NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 34, 2017
www.incda-fundulea.ro Print ISSN 1222-4227; Online ISSN 2067-5720

# BAKING QUALITY OF WHEAT GRAIN AS INFLUENCED BY AGRICULTURE SYSTEMS, WEATHER AND STORING CONDITIONS

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## ABSTRACT

**The basic principle of the production of a good quality bakery product is the knowledge of the quality parameters of raw materials introduced in the production process and the ability to use their potential to the maximum. The aim of the study was to establish influence of agriculture systems and weather conditions on grain quality. The particular parameters of bread wheat baking quality were studied and evaluated in 2010, 2011 and 2012 under long-term storing. The effect of each factor was calculated for all experiment variants as the initial of grain baking properties and the changing of these indicators over the 12-month storage. Among the growth factors (agriculture systems and weather conditions) the weather conditions of the growing season were more significant, determining the quality of just harvested grain at 46-53%, while agriculture systems, including such components as fertilizing and plant protection system had a share of only 40-48% to determine suitability of grain to the baking industry. Among the tested storage factors terms of storage were more significant for grain harvested at all studied agriculture systems. As a result, selection of the right combination of grain storage modes and terms together with the original grain quality can help to achieve better safety of grain technological properties during the storage period.**

**Key words:** wheat grain, bread-making value, storage terms and modes, agriculture systems, weather conditions.

## INTRODUCTION

Wheat is the most important grain crop in the world. It is responsible for the development of the great bread-wheat civilization from Mesopotamia to India, from China to Egypt, from Greece and then to our region (Johnson et al., 1972). During last two decades Ukrainian bread wheat production has constituted more than half of Ukraine's total wheat production. This level of production can be explained by the importance of bread in the Ukrainian diet. Bread, mostly wheat and rye, is considered to be the staple food for majority of people and is consumed on a daily basis.

The baking potential of wheat is influenced by many factors, most notably by protein content. Gluten and protein content are influenced in turn mainly by nitrogen fertilization, while their quality is determined primarily by the gene and variety particularity (Gomez et al., 2009; Triboi et al., 2000). On the other hand, both the quality and the content of the wheat protein are affected by the climatic conditions during wheat growing and especially during maturation (Stanciu and Neacsu, 2008). Consumer judgment is one of the most valuable tools in food quality assessment. Many studies investigating bread wheat baking performance have addressed protein properties, with particular emphasis on wet gluten strength (Pejcz et al., 2015; Koppel and Ingver, 2010). That also is variable due to fertilizing, rainfall and temperature.

When choosing grain storage conditions, we should have in mind a number of factors. However, the most efficient and cost-effective is the chosen mode of storage, which is accompanied by additional techniques to increase the stability of the grain mass throughout all storage period (Strelec et al., 2010).

As a result of the rich biochemical composition, ways of wheat grain processing are very broad and diverse. At the same time the problem of the grain quality is relevant for the different sectors of agriculture and food industry, as well as questions about the factors under the influence of which it is formed and

Received 6 November 2015; accepted 7 February 2017. First online: March, 2017. DII 2067-5720 RAR 2017-153

remains stable under different storage conditions.

In Ukraine as in many European countries the agriculture policy is oriented towards organic agriculture, the prime objective of which is to solve environmental and food safety problems.

The steadily growing demand for organic production and increasing area of organically-managed crops are the factors that encourage testing and choice of the available cultivars and development of new ones tailored for organic production (Jablonskyte-Rasce et al., 2013).

Every modern agriculture system includes such components as: scientifically well-founded organisation of ground terrain of an economy; rational frame of a crop rotation; system of soil processing; fertilizing, plant protection system, system of seed-growing and ameliorative measures directed on protection against erosion. The high yields of today's modern wheat cultivars require high input which leads to both higher production costs and a greater risk of environmental pollution. Increasing public awareness of the latter, along with growing consumer demand for healthier products, has led on one hand to greater criticism being levelled at this type of production model, and on the other to heightened emphasis on crops grown under integrated-management and organic systems (Petrenko et al., 2015).

The present study was aimed to ascertain the major characteristics of three grain samples grown under different agriculture systems and their dynamics during the storage period.

## MATERIAL AND METHODS

### Description of the experimental site

In the framework of the research the variety of winter wheat Natsionalna of the Ukrainian breeding, grown under three different agriculture systems: biological, ecological and intensive, was analysed.

