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BAKING QUALITY OF WHEAT CULTIVARS, GROWN IN ORGANIC, CONVENTIONAL AND LOW INPUT AGRICULTURAL SYSTEMS

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ABSTRACT

Organic agriculture imposes strict limitations on the use of synthetic fertilizers and pesticides, and as a result, is generally characterized by a reduced availability of nutrients (especially N and P), higher risk of weed infestation and disease or insects attack. All of these can affect the yield level and/or quality. We compared protein concentration and rheological parameters of several wheat cultivars grown under organic, conventional and low input systems for two years in Romania. All analyzed quality parameters were strongly influenced by the environmental conditions. The effect of agricultural systems was significant for protein concentration, dough strength and breakdown, as well as for estimated bread volume, while the cultivar effect was significant only for dough breakdown, elasticity, and speed of formation, as well as for bread volume. The interaction between agricultural systems and cultivars was not significant for any of the analyzed parameters, and this suggests that breeding for high bread-making quality can be efficient for improving quality in all agricultural systems. On average, with the management practices used in our tests, organic wheat had about 30% lower protein concentration, 8% longer mixing time, 23% lower dough strength, 51% lower breakdown and 44% lower bread volume. Most of the differences in rheological parameters seem to be related with the difference in protein concentration, and this suggest that special measures to increase nitrogen availability in the organic system are necessary in order to improve bread-making quality of wheat produced in this system. Cultivar differences in quality parameters were too small to counteract the effects of the management practices.

Key words: bread-making quality, wheat, nitrogen fertilization, organic system.

INTRODUCTION

Baking quality is the flour capacity to ensure high volume bread, elastic, with uniform pores and corresponding behavior in the process of mixing. Baking quality is related to the ability to retain carbon dioxide produced during fermentation, dough mixing behavior and water absorption capacity. They are influenced significantly by the concentration of proteins, polymer structure of the protein (gluten quality) and grain hardness.

Protein composition and content as the main determinants of wheat bread making quality are affected by genetics, environmental conditions and crop management (Pepo et al., 2005; Drezner et al., 2007; Marinciu, 2007; Horvat et al., 2009; Stanciu and Neacşu, 2008).

Meeting the quality requirements of bread making industry and of wheat markets is becoming increasingly difficult because grain protein concentration is negatively correlated with grain yields and because limitation of nitrogen fertilizer use, for ecological and economical reasons, negatively affects grain protein concentration (Săulescu et al., 2005).

Organic agriculture, which is becoming increasingly important in agricultural production, imposes strict limitations on the use of synthetic fertilizers and pesticides. As a result, organic agriculture is generally characterized by a reduced availability of nutrients (especially N and P), higher risk of weed infestation and disease or insects attack, and all these can affect the yield level and/or quality. Organic agriculture is also more dependent on the given site conditions (Köpke, 2005).

Information on bread-making quality of organically produced wheat is scarce and sometimes contradictory, For example, Annet

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et al. (2007) showed that organic produced grain contained more wholemeal protein than conventional grain, but both were greater than 14% protein, indicating excellent grain quality for yeast-leavened bread. However, mixograph analysis and baking tests revealed that conventional flour produced stronger bread dough than organic flour, and larger bread loaf volume. Mäder et al. (2007) found that nutritional value (protein content, amino acid composition and mineral and trace element contents) and baking quality were not affected by the farming systems and the quality of baked products obtained from conventionally and organically grown wheat was equally good. On the other hand, Mazzoncini et al. (2007) found that organic grain samples were 20 % lower in protein content and exhibited poor bread production qualities, but did not show differences in crust thickness, crumb volume and crumb alveolus structure in a visual evaluation.

Among the registered and perspective cultivars tested simultaneously in two years in Romania under conventional low-input and organic farming systems, few performed well enough in organic farming conditions. Broadening the genetic base for better-adapted varieties in such conditions was considered needed (Ittu et al., 2006).

