of emmer dough was by 13.3% higher compared to wheat dough, while the active acidity of both test samples differed but slightly throughout the observation period.

The data obtained correlate with the results of the study of the fermentation intensity in emmer and wheat yeast dough (Fig. 5-6).

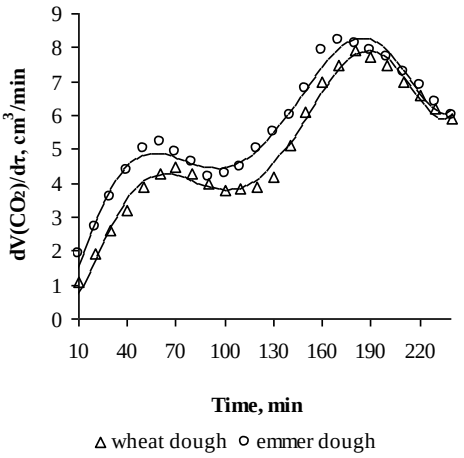


Fig. 5. Gas formation rate during fermentation of emmer (1) and wheat (2) dough

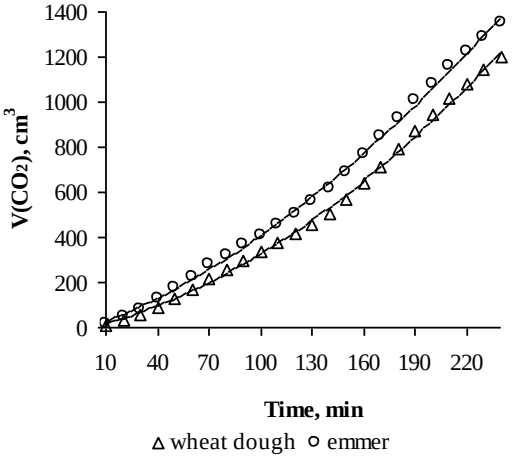


Fig. 6. Amount of gas released during fermentation of emmer (1) and wheat (2) dough

It has been found that by 12.5% more carbon dioxide is released during fermentation of emmer yeast dough compared to wheat dough (Fig. 6). The first peak of gas formation in emmer dough is observed 10 minutes earlier than in wheat dough, and the amount of gas released during this time is also larger. After 60 minutes of maturation, the intensity of gas formation decreases. This may be due to a decrease in simple sugars in the system and adaptation of the yeast to maltose fermentation. The rate of the formation starts increasing after 100 minutes from the beginning of dough fermentation, and reaches its maximum after 160–180 minutes of fermentation, which is faster than for wheat dough. The results obtained indicate a more intensive process of maturation of emmer yeast dough in comparison with wheat dough. This is probably because emmer flour is higher in free sugars and nitrogen-containing compounds (Table 1), and because the activity of amylolytic enzymes in emmer flour is higher than in wheat flour (Table 2, Fig. 2). This makes it reasonable to reduce the fermentation time of yeast dough by 10–20 minutes compared to wheat dough: it will shorten the technological process in general and reduce the cost of flour confectionery made from the emmer variety *Golikovska*.

According to the results of studying the change in the dough volume during fermentation (Fig. 7), it has been established that the maximum volume that emmer dough reaches is by 16.7% higher than wheat dough can reach, and it happens 10-20 minutes earlier than in wheat dough. This correlates with the results of determining the intensity of dough maturation (Fig. 5). This result can be explained by more intensive microbiological processes in emmer dough during fermentation and by a higher content of gluten in it (Table 3).

The results obtained were the basis for testing the recipes of unleavened and yeasted puff pastry made from emmer flour in a laboratory environment. The quality of emmer flour confectionery was evaluated by organoleptic parameters. According to the test results, it has been found that pastry made from emmer flour is not inferior in quality to pastry made from wheat flour, has a regular shape and a bright crust colour, and is large in volume.