A field experiment was set up at the National University of Life and Environmental Sciences of Ukraine Agronomy experimental station in Kyiv region during 2010-2012 period. The field experiment plan provided the combination of 3 different agriculture systems in the typical for Woodland zone crop rotation. The wheat pre-crop was clover in all experimental years. The soil of the experimental site is clay loam (*Luvic Chernozems*, Cl) with a humus content of 4.3-4.6%, pHKCl – 6.8-7.0, $P_2O_5$ – 176-187 mg $kg^{-1}$, $K_2O$ – 440-451 mg $kg^{-1}$.

### Treatments and analysis

The fertilizing and plant protection systems differed essentially depending on an agriculture system. The control treatment was the intensive system model which included applying for the winter wheat $N_{130}$, $K_{114}$, $P_{126}$ kg $ha^{-1}$ and also intensive usage of the recommended pesticides by the program of ensuring the productivity of arable lands (herbicide Grodyl 75 WG and fungicide Racsile).

The models of the biological and ecological agriculture were compared with the control treatment. These agriculture systems have a strong difference mostly in fertilizing and plant protection: in the biological system, organic fertilizers (24 t $ha^{-1}$) were applied in a crop rotation, without any mineral fertilizers and pesticides. About 17 t $ha^{-1}$ of this fertilizing was dung and no less than 7 t $ha^{-1}$ there were stubbly remains (like clover or corn stubble remains). Seed processing by biological fertilizer before sowing (Azofit) was used. Exclusively, mechanical and biological means were used against pests, diseases and weeds. This field experiment was carried out in a certified organic field in the Agronomy experimental station.

The ecological system envisaged the usage of organic and mineral fertilizers for wheat $N_{100}$, $K_{34}$, $P_{64}$ kg $ha^{-1}$ in particular, and norms of pesticides according to the criterion of the ecological economic threshold of harmful organisms.

### Meteorological conditions

Weather conditions of study years are shown in Table 1. September 2009 was really rainy and it was advantageous for wheat plant establishment. Warm and dry weather prevailed in the spring of 2010 (especially in April). At the beginning of summer there was sufficient warmth but not enough moisture for development of the wheat grain quality. During grain ripening the wheat plants were exposed not only to a strong water stress but also to extremely high temperatures. So the wheat grain productivity this particular year was the lowest in the experimental period. The drought lasted until the third decade period of May. In spring and summer of 2011, except April, hydrothermal conditions were favourable for the development of winter wheat. Autumn of this year was also within normal limits.

*Table 1.* Meteorological conditions for the years 2009-2012, according to Kagarlic weather station

| Year | Month | | | | | | | | | | | | Average meaning |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | |
| Mean air temperature, ºC | | | | | | | | | | | | | |
| 2009 | | | | | | | | 22.1 | 14.0 | 10.6 | 3.8 | 2.1 | |
| 2010 | -4.4 | -3.3 | 3.6 | 10.2 | 15.0 | 21.5 | 22.3 | 21.8 | 16.9 | 9.7 | 4.9 | 2.4 | 9.8 |
| 2011 | -7.9 | -3.1 | 2.9 | 9.9 | 17.1 | 22.3 | 23.0 | 22.5 | 15.1 | 6.3 | 9.0 | -3.2 | 9.9 |
| 2012 | -3.3 | -6.5 | 3.4 | 9.8 | 16.3 | 15.9 | 22.7 | | | | | | 9.0 |
| Sum of rainfall, mm | | | | | | | | | | | | | |
| 2009 | | | | | | | | 27 | 139 | 13 | 38 | 58 | |
| 2010 | 38 | 57 | 42 | 1 | 45 | 90 | 86 | 8 | 20 | 56 | 22 | 83 | 634 |
| 2011 | 62 | 59 | 24 | 10 | 68 | 62 | 57 | 12 | 37 | 26 | 61 | 61 | 531 |
| 2012 | 24 | 19 | 6 | 8 | 23 | 149 | 164 | | | | | | 590 |

**Statistical analyses**

The experiments consisted of a randomised complete block design which included 36 treatment combinations consisting of three agriculture systems, three modes of storage and six storage terms. The data of bread-making value was processed by a two-factor mode and a year analysis of variance (ANOVA), to establish the treatment effects. Contrasts were used to determine the effect of storage terms, modes and agriculture systems. The Fisher's LSD ($p \leq 0.05$ and $p \leq 0.01$) test was used to estimate significant treatment effects.