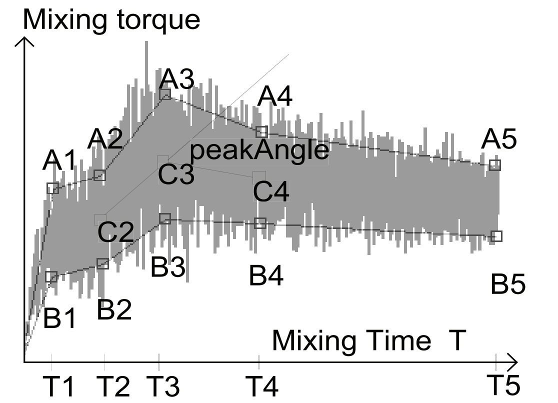
Dough rheological properties have an important effect on baking characteristics. To predict final products quality, having a good knowledge about these properties and their related parameters is necessary (Mirsaeedghazi et al., 2008).

This paper presents data on protein concentration and rheological parameters of several wheat cultivars grown under organic, conventional and low input systems for two years in Romania.

MATERIAL AND METHODS

Grain samples of 24 Romanian and foreign varieties from harvest years 2008 and 2009, tested in yield trials in three technological systems: organic, conventional, fertilized with recommended doses of nitrogen and conventional without additional nitrogen at NARDI Fundulea were analyzed for grain protein content and dough rheological characteristics. Grain protein content data were also obtained for grain samples harvested from yield trials performed at ARDS Şimnic using the same varieties and the same technological systems. The crop management measures used in the yield trials are shortly described in tables 1 and 2. Protein concentration was determined using a Perten infrared analyzer.

For assessing the rheological character-ristics we used the *Reomixer*, manufactured by Reologen i Lund AB, conforms at large to the AACC Mixograph standard, and the mixing curves produced agree well with the results of the classical pen recording National Mixograph (Bohlin, 2007), a mixograph type device that measures a total of 17 mixing parameters, including an estimated bread volume (Figure 1). Out of these we analyzed 5 parameters, found by Neacşu et al. 2009 as the most informative and meaningful for characterizing bread-making quality (initslope, peaktime, peakheight, breakdown and endwidth) and the estimated bread volume.



1 initslope	A1/T1
2 initbuildup	A2 - A1
3 widthinitbuild	(A2-B2) – (A1-B1)
4 time T1-T2	T2-T1
5 initwidth	A1 - B1
6 widthbuild	(A3-B3) – (A2-B2)
7 buildup	A3 - A2
8 peaktime	T3
9 peakwidth	A3 - B3
10 peakheight	(A3 + B3)/2
11 peakangle	(angle of C3-A4 and C3-C4)
12 breakdown	A3 - A4
13 endwidth	A5 – B5
14 areabelow	(area below curve A1-A5)
15 areawithin	(area between (A1-A5) and (B1-B5))
16 IHTP	(area under center line up to peak)

Figure 1. Definition of Reomixer mixing parameters

Table 1. Management practices in experiments with winter wheat cultivars (Fundulea and Şimnic, 2008)