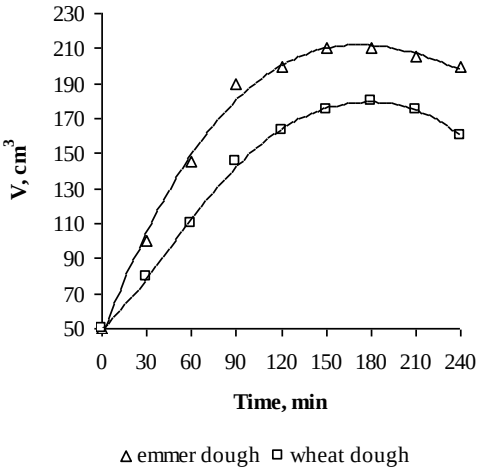


Fig. 7. Change in the volume during fermentation of emmer (1) and wheat (2) dough

Thus, emmer flour can be recommended for application in manufacturing unleavened and yeasted puff pastry of high quality.

Conclusion

As a result of the research, the functional and technological properties of emmer flour obtained from grain of the variety *Golikovska* have been studied. The advantages of using emmer flour for puff pastry production has been proved. It has been found that emmer flour contains 1.4 and 1.3 times more crude and dry gluten, respectively, in comparison with wheat flour. Emmer gluten is less strong and more elastic, it is characterised by higher hydration and water holding capacity. It has been shown that emmer dough is

formed faster than wheat dough, still it is 3 times less stable and its alveogram configuration ratio is lower by 36.4%. It has been established that in the flour samples tested, the peak viscosity of wheat starch is by 58.3% higher than that of emmer starch. However, the falling number of emmer flour is by 9.6% smaller compared to wheat flour. This may indicate differences in the structure of starch granules of emmer and wheat flour and the increased activity of amylolytic enzymes in emmer flour. It has been found that due to a higher content of free sugars and nitrogen-containing compounds, emmer dough matures more intensively than wheat dough. It has been established that maturation of yeast dough model systems results in semi-finished emmer products having the titratable acidity higher by 13.3% and the volume larger by 16.7%. The results of the test baking of unleavened and yeasted puff pastry made from emmer flour have confirmed their high quality and compliance with the requirements of regulatory documentation for this type of products.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЧНИХ ВЛАСТИВОСТЕЙ БОРОШНА ПОЛБ'ЯНОГО

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Анотація. У статті представлено результати досліджень технологічних властивостей полб'яного борошна, отриманого із зерна полби сорту Голіковська, в порівнянні з борошном пшеничним вищого ґатунку. Встановлено, що полб'яне борошно містить в 1,4 і 1,3 рази більше сирої та сухої клейковини відповідно, ніж борошно пшеничне. Показано, що клейковина полб'яного борошна є в 1,2 рази менш пружною та в 1,3 рази більш розтяжною, ніж пшенична, та може бути віднесена до ІІ групи якості. За результатами розшифрування фариограм виявлено, що дослідний зразок полб'яного тіста утворюється на 2 хв раніше та є в 3 рази менш стійким, ніж пшеничне. За результатами розшифрування альвеограм встановлено, що тісто, утворене із полб'яного борошна, порівняно з пшеничним відрізняється на 25,9% меншою пружністю, на 26,3% більшою розтяжністю, має на 36,4% менший коефіцієнт конфігурації альвеограми та на 28,2% меншу питому роботу пружної деформації. Встановлено, що крохмаль полб'яного борошна починає клейстеризуватися незначно пізніше та за дещо вищої температури, ніж крохмаль пшеничного борошна, причому максимальна в'язкість крохмального клейстеру пшеничного борошна на 58,3% більша, ніж полб'яного. Встановлено, що показник числа падіння полб'яного борошна на 9,6% менший, ніж пшеничного. Модельні системи дріжджового тіста, приготовленого на основі борошна полб'яного, виявляють на 25,0% кращу підіймальну силу порівняно з пшеничними модельними системами. Встановлено, що в полб'яному дріжджовому тісті процеси бродіння перебігають більш інтенсивно, ніж у пшеничному – наприкінці бродіння полб'яне тісто мало на 13,3% вищий показник титрованої кислотності та на 12,5% вищий показник виділеного вуглекислого газу. Об'єм полб'яного тіста був на 16,7% вищий, ніж пшеничного. За результатами оцінювання якості прісних і дріжджових листкових виробів із полб'яного борошна за органолептичним показниками встановлено, що вони не поступалися за якістю виробам із борошна пшеничного, мали правильну форму, яскраве забарвлення скоринки та високий об'єм.

Ключові слова: борошно полб'яне, борошно пшеничне, властивості борошна, бродіння, листкові вироби.

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