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THE INFLUENCE OF AGRO-ECOLOGICAL CONDITIONS ON TECHNOLOGICAL QUALITY OF MERCANTILE WHEAT
UTICAJ AGROEKOLOŠKIH USLOVA NA TEHNOLOŠKI KVALITET MERKANTILNE PŠENICE

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ABSTRACT

The results of the technological quality evaluation of wheat from harvests 2008 and 2010 were compared. Different climate conditions preceded the harvest in these two years. In 2008 in the region of Vojvodina June was characterized with higher temperatures and sum of rainfall under the multiannual average for this month. By the middle of June air temperatures further increased, and by the end of the month values of achieved temperatures were much higher than average. During the third decade of June air temperatures mainly ranged from 30 to 35^{o}C. During May 2010 the amount of precipitation was twice above average. Rainy weather conditions remained during June with the number of rainy days three to four times higher than commonly. Therefore, wheat harvest delayed and in most localities it started in July. Differences in climate conditions resulted in very different technological quality of wheat. The main characteristic of wheat crop 2008 were reduced quality of proteins and modified quality starch component due to exposure to heat stress. The main characteristics were low and varying values of flour and dough quality parameters: Extensograph energy, Alveograph W and Amylograph peak viscosity. From raw materials of such quality bread of appropriate quality level could be produced only when special purpose additives were applied. Wheat crop 2010 was characterized by altered quality of the carbohydrate component due to extremely increased rainfall which resulted in increased content of sprouted kernels. Dough rheological properties in the case of wheat crop 2010 pointed at stable values of Farinograph parameters with quality at the level of B1 quality group. Extensograph energy, depending on the production region, varied from impossibility of determination to maximal 60 cm^2. Average Extensograph ration number was under the lower limit for successful processing in bakery products. Values of Amylograph peak value are extremely varying in dependence of production region, average value is lower than optimal and related to increased amylolitic activity caused by presence of sprouted kernels. Both wheat harvests were of very uneven trade and technological quality in all wheat-growing regions of Vojvodina. Also, both crops were characterized by low values of Falling number, amylograph maximum viscosity and extensograph energy. In spite of reasonable expectations these values did not result in deterioration of wheat technological quality.

Key words: *wheat, technological quality, climate conditions.*

REZIME

U radu su upoređeni rezultati ispitivanja tehnološkog kvaliteta merkantilne pšenice roda 2008. i roda 2010. godine. Ove godine su bile različite u pogledu klimatskih uslova koji su prethodili žetvi. Jun 2008. godine na teritoriji Vojvodine karakterisalo je toplije vreme sa manje padavina nego što je uobičajeno za ovaj mesec, sredinom meseca došlo je do porasta temperature, tako da su one do kraja meseca imale vrednosti iznad ili znatno iznad prosečnih. Maksimalne dnevne temperature vazduha su tokom većeg dela treće dekade juna imale vrednosti između 30 i 35 ^{o}C. Tokom maja 2010. godine je u Vojvodini zabeležen dvostruko veći broj padavinskih dana u odnosu na normalu, i tako kišovito vreme se nastavilo i tokom juna (ukupne količine padavina nalazile su se u kategorijama kišno i vrlo kišno), a broj padavinskih dana je bio tri do četiri puta veći od uobičajenog, tako da je žetva pšenice u većini mesta počela u julu. Izrazito različiti klimatski preduslovi uslovili su i različito manifestovan tehnološki kvalitet merkantilne pšenice na teritoriji Vojvodine. Pšenicu roda 2008. godine karakterisao je pogoršan kvalitet proteina i izmenjen kvalitet skrobne komponente usled izloženosti temperaturnom stresu. Karakteristične su bile male I neujednačene vrednosti za pokazatelje kvaliteta brašna i testa: energije na ekstenzogramu, rada na alveogramu I maksimalnog viskoziteta izmerenog na amilografu. U tehnološkom procesu proizvodnje hleba od brašna ovakvih karakteristika hleb odgovarajućeg kvaliteta se mogao proizvesti isključivo uz primenu namenskih aditiva. Pšenicu roda 2010. godine je usled izuzetno povećane količine padavina karakterisao izmenjen tehnološki kvalitet ugljenohidratne komponente zrna usled povećanog sadržaja proklijalih zrna. Kvalitet testa meren reološki karakterisala je ujednačenost vrednosti pokazatelja merenih farinografom I pripadnost brašna od pšenice roda 2010. godine u proseku B1 kvalitetnoj grupi. Vrednosti energije merene ekstenzografom su se posmatrano po regionima kretale od nemogućnosti registrovanja do maksimalno oko 60 cm^2, a odnosni broj je u proseku bio manji od donje granice podesnosti za preradu u pekarstvu. Vrednosti maksimalnog viskoziteta merene amilografom su izrazito neujednačene po regionima, prosečna vrednost je bila manja od optimalne i realno je odražavala povećanu amilolitičku aktivnost usled prisustva proklijalih zrna u pšenici.