Technology	Organic farming		Low inputs		Conventional farming	
	Fundulea	Şimnic	Fundulea	Şimnic	Fundulea	Şimnic
Previous crop	Soybean	Alfalfa	Peas	Peas	Peas	Peas
Soil tillage, including bed preparation	2 Disk harrow (11.09 & 02.10.2007) 1 vibro-roller (12.10.2007)	Ploughing (03.09.2007) 1 Disk harrow (10.10.2007) 1 vibro-roller (19.10.07)	4 Disk harrow (12.07, 01.10 & 07.10.2007)	Ploughing (10.09.2007) 2 Disk harrow (03.10 & 09.10.2007) 1 vibro-roller (10.10.2007)	4 Disk harrow (12.07, 01.10 & 07.10.2007)	Ploughing (10.09.2007) 2 Disk harrow (03.10 & 09.10.2007) 1 vibro-roller (10.10.2007)
Herbicide treatment	-	-	02.08.2007 ROUNDUP (5 l/ha) 15.04.2008 LAREN PLUS + CERLIT + TREND	08.04.2008 DICOPUR TOP (1 l/ha)	02.08.2007 ROUNDUP (5 l/ha) 15.04.2008 LAREN PLUS + CERLIT + TREND	08.04.2008 DICOPUR TOP (1 l/ha)
Fertilization	-	-	30.09.2007 (80 kg P_2O_5/ha)	04.10.2007 (200 kg/ha: 20:20:0)	30.09.2007 (80 kg P_2O_5/ha) 05.03 & 16.04.08 (120 kg N/ha – urea)	04.10.2007 (200 kg/ha: 20:20:0) 10.03.2008 (66 kg N/ha - NH_4NO_3)
Seed treatment	-	-	08.10.2007 DIVIDENT (1 l/t)	08.10.2007 DIVIDENT (1 l/t)	08.10.2007 DIVIDENT (1 l/t)	08.10.2007 DIVIDENT (1 l/t)
Sowing	26.10.2007	19.10.2007	11.10.2007	11.10.2007	11.10.2007	11.10.2007
Weeding	28.02.2008 (harrowing) 19.03 & 27.05.2008	27.04.2008 (manually)	-	-	-	-
Harvesting	08.07.2008	10.07.2008	10.07.2008	30.06.2008	10.07.2008	30.06.2008

Table 2. Management practices in experiments with winter wheat cultivars (Fundulea and Şimnic, 2009)

Technology	Organic farming		Low inputs		Conventional farming	
	Fundulea	Şimnic	Fundulea	Şimnic	Fundulea	Şimnic
Preceding crop	Lentil	Sunflower	Peas	Peas	Peas	Peas
Soil tillage, including bed preparation	3 Disk harrow (15.07, 31.07 & 24.09.2008) 1 vibro-roller (09.10.2008)	Ploughing (28.09.2008) 1 Disk harrow (18.10.2008) 1 vibro-roller (18.10.2008)	4 Disk harrow (15.07, 01.10 & 02.10.2008) 1 vibro-roller (09.10.2008)	Ploughing (15.08.2008) 1 Disk harrow (04.10.2008) 1 vibro-roller (15.10.2008)	4 Disk harrow (15.07, 01.10 & 02.10.2008) 1 vibro-roller (09.10.2008)	Ploughing (15.08.2008) 1 Disk harrow (04.10.2008) 1 vibro-roller (15.10.2008)
Herbicide treatment	-	-	05.08.2008 ROUNDUP (5 l/ha) 03.04.2009 LAREN PLUS + CERLIT + TREND	14.04.2009 MUSTANG (0.5 l/ha)	05.08.2008 ROUNDUP (5 l/ha) 03.04.2009 LAREN PLUS + CERLIT + TREND	14.04.2009 (MUSTANG – 0.5 l/ha)

Fertilization	-	-	28.09.2008 (80 kg P_2O_5/ha)	05.10.2008 (200 kg/ha: 8:40:0)	28.09.2008 (80 kg P_2O_5/ha) 03.03.2009 (100 kg N/ha - urea)	05.10.2008 (200 kg/ha:8:40:0) 10.03.2009 (66 kgN/ha- NH_4NO_3)
Seed treatment	09.10.2008 ($CuSO_4$ – 5%)	-	10.10.2008 NUPRID MAX (2.5 l/t)	04.10.2008 DIVIDENT (1 l/t)	10.10.2008 NUPRID MAX (2.5 l/t)	04.10.2008 (DIVIDENT-1l/t)
Sowing	09.10.2008	19.10.2008	13.10.2008	16.10.2008	13.10.2008	16.10.2008
Weeding	27.03.2009 (harrowing) 27.03.2009 (manually)	15.04.2009 (manually)	-	-	-	-
Harvesting	16.07.2009	18.07.2008	21.07.2009	04.07.2009	20.07.2009	21.07.2009

ANOVA was used to analyze the results obtained for every parameter, significance being tested against the interaction between treatments (agricultural systems*cultivars) and environments (years*locations for protein concentration and years for rheological parameters).

RESULTS AND DISCUSSION

ANOVA showed that, when tested against the interaction between treatments and environments, the effect of environments was significant for all analyzed parameters (Table 3).

