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CHARACTERISTIC OF ORGANIC FLOUR PRODUCED FROM EINKORN WHEAT AND RHEOLOGICAL PROPERTIES OF EINKORN DOUGH IN TERMS OF BREAD OBTAINING

Summary

Varieties of common wheat, adapted to conventional farming system, transferred to organic farming, bring crops lower yielding than in conventional cultivation, whilst the nutritional value of grain doesn't increase. Therefore growing of ancient wheat, including diploid einkorn Triticum monococcum gives a chance to develop local producers of food and contributes to maintaining agricultural biodiversity and obtaining grain characterized by higher content of biologically active compounds. Another reason to reach for the old varieties of cereals, including the first form of cultivated wheat is growing consumers' interest in nutritionally valuable food ingredients including an antioxidant phytochemicals (tocols, coupled polyphenols, phytosterols, carotenoids). The aim of this work was to evaluate organic flour made from einkorn, available on Polish market, in terms of physico-chemical properties (protein content, yield and quality of gluten) and determine the rheological properties of the dough obtained from einkorn flour. Antioxidant activity of flour was assessed and researches performed including characterization of microbial ecosystem of flour. It has been found that the quality of the proteins of the test batch of einkorn flour was very low, the amount of wet gluten was significantly lower than the minimal level required for bread flour (25%). Gluten of einkorn had a high viscosity and plasticity. In einkorn flour low number of lactic acid bacteria was detected. The evaluation of einkorn dough revealed that einkorn flour had weak reological (farinographic) properties, it means low water absorption, short development time of dough, short stability. The high degree of softening indicated low grow tolerance of dough. Therefore it is necessary to use technological additives like gluten or mixing einkorn and wheat flour. In order to improve einkorn bread quality it is advisable to apply sourdough technology with use of starter culture . Einkorn flour gives to bread functional features, with the added value in the form of increased content of polyphenolic compounds and antioxidant activity.
***Key words**: einkorn flour, bread, rheology*

CHARAKTERYSTYKA JAKOŚCI MĄKI EKOLOGICZNEJ Z PSZENICY SAMOPSZY I WŁAŚCIWOŚCI REOLOGICZNYCH CIAST OTRZYMANYCH Z UDZIAŁEM TEJ MĄKI (W ASPEKCIE OTRZYMYWANIA PIECZYWA)

Streszczenie

Odmiany pszenicy zwyczajnej, przystosowane do uprawy konwencjonalnej w systemie ekologicznym, plonują stosunkowo nisko, a wartość odżywcza ziarna nie ulega znaczącej poprawie. Dlatego uprawa pszenic pierwotnych, do których należy diploidalna samopsza Triticum monococcum daje szansę rozwoju lokalnym producentom żywności, a także przyczynia się do podtrzymania bioróżnorodności środowiska rolniczego i pozyskania ziarna konsumpcyjnego o potencjalnie większej zawartości składników biologicznie czynnych. Kolejną przesłanką do sięgnięcia po stare odmiany zbóż, w tym pierwsze formy uprawne pszenicy, jest wzrastające zainteresowanie i świadomość konsumentów odnośnie do cennych pod względem odżywczym składników żywności w tym fitozwiązków o charakterze antyoksydacyjnym jak tokole, sprzężone polifenole, fitosterole karotenoidy (np. luteina). Celem badań była ocena jakości ekologicznych mąk z pszenicy samopszy, dostępnych na rynku w Polsce pod względem właściwości fizykochemicznych (m.in. zawartości białka, ilości i jakości glutenu) oraz określenie właściwości reologicznych ciast uzyskanych z udziałem mąki z samopszy. Określono aktywność antyoksydacyjną mąki. Wykonano również badania mikrobiologiczne, obejmujące charakterystykę ekosystemu mąki. Stwierdzono, że jakość białek z badanych partii mąki z samopszy była bardzo niska a ilość glutenu mokrego była znacznie niższa od minimalnego poziomu wymaganego dla mąk na chleb (25%). Gluten z samopszy wykazywał dużą lepkość i plastyczność. W mąkach z samopszy stwierdzono niską liczbę bakterii fermentacji mlekowej. Ocena właściwości ciast otrzymanych z samopszy wykazała, że mąki z samopszy charakteryzowały się słabymi właściwościami reologicznymi (farinograficznymi) sformowanych z nich ciast: niską wodochłonnością, krótkim czasem rozwoju ciasta i krótką stałością, natomiast bardzo duże rozmiękczenie w badaniach farinograficznych wskazywało na niską tolerancję rozrostową. Dlatego konieczne jest stosowanie dodatków technologicznych np. dodatku glutenu lub wykorzystanie w recepturze mąki pszennej. W celu poprawy jakości pieczywa z samopszy wskazane jest inicjowanie fermentacji poprzez stosowanie kultur starterowych. Mąka z samopszy nadaje pieczywu cechy funkcjonalne, z wartością dodaną w postaci podwyższonej zawartości związków polifenolowych i aktywnością przeciwutleniającą.
***Słowa kluczowe**: mąka z samopszy, chleb, reologia*