Oba roda pšenice su bila neujednačenog kvaliteta posmatrano po žitorodnim regionima, što je karakteristično za žetve pšenice u poslednjih nekoliko godina. Takođe, oba roda pšenice odlikuju niske vrednosti broja padanja, maksimalnog viskoziteta na amilogramu, kao i energije na ekstenzogramu koje i pored opravdanih očekivanja nisu rezultirale tehnološkim kvalitetom koji odstupa od višegodišnjih proseka.

Ključne reči: *pšenica, tehnološki kvalitet, klimatski uslovi.*

INTRODUCTION

Wheat quality is a function of grain composition (Triboï et al., 2000), and quality varies considerably as a result of environmental conditions during grain-fill (Dupont and Altenbach, 2003). A considerable volume of literature addresses the effects of environment on the developing wheat grain, both in field experiments and controlled growth experiments. In some studies, the effects of environment have been assessed simply in terms of kernel weight, while the rate and duration of grain fill have been

evaluated in others. The manifestation of environmental effects in the developing kernel impacts the value of the crop by influencing yield, grain characteristics and flour quality and the effect of an environmental factor depends on the developmental stage of the plant (Altenbach et al., 2003; Triboï et al., 2006). One consequence is that conditions that shorten grain-filling, such as high temperature or drought, affect the balance of protein fractions (Jamieson *et al.*, 2001; Triboï *et al.*, 2003)

The other consequence is that exposure to high temperatures, as reported by Dupont and Altenbach, (2003) increases the proportions of larger and decrease the proportions of smaller granules in wheat, representing an effect consistent with a shorter duration of starch accumulation. The aim of this research was to define possible relations of changes in climate conditions to the technological quality of mercantile wheat.

MATERIAL AND METHODS

Three hundred wheat samples from crop 2008 and three hundred and seventy wheat samples from crop 2010 were investigated. Single samples of wheat crop 2008 and 2010 were collected from the most important locations from all wheat growing regions in Vojvodina. Composite samples were formed from collected single samples from every location and technological quality of composite samples was determined. In all single samples content and structure of impurities was determined according to the Regulation of methods of physical and chemical analysis for quality control of grain, milling and bakery products, pasta and quick frozen dough (Službeni list SFRJ, 74, 1988, 1854-1887). After milling the flour with ash content at the level responding to flour type 500 was obtained (Regulation on quality of cereals, flour and bakery products, pasta and quick frozen dough 1995, 2003, 2004). Standard Farinograph Extensograph, Amylograph tests were conducted for composite samples according to the methods prescribed in Regulation of methods of physical and chemical analysis for quality control of grain, milling and bakery products, pasta and quick frozen dough (Službeni list SFRJ, 74, 1988, 1854-1887). In order to obtain more detailed defining of protein quality for flour from wheat crop 2008 additional determination of Alveograph (ICC Standard No. 121), wet gluten content (ICC Standard No. 106/2), gluten index (ICC Standard No. 155) and modified gluten index (Torbica et al., 2007) were conducted. Laboratory baking test was conducted according to the internal method. The significance of differences between the results obtained was analyzed by the Analysis of Variance (ANOVA) and Tukey Test. For all calculations, statistical software Statistica 8.0 (Statsoft, Tulsa, USA) was used. Agrometeorological data during the period from 2007/2008 to 2009/2010 were taken from official web site of Republic Hydrometeorological Service of Serbia (RHZS).