**Baking experiment**

After harvesting grain was cleaned and dried up to moisture content of 13.5-14.0%. The dry grain is characterized by a low state of metabolism capable of withstanding extreme environment variations. Then it was stored for one year in three different modes (temperature and packing conditions) that are the most popular in agriculture enterprises. The first mode included storing grain in a not heated barn in burlap bags (in a dry state), the second one – also in a not heated barn but in hermetic plastic bags white colour outside and black inside, thick 90 micron (without air access) and the third mode - in cold storage room, with the temperature +6±2ºC in burlap bags (in a cool state). The mass of each sample of grain was 50 kg.

Laboratory baking test was done before putting grain on storage and then after one, three, six, nine and twelve months. Before baking, the grain was milled into flour with 70% flour extraction using Buhler MLU-202 laboratory mill. From this fraction the baking experiment was carried out according to the methodology of the research workplace. Experimental baking was realized under laboratory conditions from 1000 g of flour, processed with the addition of salt, sugar and yeast in the laboratory kneading machine Kenwood Chief (programme 15 seconds on 10 Hz, 120 seconds on 25 Hz and 300 seconds on 50 Hz). Fermentation in the electronically regulated deck oven with fermentation area (Rosella) for 40 minutes at 30ºC was followed by the baking with steaming (5 minutes 220ºC and then 30 minutes 200ºC). The dough for baking experiment was prepared according to the following recipe:

– water according to the water adsorption capacity, so that the resulting dough farinograms consistency without the addition of yeast was 500 FU;

– addition of 2% of salt on flour weight;

– addition of 4% of pure culture yeast on flour weight;

– addition of 2% of sugar on flour weight.

After 16 hours of cooling the following quality indexes of baked loaves were estimated: loaf volume by bread volume measure R3-BIO; surface, shape, colour, porosity, elasticity, taste and flavour. The detailed description of estimating quality indexes could be found below in Table 2.

*Table 2.* The scale of assessment for bread following the baking test from wheat flour extraction 70% yield

| Quality indexes | Point | | | | |
|---|---|---|---|---|---|
| | 1 | 3 | 5 | 7 | 9 |
| Bread volume, ml/100 g flour | less then 300 | 300-400 | 400-500 | 500-600 | more then 600 |
| Visual appearance: surface | torn | fractured | rough, humped | smooth | sleek, glossy |
| Shape | concave | flat | semi-oval | oval | domed |
| Colour of bread crust | ash-colored | pale with a greyish tinge | yellow | light brown | golden brown |
| Porosity | massive, sporadic, thick-walled | massive, homogeneous, thick-walled | moderately massive, homogeneous | narrow, thin-walled, sporadic | narrow, thin-walled, homogeneous |
| Elasticity | inelastic, not restored | inelastic, poorly restored | a bit flexible, poorly restored | moderately flexible, well restored | elastic, quickly restored |
| Colour of bread crumb | dark | dark grey or dirty yellow | light with a greyish tinge | light with yellow tint | white or white with a yellowish tinge |
| Taste and flavour | does not correspond to wheat bread | does not correspond to wheat bread | without specific taste,deflating | typical for wheat bread | pleasant, representative for wheat bread |

## RESULTS AND DISCUSSION

Traditionally loaf volume has been considered as the most important criterion in estimating wheat grain for bread making quality. According to other scientists' research (Bojnanska and Mocko, 2014) loaf volume is generally taken as the best single factor on which the judgment is based. In the analysed grain samples the value of this parameter ranged from 435 $cm^3$ to 550 $cm^3$, with higher values observed after 3 and 6 months of storage exceptionally in cool state, in comparison to just harvested grain as well as the samples that were stored without air access mode during 9-12 months.

The general indicator that covers all the qualitative characteristics of laboratory test breads is bread-making value. The experimental results are shown in Table 3.

Before storage bread-making value was higher in samples that were grown with using intensive agriculture system. Consistent with other researches' data (Zavalin and Saergaliev, 2000; Knapowski et al., 2009), if high doses of nitrogen are applied during wheat vegetation development, grain yield and protein quality increase significantly; besides it also has good influence on grain bread-making quality. In comparison to biological and ecological agriculture systems these samples have higher values, on average 0.21-0.33 point.