1. Introduction

In recent years, a growing interest in old wheat varieties have been observed among organic crop farmers (plant breeders) and nutritionists. One of the reasons lies in the low yield in the organic system of common wheat varieties, that are adapted to the cultivation in conventional farming system. Moreover ancient wheat shows better adaptability to adverse environmental conditions, higher tolerance to diseases, and doesn't require so intensive agrotechnical treatments as common wheat in organic farming system. Another reason of old cereals varieties attractiveness, in-

cluding wheat crops first forms, stems from an awareness of consumers of nutritionally valuable food ingredients and demand for food with such "added value". Diploid *Triticum monococcum*) – einkorn is the most primeval of the ancient varieties of wheat [5, 20].

Its cultivation can be an opportunity for development of local food producers, also can contribute to the maintenance of biodiversity of agricultural environment and gain edible grains of potentially higher content of biologically active compounds compared to modern wheat. Pro-health value of einkorn grain is predominantly associated with high levels of carotenoids and tocols [1, 8, 9, 11, 12]. Einkorn is also characterized by higher, relative to the polyploidy wheat, amount of lipid (including the unsaturated fatty acids) and trace elements (Zn, Fe) [11, 20]. Nutritive value of einkorn whole-meal flour is related to its high protein content and determined by an antioxidant compounds such as carotenoids (including lutein), tocols, conjugated polyphenols, phytosterols and due to low activity of enzymes responsible for the degradation of the antioxidants during food processing [8, 9, 10, 15, 16]. It has been shown that properties such as tocopherol and fat content are mainly genetically determined, while the protein, tocotrienols and lutein contents are also affected by environmental factors (agrotechnical factors) and location of the crop cultivation [7, 10, 14].

Regardless of the high content of biologically active compounds the usefulness of einkorn flour as the raw material for bakery is relatively low [2]. One of the factors affecting the technological properties of the einkorn includes the fractional composition of gluten proteins in the einkorn flour and its influence on physico-chemical and viscoelastic properties of gluten matrix [12]. According to Jankowska and al. [12] einkorn gluten exhibits less elastic properties and it is characterized by a larger share of viscous characteristics than gluten of wheat. Compared to the wheat gluten, the einkorn gluten showed a lower swelling capacity. For this reason it is important to assess the physico-chemical properties of the einkorn flour to predict the bread dough performance during dough-making and baking, which helps in adjusting the process parameters to the specific flour. Use of sourdough process is the common accepted method to improve quality of bread. Necessary in rye bread, where acidification of dough is mandatory to obtain an appropriate texture of bread, sourdough can improve also sensory characteristic of einkorn bread and increase its nutritional value.

The aim of the work was to evaluate the quality of the organic flour, made from einkorn available on the market in Poland, in terms of physico-chemical properties and to determine the rheological properties of the dough obtained from this flour.

2. Materials and methods

The experimental material consisted of einkorn organic flour made from grain grown in Kujawsko-Pomorskie (local population 2-941, according to oral information from the National Centre for Plant Genetic Resources in Radzików). Whole-meal flour was produced by Manufacturing "BIO" Babalscy. Three batches (samples) of Polish flour made from einkorn were tested: one of the crop in 2013 (indicated as sample I) and the two parts from the crop in 2014 (sample II and III), there were tested also organic einkorn flour from Italy and organic flour from common wheat type 550.

Bread-making quality of einkorn flour was assessed based on the results of the analysis of the chemical composition and physical characteristics of the flour, the rheological properties of dough using farinograph and direct assessment in baking test, compared to wheat flour type 550.