RESULTS AND DISCUSSION

The quantity of impurities in wheat is indirect consequence of climatic conditions and applied agro technical measures during seedtime, growing and harvest. Impurities in wheat bulk, especially the irremovable ones have direct influence on wheat technological quality and because of that the determination of content and structure of the impurities is necessary. In table 1 content and structure of irremovable impurities in wheat crop 2008 is presented by wheat growing regions with average values and ranges for the territory of Vojvodina.

Obtained values point out that the structure of irremovable impurities was more or less even regardless of the region and the contents were similar among regions. Despite of surplus of rainfall in May and June (RHZS, 2008), the quantity of sprouted kernels was negligible. Results of standard tests of technological quality of flour from wheat crop 2008 are presented in tables 2 (Farinograph), 3 (Extensograph) and 4 (Amylograph).

Values of Farinograph parameters determined in flour samples point out at uneven results varying in relatively narrow range so that all samples but one are at the level of B1 quality group. Average flour sample from West Bačka region stands out based on better technological quality parameters: high water absorption, short dough development time and long dough stability time, degree of softening lower than average and quality number on the level of A2 quality group. The closest quality level estimated on the basis of Farinograph parameters to the flour from region Zapadna Bačka was determined for flour from Srem region.

Table 1. Content and structure of irremovable impurities in wheat crop 2008

2008. Region	Sprouted kernels (%)	Wheat bug damaged kernels (and kernel damaged by pest) (%)	Fusarious and spoiled kernels (%)	Black spot kernels (%)	Irremovable impurities (%)
North Bačka	0.06	0.20	0.35	0.68	2.29
West Bačka	0.02	0.81	0.32	0.74	1.89
South Bačka	0.01	1.04	0.23	0.83	1.99
North Banat	0.03	1.02	0.36	0.91	2.29
Middle Banat	0.12	1.10	0.38	0.77	2.27
South Banat	0.02	1.02	0.51	0.50	1.85
Srem	0.23	0.98	0.29	0.60	1.91
Average	0.07	1.03	0.35	0.72	2.07

Table 2. Values of Farinograph parameters of flour from wheat crop 2008

2008 Region	Water absorption (%)	Dough development time (min)	Dough stability (min)	Dough resistance (min)	Degree of softening (FU)	Quality number	Quality group
North Bačka	57.3^{b}	2.75^{ab}	2.0^{ab}	4.75^{abc}	87.5^{cd}	60.75^{a}	B1
West Bačka	57.1^{ab}	2.0^{a}	5.5^{c}	7.5^{d}	55^{a}	70.2^{b}	A2
South Bačka	57.3^{b}	4.0^{b}	2.5^{ab}	6.5^{cd}	45^{bc}	67.8^{b}	B1
North Banat	56.3^{ab}	2.75^{ab}	3.5^{b}	6.25^{bcd}	62.5^{ab}	67.5^{b}	B1
Middle Banat	56.8^{ab}	4.0^{b}	2.25^{ab}	6.75^{cd}	70^{b}	66.25^{b}	B1
South Banat	55.3^{a}	2.0^{a}	1.0^{a}	3.0^{a}	90^{d}	59.4^{a}	B1
Srem	56.5^{ab}	1.75^{a}	2.25^{ab}	4.0^{ab}	70^{b}	69.05^{b}	B1
Average	56.6	2.6	2.8	5.5	72	65.6	B1