The effect of technological systems was significant only for protein concentration, breakdown, peak height and estimated bread volume, while the cultivar effect was significant for estimated bread volume, breakdown, endwidth and initslope. The interaction between cultivars and technological systems was not significant for any of the analyzed traits.

Table 3. ANOVA for several quality indices

Quality indices	F values			
	Technological systems	Cultivars	Technological systems *cultivars	Environments
DF	2	23	46	3
F values for P<5%	3.037	1.579	1.424	2.65
Protein concentration	104.674	1.348	0.798	216.36
DF	2	23	46	1
F values for P<5%	3.12	1.68	1.53	3.98
Peaktime	1.06	1.30	1.21	6.31
Peakheight	10.32	0.34	0,10	37.05
Breakdown	135.28	3.44	1.01	131.52
Initslope	2.36	4.05	1.09	114.13
Endwidth	1.12	2.47	1.00	33.48
Bread volume	329.39	2.80	1.40	106.23

Averaged over cultivars and environments, grain protein concentration was significantly lower in the organic system than both conventional with recommended rates of N fertilizer and low input conventional, where no additional N was applied in the spring (Table 4).

However, large variation was found between environments, for each agricultural system (Table 4 and Figure 2).

Table 4. Grain protein concentration

Variety	Organic Average	Fertilized Average	Unfertilized Average
Average	11.38	14.17	12.50
Limits of variation	9.10-11.60	13.43-16.65	11.70-13.80

At Şimnic in 2008, wheat grown after alfalfa in organic agriculture had higher protein content than wheat grown under fertilized conventional system, and much higher than the wheat grown under conventional system without N fertilizer. On the contrary, in 2009 at the same location, when organic wheat was grown after sunflower, its protein concentration was significantly lower than the one of low input wheat, without N fertilizer but grown after peas. These findings underline the fact that, especially under organic agriculture, the ability of the preceding crop to improve nitrogen availability is very important.

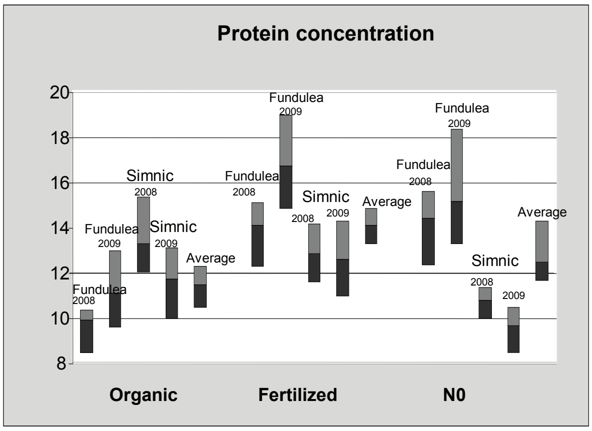


Figure 2. Protein concentration for cultivars grown at Fundulea and Şimnic in 2008 and 2009, in organic, conventional fertilized with nitrogen and low input conventional system

Cultivar and agriculture systems influence on the time of dough development „peaktime" was small and not significant, and only the environments had a large influence.

Peakheight, which reflects the dough strength and generally correlates with grain protein concentration, was significantly influenced by environments (years) and technological systems. On average, the highest dough strength was found in conventional N fertilized system, and the lowest strength was found in the organic system (Figure 3). However, the influence of the weather conditions was very significant; in 2009 average dough strength of organically grown wheat was comparable with the conventionally grown wheat, with some cultivars having dough strength comparable with conventionally grown wheat and much higher than the low input wheat.

Dough breakdown after optimum consistency was much lower in organically grown wheat than in conventional wheat, regardless of fertilization (Figure 3). Although lower values of breakdown are desirable, the values obtained for organic wheat are misleading, because they are associated with lower dough strength, and a mixing curve with reduced height (lower strength) will always show a smaller loss of strength during mixing.

