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Relation between Hagberg-Perten falling number and acidity of wheat flour according to storage and agricultural systems

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Summary: Wheat flour samples from three agricultural systems and two storage modes were evaluated and compared in dynamics of their titratable acidity and Falling number by Hagberg-Perten method during one year storage and their interaction. The obtained results indicate strong relationships between increasing acidity and lowering α-amylase activity using samples after biological, ecological agriculture systems and dry storage mode (without temperature control). On the other hand, intensive agriculture and cool storing (T +6±2ºC) provided independent change in those indices and better technological properties for the end of the storage period.

Keywords: acidity, agricultural production systems, falling number, flours, storage, wheats

Introduction

Wheat is today, together with rice and maize, the largest staple cereal in the world. Due to wheat biochemical content and annual production, it is the main resource for multiphase production of different food, chemical and pharmaceutical products (Almansouri et al. 2001). However, wheat is mostly used for flour production and it is not easy to store it without losses (Yazchuk 2008, Jablonskytė-Rašce et al. 2013, Strelec et al. 2010).

In the Eastern Europe, bread is one of the main energy and nutrient sources for humans. Therefore, wheat and rye quality is especially important and focus on the technological parameters like rheological properties and enzyme activity (Dromantienė et al. 2013, Petrenko 2014).

There has been an increasing interest in organic agriculture systems worldwide due to many advantages these systems may offer to consumers: environmental advantages, which range from food free from harmful chemicals to increased biodiversity throughout the food-chain, and economic benefits of marginal areas suitable for organic production. Consequently, this has raised the importance of wheat which is naturally adapted for organic production (Filipcev et al. 2013).

Wheat researchers, instead of milling industry, need to perform experiments regarding quality and determine the important constituents such as protein, wet gluten content, acidity, falling number, because the ingredients dictate the intended use of flour (Collins 2010, Glevitzky et al. 2011). Flour is a raw material, which is very sensitive to external influence. The storage conditions, especially temperature, have a great influence on the falling number and acidity. The content of ferments depends on grain quality, increasing germination and wet grain (Al-Yahya 2001, Trufanov et al. 2003).

Amylases are one of the enzymes that decompose starch granules to dextrin and sugars. α-amylase has the main role in this process since it can decompose non-modified starch granules. Attention to this group of ferments is explained by their influence in creating the technology and biology quality properties and in list of technology process. Flour tends to lack or to

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abudance α-amylase is not available for bakery without special additives. The diastatic activity of the flour is expressed by the falling number, i.e. the Hagberg number, and good quality flour has a falling number between 200 and 250 seconds (Cupic et al. 2005, Dromantienė et al. 2013, Gomez et al. 2009).

From different literature sources (Sahedi et al. 2009, Li et al. 2008) it is well known that α-amylase is not found in endosperm and it is separated with germ and bran when grain is milled. Therefore, there is a lack of information about biosynthesis of α-amylase in wheat flour. But this question is important in long term storage of wheat flour in different storage modes.

The aim of this study was to find relation between wheat flour acidity and falling number of flour during long term storage gained from organically grown wheat.

Materials and Methods

Field trial was set up at the Agronomic experimental station of the National University of Life and Environmental Sciences of Ukraine during 2011-2013. The field trial plan provided combination of three different agricultural systems typical for woodland zone crop rotation. In our study the samples of the winter wheat (the cultivar "Natsionalna" of the Ukrainian breeding) were grown in biological, ecological and intensive agricultural production systems. The preceding crop was clover in all experimental years. The fertilizing and plant protection systems differed essentially concerning agriculture systems. The control treatment was the intensive system model with application of N_{130}, K_{114}, P_{126} kg ha $^{-1}$ for the winter wheat, and intensive usage of the recommended pesticides (herbicide Grodyl 75 WG and fungicide Racsile) by the program of ensuring the productivity of arable lands.

The models of the biological and ecological agricultural production were compared with the control treatment. These agricultural systems are widely different, mostly in fertilizing and plant protection submitted below (Tanchik 2009). In the first system, organic fertilizers (24 t ha^{-1}) were applied in crop rotation, without any mineral fertilizers and pesticides. About 17 t ha^{-1} of this fertilizing was manure and no less than 7 t ha^{-1} were crop remains (such as clover or corn stubble). Additionally, wheat seed was processed by biological fertilizer before sowing (Azofit). Exclusively mechanical and biological means were used to manage pests, diseases and weeds. This field trial was carried out in a certified organic field at the Agronomic experimental station.

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

Wheat grain was refined after harvesting, dried up to moisture content 13.5–14.0%, and milled into flour with 70% flour extraction using Buhler MLU-202 laboratory mill. Then it was put into long term storage for one year in burlap bags in two different modes (temperature conditions): the first was non-heated storage (in a dry state), and the second was in cold storage room, with the temperature +6±2ºC (in a cool state). The weight of each flour sample was 50 kg.