Extensograph and Amylograph parameters values, especially Extensograph energy value varied more than Farinograph parameters (tables 3 and 4). Such results were expected considering the temperature stress to which wheat was subjected in preharvest and harvest periods (RHSZ, 2008). Influence of temperature stress manifested in low average values of Extensograph resistance and increased dough extensibility. These phenomena are directly the consequence of altered biosynthesis paths of gluten complex proteins. High temperature resulted in synthesis of larger quantity of gliadins in respect to glutenins Blumenthal *et al.* (1993) i Gibson *et al.* (1998), and disturbed usual 1:1 ratio considered as optimal by most researchers (Fido at al., 1997, Goesaert at al., 2005, Radovanovic at al., 2002, Peña, 2002). Analog to influence on protein biosynthesis, high temperatures disturbed also the regular paths of carbohydrate i.e. starch wheat

kernel component biosynthesis (Dupont and Altenbach, 2003).. This manifested in low values of Amylograph peak viscosity. Similarly to Farinograph values, average wheat flour sample from West Bačka region was characterized with excellent Extensograph and Amylograph parameters values.

Table 3. Values of Extensograph parameters of flour from wheat crop 2008

2008 Region	Energy (cm^2)	Resistance at 5 cm (EU)	Extensibility (mm)	Ratio R/E
North Bačka	14^{a}	67.5^{a}	151^{bc}	0.445^{a}
West Bačka	55^{bc}	210^{b}	147^{ab}	1.43^{b}
South Bačka	62^{c}	220^{b}	158^{c}	1.39^{b}
North Banat	33^{ab}	135^{ab}	152.5^{bc}	0.885^{ab}
Middle Banat	32.5^{ab}	130^{ab}	148.5^{ab}	0.875^{ab}
South Banat	37^{ab}	170^{ab}	141^{a}	1.20^{ab}
Srem	39.5^{bc}	175^{b}	140^{a}	1.27^{b}
Average	35	146	147	1.00

Table 4. Values of Amylograph parameters of flour from wheat crop 2008

2008 Region	Peak viscosity (AU)
North Bačka	310^{ab}
West Bačka	500^{c}
South Bačka	190^{a}
North Banat	330^{ab}
Middle Banat	395^{bc}
South Banat	260^{ab}
Srem	325^{ab}
Average	354

Results of Alveograph testing of characteristics of flour from wheat crop 2008 are presented in table 5, while table 6 presents comparatively values of wet gluten content, gluten index and modified gluten index.

Table 5. Values of Alveograph parameters of flour from wheat crop 2008

2008 Region	P (mm H_2O)	L (mm)	G	W ($10E^{-4}$ J)	P/L
North Bačka	44^{a}	95.5^{a}	21.75^{a}	101^{a}	0.46^{ab}
West Bačka	56^{b}	106^{a}	22.9^{a}	172^{b}	0.53^{bc}
South Bačka	51^{ab}	104^{a}	22.7^{a}	156^{ab}	0.49^{ab}
North Banat	45^{a}	106^{a}	22.9^{a}	128.5^{ab}	0.425^{a}
Middle Banat	47^{ab}	98^{a}	22.05^{a}	128^{ab}	0.48^{ab}
South Banat	47^{ab}	95^{a}	21.7^{a}	135^{ab}	0.49^{ab}
Srem	50.5^{ab}	86.5^{a}	20.65^{a}	128^{ab}	0.59^{c}
Average	48	98	22.0	132	0.49

Values of Alveograph parameters indicate that W - alveograph work (deformation energy) as the indicator of dough strength by biaxial extension has more even values than Extensograph energy as the indicator of dough strength by uniaxial extension.