Physico-chemical analyses (protein and ash content) were performed according to standard methods, including protein (N x 5.7) content by Kjeldahl method PN EN ISO 20483: 2007, total ash content PN-EN ISO 2171: 2010 and dry matter of samples was determined by gravimetric method. Zeleny sedimentation index was determined according to PN-EN ISO 5529:2010 by measuring the volume of sediment resulting from the suspension of the test flour solution with mixture of lactic acid and isopropanol in the presence of bromophenol blue. Falling number, the parameter determines the activity of α-amylase of flour according to PN-EN ISO 3093: 2010.

In order to assess the mechanical resistance of the einkorn dough during mixing and kneading farinograph was used. Farinograph test was performed in accordance with official method standard PN-ISO 5530-1:1999. Water absorption of flour were determined and rheological parameters of the dough: development time, stability of dough, dough softening, the number of quality. The amylograph parameters were assessed in compliance with PN-ISO 7973:2001.

Assessment of microbiological quality of flour was made according to standards PN-EN ISO 4833:2004, ISO 21528-2:2005, ISO 21527-2:2009, ISO 15214: 2002; BS EN ISO 7932: 2005; BS EN ISO 6887-1: 2000. There were assessed the number lactic acid bacteria, bacteria of the family *Enterobacteriaceae*, bacteria of the species *Bacillus cereus*. and *Bacillus subtilis*, proteolytic bacteria, spore-forming bacteria, mucous bacteria of the genus *Leuconostoc* and the number of yeast and mould.

Determination of antioxidant properties and phenolic compounds content were performed in sample extracted with a mixture of acetone and water in a ratio of 7: 3 (v: v) and with a mixture of methanol and water in a ratio of 7: 3 (v: v). The content of phenolic compounds was determined with the Folin-Ciocalteu reagent (with use of spectrophotometer) and was computed by using gallic acid as standard equivalents (GAE) [13,19]. The antioxidant activity was evaluated as total free radical scavenging capacity of whole-meal flour extracts, using the ABTS + (2,2-azynobis-(3-ethylbenzthiazoline-6-sulfonate) [4, 18]. 6-Hydroxy-2,5,7,8-tetramethylchroman- 2-carboxylic acid (Trolox) was used as a reference antioxidant. The alpha-tocopherol quantification was performed by HPLC according to standard method (PN-EN 12822: 2002).

The results of the analyzes of at least two independent experiments are reported as arithmetic means with standard deviation.

The breads were prepared with einkorn flour (sample II). In order to improve their sensory characteristic part of the flour was introduced as sourdough, obtained with starter culture. Starter cultures were composed of strains of lactic acid bacteria isolated from einkorn flour. Baking tests were conducted on three loaves from each bread type (including control bread). In assessing the overall physical and chemical dough properties according to PN-A-74100: 1992 were performed: determination of pH and total acidity by titra-

tion. Performance and dough fermentation time were established. Bread quality was assessed according to Polish standard (PN-A-74108: 1996).

3. Results and Discussion

Results of physico-chemical characteristics of the einkorn flour tests were shown in Table 1.
The ash content is the basis of type of flour designation, in the case of einkorn flour Polish manufacturers offer flour without type indication but the most produced einkorn flour is whole-meal flour. Samples I and II of einkorn flour contain less than 1% of ash in dry matter, and can therefore be classified as bread baking flour, other samples characterized by higher content of ash as in whole-meal flour. The color of whole-meal wheat flour is usually darker compared with flour containing a small amount of bran. Regarding einkorn flour its yellow color is connected with carotenoids, for example lutein, whose concentration is higher indeed in the germ and in endosperm than in bran, so einkorn bread flour is characterized by light yellow color, consequently bread has yellowish crumb [9].

The contents of protein, differed in analyzed samples and remained at a similar or even lower level than in common wheat. According to data reported by Hidalgo at al. [9, 11], usually the content of protein in einkorn flour is higher, but Polish einkorn has been not examined by these authors.

The protein content of the common wheat flour determines its suitability for baking. Depending on the amount and quality of gluten proteins in particular, upon hydration a continuous network of gluten is forming, responsible for dough viscoelastic structure formation. Gluten complex is capable of retaining gas produced during the fermentation.