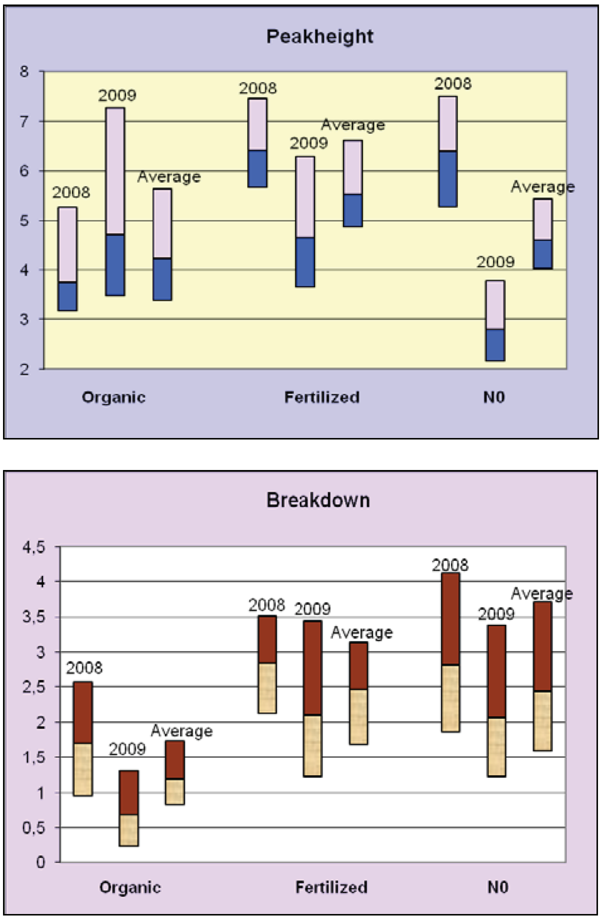


Figure 3. Peakheight and breakdown parameters for cultivars grown at Fundulea in 2008 and 2009, in organic, conventional fertilized with nitrogen and low input conventional system

Cultivars had a smaller but significant effect on breakdown variation, only part of which explainable by the peakheight variation (Figure 4).

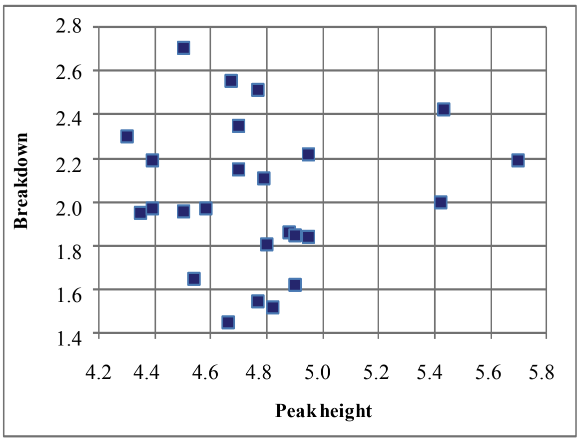


Figure 4. Relationship between dough strength (peakheight) and breakdown in 24 wheat cultivars

The speed with which the dough gained its maximum consistency, as expressed by the parameter „initslope", as well as the dough elasticity described by the parameter „endwidth", were not significantly affected by agricultural systems. They were significantly influenced by environments and to a smaller but significant amount by cultivars. Cultivar effects were similar in all management systems, as proved by the non-significant effect of the cultivar*systems interactions.

Cultivar differences in the speed of dough formation (initslope) were generally small and partly correlated with differences in dough development time and strength. Of more interest were differences in dough elasticity. Cultivars Flamura 85, Josef, Ciprian, Boema and Capo showed the highest dough elasticity (average endwidth over 0.7), while Romulus, Albota 69, Crina, Apache and Exotic had the lowest elasticity (endwidth below 0.5), and this behaviour was similar over all agricultural systems.

The bread volume is estimated by the software provided by the Reomixer manufacturer taking into account the protein concentration and some of the mixing parameters („buildup, peakheight, initbuild"). It was significantly influenced by the agricultural systems, environments and cultivars. It was lower for organically grown wheat than for wheat grown conventionally, with or without N fertilizer. Only in 2008 best cultivars grown under organic system equalled the worst cultivars grown with N fertilizer (Figure 5). This was partly due to the lower grain protein concentration of organically grown wheat, as the relationship between protein concentration and estimated bread volume was close significance, but also to differences in other important parameters.