Titratable acidity in the flour (AACC Method 02-31) and the Falling number as a measure of α-amylase activity (AACC Method 56-81B according to Hagberg-Perten) had been determined before the flour was put in storage, and then after one, three, six, nine and twelve months.

The experiments consisted of a randomized complete block design which included 36 treatment combinations consisting of three agriculture systems, two modes of storage and six terms. The data of falling number and acidity was processed by a two-factor mode and 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.

Results and Discussion

It was found that all flour samples had significant difference in their technological properties after milling (Tables 1 and 2). Better quality was found in flour from intensive agricultural system, which confirmed conclusions of other authors (Abedi et al. 2010, Guarda et al. 2008) who claimed mineral fertilizers were of vital importance for wheat grain quality.

The acidity of the flour is an important indicator of its freshness. The fats and phosphotides are broken down with enzymes during storage. This breakdown is accelerated by high water content, high temperatures and a high degree of extraction. By determining the acidity of the flour, taking the degree of extraction into account, it is possible to monitor the progress of maturing and the possible start of deterioration. Obtained results are consistent with previous studies of flour acidity during storage of wheat and wheat products (Hruškova & Machova 2002). The increase of flour acidity could also be attributed to the increased concentration of free fatty acids and phosphates resulting from increased seed deterioration due to molecular alterations and free radical induced oxidation, as well as to the presence of acid by-products of advanced Maillard reactions (Rehman & Shah 1999). The data on the flour acidity dynamics are given in Table 1.

Before storing in both years this index was close to the optimal (less than 3) and did not show significant difference in samples from all agriculture systems. Increasing on flour acidity started from the first storage month and more rapidly it was observed in dry mode storage. This tendency was typical for all periods of our experiment. In the first experimental year the difference between the storage modes was significant (F_{fact}= 41.33**, LSD_{05}= 0.11). Also in 2012 the difference between the storage modes was significant (F_{fact}= 9.89**, LSD_{05}= 0.10).

Falling number value drop is inversely proportional to α-amylase activity of flour and acceptable field depends on cereal. When we have a low falling number dextrin formed by α-amylase action leads to bread crumb stickiness (Hamida et al. 2009). Changes in falling number values are given in Table 2.

Higher value of the falling number before storage was marked in 2012, as a result of better weather conditions (lack of rainfall during harvest). The average falling number values were higher for 20-30 s in all three agricultural systems in comparison to 2011. During storage process particular attention was paid in distinguishing experimental storage modes. In general we could say that storing flour in dry mode caused increase of falling number value from all periods because of inactivation of α-amylase which was presented before the storage of wheat flour; however in cool mode there were not any such tendencies.

The influence of both factors was significant. For agriculture systems (factor A) F_{fact}= 18.66**, LSD_{05}= 5.3 and terms of storage (factor B) significantly differed between storage modes F_{fact}= 15.30**, LSD_{05}= 6.6. The highest falling number was recorded for dry storing after 12 months of storage (average 270-280 s) and for cool storing after 6 months (average 250-265 s).

Table 1. Wheat flour acidity change during storage period, degree

Term of storage, month (Factor B)	Winter wheat flour (Factor A)												Mean factor B		
	2011						2012								
	Biological		Ecological		Intensive		Biological		Ecological		Intensive				
	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Biological	Ecological	Intensive
Before storage	2.2	2.2	2.2	2.2	2.1	2.1	2.3	2.3	2.1	2.1	2.1	2.1	2.25**	2.15	2.10
1	2.5	2.3	2.6	2.4	2.4	2.2	2.6	2.3	2.4	2.3	2.4	2.1	2.43**	2.43**	2.28
3	2.8	2.5	3.0	2.7	2.8	2.6	2.7	2.4	3.0	2.8	2.6	2.7	2.60**	2.88**	2.68
6	3.1	2.7	3.2	2.8	3.0	2.8	3.0	2.9	3.1	3.0	2.8	2.7	2.93**	3.03**	2.83
9	3.4	3.0	3.2	3.1	3.0	3.1	3.2	3.1	3.3	3.1	3.1	3.0	3.20**	3.18**	3.05
12	3.4	3.2	3.5	3.2	3.4	3.1	3.3	3.3	3.3	3.1	3.3	3.1	3.30*	3.28	3.23
Mean factor A	2.90	2.65	2.95*	2.73*	2.78	2.65	2.85*	2.72*	2.87*	2.73*	2.72	2.62	2.90*	2.83**	2.70

*- P < 0.05, **- P < 0.01

Table 2. Wheat flour falling number change during storage period, second

Term of storage, month (Factor B)	Winter wheat flour (Factor A)												Mean factor B		
	2011						2012								
	Biological		Ecological		Intensive		Biological		Ecological		Intensive				
	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Dry	Cool	Biological	Ecological	Intensive
Before storage	240	240	214	214	236	236	258	258	254	254	266	266	249	234**	251
1	249	241	219	218	249	240	262	258	256	253	271	279	253**	237**	260
3	249	252	236	221	253	244	255	267	260	250	270	278	256*	242**	261
6	259	261	244	240	259	255	278	273	273	251	264	276	266	252**	264
9	261	243	260	239	264	253	275	256	269	253	265	272	259*	255**	264
12	270	241	265	237	273	255	278	238	282	252	276	265	257**	259**	267
Mean factor A	255**	246*	239	228**	256**	247*	268	258	266	252*	269	273	257*	247**	262