The examined einkorn flour met the criteria for bread flour (protein content is higher than 11.5% dm). However, results of Zeleny sedimentation test indicated a very poor quality of these proteins in terms of baking, because the proper level required for bread wheat is minimum 25 ml. The amount of wet gluten in the einkorn flour, was also significantly lower than in wheat flour and as the minimal level required for bread flour (25%). Moreover, gluten from einkorn flour differed from the gluten of common wheat; had a high viscosity and plasticity - the characteristics of gliadin fractions, which meant that it was very difficult to wash out.

These properties were reflected also in the flowing values of gluten (gluten spreadability) flour samples obtained from einkorn up to 12 mm. The proper value of gluten flowing for the bread flour is generally recognized 5-7 mm, so high value as assessed in einkorn (more than 9 mm) may indicate problems with maintaining the shape of the bread.

The einkorn flour samples showed higher sum of phenolic compounds and antioxidant activity (AOA) with ABTS than wheat flour, what imply their biological value. Reggae [17] reported that the total polyphenol content in wheat was approximately 500 µg GAE/g (50mg GAE /100g), based on gallic acid), Alvarez - Jubete [3] showed the level of polyphenols in wheat as 53.1 mg GAE / 100g. Taking into account these data, einkorn flour samples were assessed as rich in polyphenols. The content of phenolic compounds in ancient wheat according to the literature varied depending on the variety, the area of cultivation and agronomic conditions. Giambanelli et al. [7] showed that in the einkorn accession, grown in the Mediterranean area, content of these compounds may vary from 819 mg/kg to 1465 mg/kg.

Comparison of the values obtained in this work with the data in the literature is difficult because of differences in the methods and units of presented results. Antioxidant activity expressed in Trolox equivalents is higher compared to the value given by Lachman [14] (average for einkorn antioxidant activity at level 20 mg/100 g), however that study was performed using a different reagent (DPPH) making it difficult to compare results. It is also difficult to compare the contents of tocopherol with results of other study. Hidalgo [9] gives the average content of sum of tocopherols in einkorn at 77.96 µg/g dm, the content of α-tocopherol in the examined samples were lower. Studying the antioxidant activity of einkorn, spelled, durum and common wheat Lachman et al. [14] concluded that, in the case of cereals this activity is highly correlated with the content of polyphenolic compounds and higher (1.84 times even in the case of einkorn) in comparison to the antioxidant activity of common wheat, the result confirmed also a higher content of carotenoids and tocols in einkorn than in wheat.

The determinant factor to assess the baking properties of flour includes also the dough characteristics revealing the influence of flour constituents and additives on dough behaviour during bread-making [6]. Wheat dough features necessary to achieve good bread should meet the balance between the elasticity, viscosity and the appropriate extensibility characteristic.

Table 1. Chemical compounds and characteristic of flour, expressed as dry matter [DM]) content (± s.e.) of whole flour
Tab. 1. Parametry fizykochemiczne mąk z samopszy w porównaniu do mąki z pszenicy zwyczajnej

Quality parameters	Sample of flour				
	wheat type 550	einkorn I	einkorn II	einkorn III	italian einkorn
moisture,%	13,3 ± 0,3	12,4± 0,1	12,8 ± 0,2	12,0 ± 0,1	11,8 ± 0,2
ash (g/100 g)	0,51 ± 0,12	0,99± 0,24	0,79± 0,27	1,97± 0,23	1,89± 0,34
total protein, (g/100 g dm)	14,4 ± 0,5	14,8± 0,4	12,34± 0,2	13,7± 0,5	13,5± 0,2
moist gluten, %	32± 0,8	10,8± 0,9	18,0± 1,6	9,6± 1,0	13,5± 1,4
flowing of gluten, mm	3,0± 0,6	12,0± 1,2	9,0± 1,4	11,0± 1,0	10,0± 1,2
sedimentation index Zeleny's, ml	52± 1,0	< 10	10± 1,0	<10	14± 1,0
falling number, s	420± 5	319± 5	351± 6	340±5	386±5
sum of phenolic compounds [mg GAE/100g]	47±2,1	110±1,9	134±2,3	-	89±1,1
antioxidant activity (AOA) with ABTS [mg TE/100g]	150±2,6	299,8±4,3	244,2±15,2	-	232,2±7,4
tokopherol (vitamin)mg/100g	0,10±0,01	0,27±0,01	0,10±0,01	-	0,12±0,1

GAE - gallic acid equivalent, TE-trolox

Source: own work / Źródło: opracowanie własne

The structure of wheat dough is associated with the formation of a continuous three-dimensional matrix of gluten as a result of the hydration, swelling and aggregation of particles of gliadin and glutenin. The properties of dough made from einkorn flour are shown in Table 2.