During the storage process the bread quality improved significantly, after the first month of storing for all agriculture systems. In the majority of grain samples bread-making value continued its development in the period of up to 6 months of storage. In particular this index increased in samples grown at biological system by 0.33-0.72 point, ecological – 0.27-0.77 and intensive – 0.15-0.66 point. It assured the highest value of laboratory baking test bread on the level of 6.10-6.21 point.

*Table 3.* Change of wheat grain bread-making value during storage period

| Year (Factor A) | Agriculture systems (Factor B) | | | Mean for A factor |
|---|---|---|---|---|
| | Biological | Ecological | Intensive | |
| Before storage | | | | |
| 2010 | 5.16 | 5.21 | 5.58 | 5.40 |
| 2011 | 5.44 | 5.39 | 5.62 | 5.52 |
| 2012 | 5.40 | 5.53 | 5.71 | 5.54 |
| Mean for B factor | 5.37 | 5.43 | 5.65 | |
| $LSD_{0.5A}$=0.17 $LSD_{0.5B}$=0.22 $LSD_{0.5A\times B}$=0.24 | | | | |
| 1 month of storage | | | | |
| 2010 | 5.29 | 5.37 | 5.71 | 5.46 |
| 2011 | 5.63 | 5.73 | 5.86 | 5.74 |
| 2012 | 5.67 | 5.71 | 6.00 | 5.80 |
| Mean for B factor | 5.53 | 5.60 | 5.86 | |
| $LSD_{0.5A}$=0.19 $LSD_{0.5B}$=0.32 $LSD_{0.5A\times B}$=0.41 | | | | |
| 3 months of storage | | | | |
| 2010 | 5.60 | 5.66 | 5.79 | 5.68 |
| 2011 | 5.97 | 5.84 | 6.11 | 5.97 |
| 2012 | 6.05 | 6.08 | 6.16 | 6.10 |
| Mean for B factor | 5.87 | 5.86 | 6.02 | |
| $LSD_{0.5A}$=0.22 $LSD_{0.5B}$=0.31 $LSD_{0.5A\times B}$=0.66 | | | | |
| 6 months of storage | | | | |
| 2010 | 5.61 | 5.83 | 5.90 | 5.78 |
| 2011 | 5.83 | 5.79 | 5.97 | 5.86 |
| 2012 | 6.02 | 5.97 | 6.10 | 6.03 |
| Mean for B factor | 5.82 | 5.87 | 5.99 | |
| $LSD_{0.5A}$=0.21 $LSD_{0.5B}$=0.24 $LSD_{0.5A\times B}$=0.37 | | | | |
| 9 months of storage | | | | |
| 2010 | 5.57 | 5.80 | 5.88 | 5.75 |
| 2011 | 5.82 | 5.78 | 5.94 | 5.85 |
| 2012 | 5.89 | 5.93 | 5.92 | 5.91 |
| Mean for B factor | 5.76 | 5.84 | 5.91 | |
| $LSD_{0.5A}$=0.18 $LSD_{0.5B}$=0.35 $LSD_{0.5A\times B}$=0.55 | | | | |
| 12 months of storage | | | | |
| 2010 | 5.40 | 5.39 | 5.50 | 5.43 |
| 2011 | 5.54 | 5.66 | 5.72 | 5.63 |
| 2012 | 5.69 | 5.81 | 5.87 | 5.79 |
| Mean for B factor | 5.55 | 5.62 | 5.70 | |
| $LSD_{0.5A}$=0.25 $LSD_{0.5B}$=0.33 $LSD_{0.5A\times B}$=0.39 | | | | |

During the last part of storage period from 6 to 12 months bread-making value was reduced. This process was proceeding less intensively during grain storing in cool state. Among the samples of grain, which were stored in a dry state, the highest score in the end of storage was found in samples grown at intensive cropping system 5.50-5.87 points.

Influence of storage modes on bread-making value is presented on Figure 1. The average value of studied index before storing in experimental grain samples was 5.48±0.05 point. As we can see from the showed graph, a rapid increase of grain bread-making quality was determined by cool state storage. More clearer it was fixed during first 3 months of storing. Starting from the sixth month up to nine month the studied index showed relative stability, and then its value started reducing.

The most intensive process of the bakery quality deterioration was observed in grain samples stored without air access. Results from laboratory baking by the end of storage period were even worse than from just harvested grain.