*- P < 0.05, **- P < 0.01

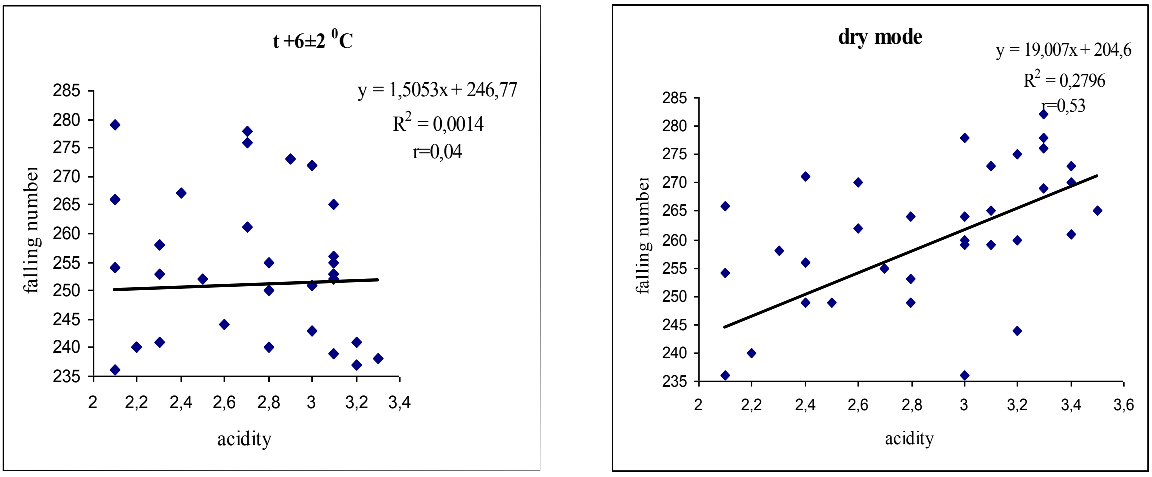

Figure 1. The relationship between falling number and acidity of wheat flour during storage

It should be noted that there were no significant interactions among factors A and B in both Tables: they were discussed as separate factors.

The results of the correlation-regression analysis of titratable acidity and falling number values showed a negligible relationship between them. The correlation-regression analysis of agriculture systems and storage modes revealed a variable relationship between these parameters. For biological and ecological systems the correlation coefficient between acidity and falling number was statically significant - 0.52 and 0.51, respectively. It can be seen from Figure 1 that the values of falling number in wheat flour also increased with increasing acidity. On the other hand, the intensive system trials suggested that the values fall turnover does not shrink in direct proportion to the grain acidity (r=0.34). This analysis proved technological properties to be a strong, rather stable trait for grain grown under intensive system which was also reported by other researchers (Dinelli et al. 2013, Hamida et al. 2009, Pastukhov & Dogan 2014).

Also we conducted correlation-regression analysis of titratable acidity and falling number between both storage modes and received confirmation that cool mode is more preferred for long term storage than dry mode (Fig. 1). In the last correlation coefficient between acidity and falling number was statically significant - 0.53 and in the cool mode coefficient was only 0.04.

Conclusions

From this study it can be concluded that long term storage (more than 6 months) for wheat flour from biological and ecological agricultural systems is vitally important to conduct using cool mode (+6±2 °C) as a result of rapid increasing of titratable acidity. However, it was not so relevant for the intensive agricultural system. It was also demonstrated that long term storing of wheat flour causes increase of falling number values (reduces α-amylase activity of flour). In order to avoid this, it is advisable not to use wheat flour from organic agricultural system for long term storage.

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Broj padanja prema Hagberg-Perten metodi i kiselost pšeničnog brašna u odnosu na način skladištenja i sistem poljoprivredne proizvodnje

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Sažetak: Uzorci pšeničnog brašna iz tri sistema poljoprivredne proizvodnje i dva načina skladištenja su ocenjeni i poređeni u odnosu na dinamiku njihove titracijske kiselosti i broja padanja prema Hagberg-Perten metodi tokom jedne godine skladišenja i njihove interakcije. Dobijeni rezultati ukazuju na snažnu povezanost između povećanja kiselosti i smanjenja aktivnosti α-amilaze koristeći uzorke iz biološkog i ekološkog poljoptivrednog sistema proizvodnje i suvog skladištenja (bez kontrole temperature). S druge strane, intenzivna poljoprivreda i skladištenje sa hlađenjem (T +6±2ºC) rezultirali su nezavisnom promenom ovih indeksa i boljim tehnološkim osobinama na kraju perioda čuvanja.

Ključne reči: brašno, broj padanja, kiselost, pšenica, sistem poljoprivredne proizvodnje, skladištenje