Dough prepared from einkorn flour have been examined in terms of farinograph and amylograph parameters. Einkorn flour was characterized by poor rheological properties.

Farinograph provided information about mixing properties of flour. Einkorn flour had a low water absorption, short dough development time, and a short stability, but a very high softening degree, particularly in the case of flour I and III, indicating a low tolerance to growth of dough. Amylographic experiment have revealed high maximum viscosity and temperatures of gelatinization, what may inhibit the rise of bread during baking in oven.

Microbiological characteristics of flour have also been conducted, including assessing the presence and the number of the main groups of microorganisms: necessary like lactic acid bacteria (LAB) and yeast, and disadvantageous in the technology of bread. Results are shown in table 3.

Microbiological analysis of flour revealed generally low level of microorganisms representing various groups, including lactic acid bacteria (LAB). The number of LAB reached the level 10^3 cfu/g only in einkorn flour III, while the number of mould was on the same level, the disadvantageous bacteria, representing the genus *Bacillus* and the family *Enterobacteriaceae* were also present. Low numbers of LAB indicated that einkorn flour was not a suitable raw material for the developing naturally fermented sourdoughs and manufacturing bread.

The results of chemical composition analysis and rheological tests of einkorn flour implied the low suitability of that flour as an entire ingredient for obtaining good quality bread.

In order to improve bread quality and keep the organic manufacturing conditions it is advisable to carry out lactic acid fermentation of dough or introduction of other stabilizing additives. Baking tests were performed using 20% of sourdough made from einkorn flour according to recipe of bread dough. Here are the basic bread variants tested.

1 - 100% einkorn flour bread
2 - 100% einkorn flour bread with the addition of gluten 3%
3 - Bread made with einkorn flour 70% and 30% of wheat flour type 550
4 - Bread made with einkorn flour 50% and 50% of wheat flour type 550.

Sourdough was obtained in one stage with selected starter culture containing strains of LAB isolated from the einkorn flour and after 24 hours of fermentation was used to prepare bread dough. Flour introduced with sourdough constituted 20% of the total amount of flour in the dough.

The dough was fermented in mass for 30 min and then separated into 250 g pieces. The growth of dough was performed in atmosphere 75% of humidity, at a temperature 35°C. Baking was carried out in a baking oven, in an atmosphere of steam at temperature 230°C. The evaluation of bread characteristics are presented in table 5.

Table 2. Reological parameters of dough evaluated with farinograph and amylograph
Tab. 2. Reologiczne parametry ciast wyznaczone przy użyciu farinografu i amylografu

Parameters	Samples of flour			
	Einkorn I	Einkorn II	Einkorn III	wheat
Farinograph parameters				
- water absorption, %	53,4±0,15	52,3±0,14	55,4±0,16	57,5±0,13
- dough development time, min	2,0±0,45	1,8±0,35	1,7±0,30	2,2±0,40
- dough stability, min	1,6±0,14	2,3±0,17	1,2±0,12	5,9±0,29
- degree of softening after 12 min, FU	160±4,4	112±4,2	142±4,3	60±2,2
Quality number	29	43	29	71
Amylograph parameters				
- peak of viscosity, maximum, AU	940±25	-	915±20	2060±45
- starting temperature of gelatinization, ^oC	58,5±0,1	-	59,0±0,1	60±0,1
- temperature at peak of gelatinization, ^oC	90±0,1	-	90,0±0,1	90±0,1

Source: own work / Źródło: opracowanie własne

Table 3. Microbiological analysis of einkorn flour
Tab. 3. Analiza mikrobiologiczna mąki z samopszy