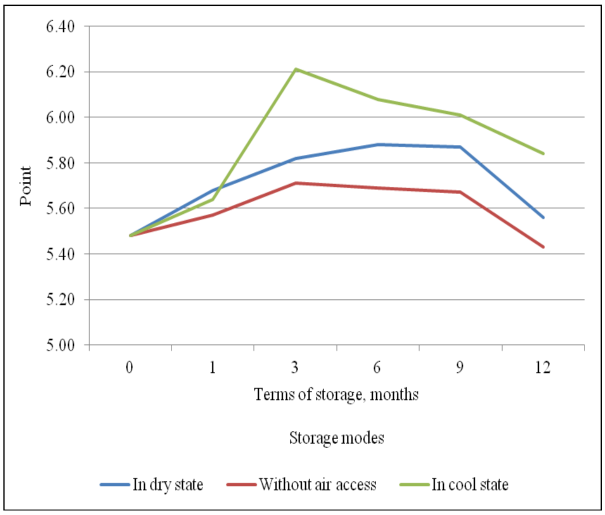


*Figure 1*. Changes of bread-making value according to storage modes and duration

Nowadays there is a discussion between scientists about the effect of each factor on bread-making quality of wheat grain during its cultivating and storing (Dowell et al., 2008; Erekul and Kohn, 2006; LeBail and Meynard, 2003). Since the bread-making value is a final generalizing index of its suitability for different types of bakery production we decided to conduct the detailed statistical analysis of different factors influence on grain quality during its long term storage.

Firstly we determined the influence of weather conditions and agriculture systems on initial bread-making value. The results we got are demonstrated on Figure 2. These data show, that lack of rainfall and high temperatures in 2009/2010 season had a strong negative impact on studied index, whereas next two seasons were more favourable for developing high technological properties of grain. Experimental bread-making value exceeded the basic (average for all experiment variants) level 5.48±0.05 point on 0.61-0.91% received in 2010/2011 and 2011/2012 vegetation seasons (Figure 2).

Agriculture systems also had variable influence on bread-making value of just harvested grain. Intensive cropping system provided higher quality bread samples in comparison to ecological and biological systems. It confirms data from other scientists (Ahmad et al, 2013; Jablonskytė-Rašce et al, 2013) that nitrogen fertilizing during vegetation season has a great influence on grain technological properties.

Usage of the intensive cropping system increased bread-making value on average by 3.04% for three years, whereas other two systems reduced the studied index by about 0.9-2.1%.

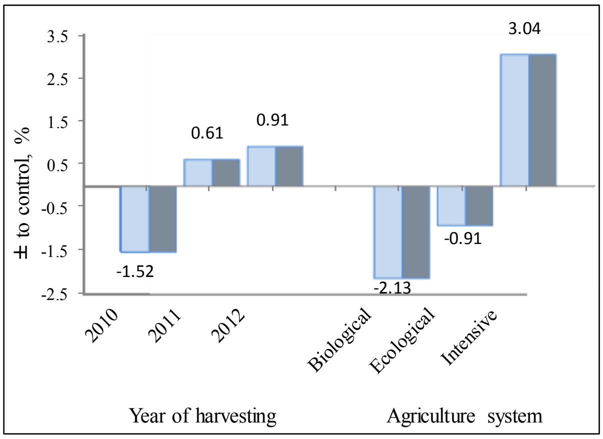


*Figure 2*. Influence of weather conditions in experimental years and studied agriculture systems on wheat grain bread-making value

On Figure 3 we presented the share of growing factors in the variation of the overall indicator value. The analysis of experimental variances showed that weather conditions and agriculture systems had both significant and approximately equal influence on wheat grain bread-making value. At the same time their interaction did not exceed 8%.

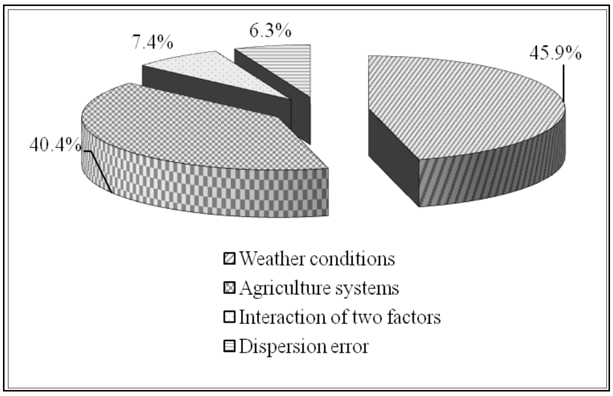


*Figure 3*. Share of weather conditions and agriculturer systems in their influence on wheat grain bread-making value after harvesting

The research of significance of weather conditions, agriculture systems, storage terms and modes on bread-making value is shown in Figure 4.