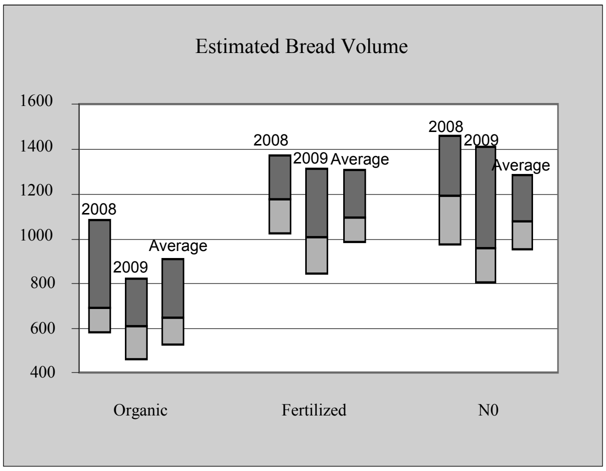


Figure 5. Estimated bread volume for varieties at Fundulea in 2008 and 2009, in conventional fertilized with nitrogen, low input conventional and organic

Several cultivars, such as Capo, Delabrad and Dropia had relatively high bread volume under all management systems (over 700 cm^3 under organic system and over 1200 cm^3 under conventional system with N fertilizer), while other cultivars (such as Apache, Serina, Şimnic 30) consistently produced lower volume bread. However, genetic differences were not able to compensate the stronger effect of the management practices.

Figure 6 summarizes some of the differences found in our tests between organically grown wheat and wheat conventionally grown with or without N fertilizer. On average, organic wheat had 30.5% lower protein concentration, 8% longer mixing time, 23,6% lower dough strength, 51.9% lower breakdown and 44.7% lower bread volume.

Most of the differences in rheological parameters seem to be related with the difference in protein concentration. Taking into account the fact that differences between cultivars could not compensate the reduced nitrogen availability found in the organic system, special measures to increase nitrogen availability in the organic system are necessary in order to improve bread-making quality of wheat produced in this system.

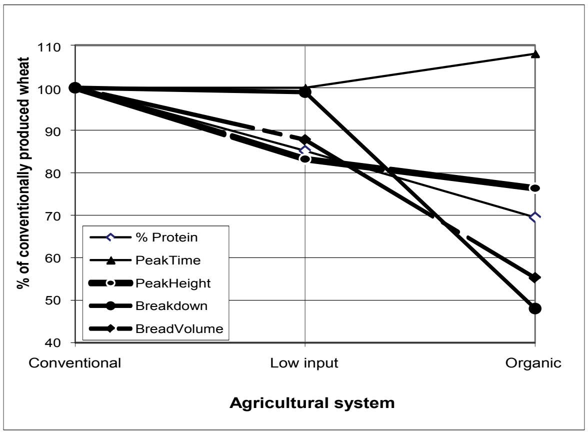


Figure 6. Summary of average differences between conventional, low input and organic wheat for several quality indices

CONCLUSIONS

The analyzed quality parameters were all strongly influenced by the environmental conditions of years (and locations respectively).

The effect of agricultural systems was significant for protein concentration, dough strength and breakdown, as well as for estimated bread volume, while the cultivar effect was significant only for dough breakdown, elasticity, and speed of formation, as well as for bread volume.

On average, with the management practices used in our tests, organic wheat had lower protein concentration, longer mixing time, lower dough strength, lower breakdown and lower bread volume. Most of the differences in rheological parameters seem to be related with the difference in protein concentration, and this suggests that special measures to increase nitrogen availability in the organic system are necessary in order to improve bread-making quality of wheat produced in this system.

Cultivar differences in quality parameters were too small to counteract the effects of the management practices.

The interaction between agricultural systems and cultivars was not significant for any of the analyzed parameters, and this suggests that breeding for high bread-making quality can be efficient for improving quality in all agricultural systems.

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