Mikroorganisms	sample of flour, presence of microorganisms, cfu/g			
	I	II	III	italin einkorn flour
yeast	n.d.	n.d.	$1,2x\ 10^1$	n.d.
lactic acid bacteria	$4,0x10^2$	$1,2x10^1$	$1,5x10^3$	n.d.
mould	$1,2x10^3$	$1,0x10^3$	$1,0x10^3$	$1,0x10^3$
bacteria of *Leuconostoc* genus	$4,0x10^1$	$1,8x10^1$	$1,2x10^3$	$1,2x10^1$
Bacillus cereus	$3,0\ x\ 10^1$	$1,2\ x10^1$	n.d.	n.d.
Bacillus subtilis	n.d.	$1,0\ x\ 10^1$	$1,2x10^1$	n.d.
proteolitic bacteria	$2,0x10^2$	$1,0\ x10^4$	$1,0x10^3$	$1,2x10^2$
spore-forming bacteria	$4,0\ x\ 10^1$	$3,0\ x\ 10^1$	$1,8x10^1$	n.d.
bacteria of *Enterobacteriaceae* family	$6,0x10^4$	$3,1x10^3$	n.d.	$1,6\ x\ 10^2$

n. d. - not detected

Source: own work / Źródło: opracowanie własne

Table 4. Technological parameters of bread dough
Tab. 4. Parametry technologiczne ciasta

Parameters		Sample of dough, einkorn flour content – S, common wheat content Z			
acidity of dough		S 100%	S 100% + gluten	S / Z 70%/30%	S / Z 50%/50%
saurdough 0 h	titratable acidity, degrees	2,0±0,05			
	pH	6,21±0,02			
sourdough 24h	titratable acidity, degrees	16,2±0,13			
	pH	3,57±0,01			
baking dough	titratable acidity, degrees	7,2±0,05	6,7±0,04	6,1±0,03	6,1±0,03
	pH	4,7±0,02	4,8±0,05	4,6±0,02	4,49±0,02
yield of dough (flour +water)		160	165	160	160
fermentation time in pieces of dough		63	75	75	75

Source: own work / Źródło: opracowanie własne

Table 5. The characteristics of einkorn bread quality
Tab. 5. Charakterystyka jakościowa chleba z mąki z samopszy – S i mąki z pszenicy zwyczajnej – Z

Evaluation of individual properties	einkorn 100%	einkorn 100% + gluten	einkorn/ common wheat 70%/30%	einkorn/ common wheat 50%/50%
Yield of bread made with100g of flour	131,0	140,0	131,8	132,0
Volume of bread, cm^3/100g	259±2,5	280±2,9	277±2,8	288±3,0
Volume of bread, cm^3/100 g flour	341	392	365	380
Crumb moisture content, %	42,0±0,2	43,0±0,4	42,8±0,5	43,6±1,0
Titratable acidity , degrees	4,7±0,2	4,5±0,1	4,6±0,1	4,6±0,1
Crumb hardness (Instron), [N]	25,5	20,6	18,6	20,1
Organoleptic evaluation, according to PN, points	30,1	34,5	35,3	36,0

Source: own work / Źródło: opracowanie własne

Bread obtained according to first recipe with 100% of the einkorn flour had the lowest volume, the lifted crust, the structure of crumb with thick walls of the crumb pores and irregular porosity. This result was in line with prediction effect of baking test, formulated on the basis of the quality of the einkorn flour. The addition of 3% of gluten in einkorn flour resulted in better bread structure, having a higher volume of loaves, better crumb wall thickness and porosity. In order to improve the quality of einkorn bread tests with replacing part of the flour with common wheat flour (30% and 50%) were accomplished. The parameters of breads are presented in table 5. Replacement parts of einkorn flour with wheat flour increased the bread volume according to share of wheat. Addition of wheat flour improved significantly the structure and crumb elasticity. It must be emphasized that the bread containing 100 % of einkorn flour with the addition of gluten in organoleptic evaluation scored 34,5 points, a similar note received bread containing 30% of wheat flour, this high evaluation was due to reach aroma of 100% einkorn bread.

4. Summary

Organic sourdough einkorn bread is an attractive proposition for conscious and demanding consumers, who prefer white common bread but decided to buy breads of high nutritional value and sensory qualities. The bread made from einkorn flour, even with large share of bran, is characterized by a clear – yellow color, differing from dark color of whole-meal flour. It has been found that it is possible to obtain bread with einkorn flour without mixing with wheat flours, Due to use sourdough obtained with starter culture containing selected strains of indigenous LAB has been achieved bread with good organoleptic quality. Einkorn flour gives the bread functional features, with the added value in the form of increased content of polyphenolic compounds and antioxidant activity.

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