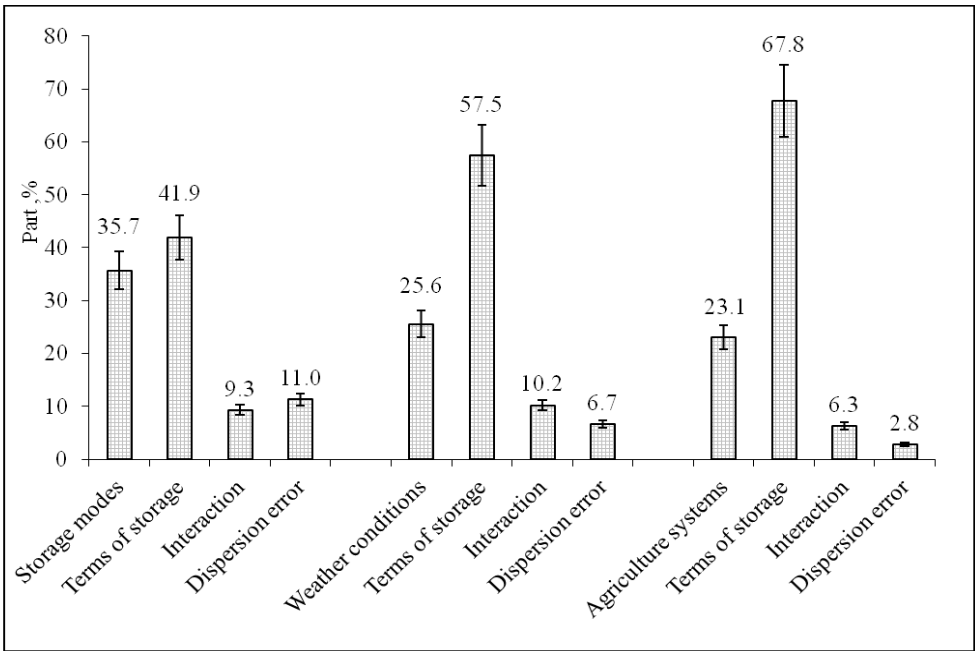


*Figure 4.* Part in influence of storage modes, weather conditions and agriculture systems in comparison to terms of storage on wheat grain bread-making value during 12 months of storage

The statistical analysis of all studied factors that determined wheat grain bread-making value showed that the contribution of each of them was significant. In particular the storage duration had more influence on studied index than modes of storage. Taking into account the interaction of the storage modes, the terms of storage determined the bread-making value ranging from 41.9 to 51.2%. That is why the last two factors – agriculture systems and weather conditions we equalize with terms of storage. The experiment data showed that the main condition in safety of the wheat grain bread-making quality is terms of storage in comparison to other studied factors. This is strongly pronounced in the bread samples obtained from the grain samples stored during 9-12 months (Figure 5).


*Figure 5.* Bread samples baked from wheat grain grown at biological agriculture system after 12 months of storing, 10 – without air access; 17 – in a cool state

## CONCLUSIONS

Based on data from this paper regarding the bread-making value of winter wheat grain, obvious differences between different weather conditions, agriculture systems and storage conditions can be observed.

The field experiments showed that on average over all research treatments wheat grain grown at intensive agriculture system produced better bread samples in all experimental years compared with other studied agriculture systems.

In separate experimental years, the weather conditions played an important role in shaping of bakery properties and for the efficiency of fertilizing and plant protection system. The best one was in 2012 harvesting year when grain bread-making value was higher for all studied samples before their storage.

Our results demonstrated that stability parameters are applicable for describing the dynamics of bread-making value using storage mode – in a cool state. Grain samples stored without air access were inferior to bread production after 9 months of storage.

The research done proved that in relation to the long-term storage of winter wheat grain produced in various cropping systems, the terms of storage have the greatest impact on the change of its baking valuation compared with other studied factors.

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