Table 6. Values of wet gluten content, gluten index and modified gluten index of flour from wheat crop 2008

2008 Region	Wet gluten content (%)	Gluten index (%)	Gluten index at 37°C (%)
North Bačka	32^{bcd}	88.5^{ab}	26.5^{a}
West Bačka	32^{bcd}	90^{ab}	62^{bc}
South Bačka	28^{ab}	94^{b}	69^{c}
North Banat	34^{d}	77.5^{a}	38^{ab}
Middle Banat	33^{cd}	86.5^{ab}	42.5^{abc}
South Banat	27^{a}	93^{b}	48^{abc}
Srem	29^{abc}	92.5^{b}	53.5^{abc}
Average	31.3	87.71	44.76

Considering protein quality as the most important factor for wheat flour processing which was significantly decreased under unfavorable weather conditions in 2008, real level of decrease was determined on the basis of additional tests for which results are presented in table 6. Even values of wet gluten content and gluten index do not even indicate protein damage but modified gluten index determined after 90 minutes of tempering of dough at 37 °C was confirmed, as in previous research (Torbica et.al 2007) to be more expressive measure of protein damage. The highest share of undamaged (62%) gluten proteins at gluten content of 32% has average flour sample from wheat from region of Zapadna Bačka for which the best quality based on Farinograph, Extensograph and Amylograph values was determined. Decreased values of Amylograph peak viscosity were not considered to be aggravating factor in wheat flour processing because they were not the consequence of wheat sprouting but rather the consequence of combination of altered size and distribution of size of starch granules with starch damage degree. In table 7 the content and structure of irremovable impurities in wheat crop 2010 is presented by wheat growing regions with average values and ranges in which they varied across the whole territory of Vojvodina. Unlike to 2008, in 2010 climatic conditions (RHZS, 2010) influenced on incidence of higher impurities content. In structure of irremovable impurities as consequence of rainfall surplus in flowering period the content of fusarious kernels was particularly high. Due to favorable weather conditions for wheat bug the content of kernels damaged by wheat bug was also increased. Long lasting rainy periods caused sprouting of wheat kernels.

Table 7. Content and structure of irremovable impurities in wheat crop 2010

2010. Region	Sprouted kernels (%)	Wheat bug damaged kernels (and kernel damaged by pest) (%)	Fusarious and spoiled kernels (%)	Black spot kernels (%)	Irremovable impurities (%)
North Bačka	0.49	2.46	5.57	1.22	9.74
West Bačka	0.12	2.21	5.98	4.98	13.29
South Bačka	0.02	2.40	12.02	2.10	16.55
North Banat	0.49	2.46	5.57	1.22	9.74
Middle Banat	0.35	0.62	4.46	1.40	6.84
South Banat	0.24	1.09	4.84	2.17	8.34
Srem	0.91	2.26	6.90	1.07	11.14
Average	0.67	1.99	7.58	1.93	12.17

Joint influence of increased contents of different classes of irremovable impurities in wheat crop 2010 resulted in unfavorable values of technological quality parameters determined with Farinograph, Extensograph and Amylograph (tables 8, 9 and 10).

Values of Farinograph parameters of flour samples from wheat crop 2010 point out at uneven values only in the case of water absorption while the other Farinograph parameters values differ slightly for wheat from different regions. Common characteristic of all farinograms is short dough stability time. Based on farinograph quality number half of flour samples fall in B1 and other half in B2 quality group.

Values of all Extensograph parameters (Table 9) vary which can be attributed to different degrees of wheat bug attacks resulting in different grades of proteolitic degradation. Opposite to the influence of heat stress on protein biosynthesis, wheat bug attack results in proteolitic degradation of wheat gluten proteins (Cressey *et al.*, 1987; Aja *et al.*, 2004). Comparing to damages

of wheat proteins in crop 2008, it is more difficult to conduct corrections of quality damages in wheat flour processing for flour form crop 2010.

Table 8. Values of Farinograph parameters of flour from wheat crop 2010

2010 Region	Water absorption (%)	Dough development time (min)	Dough stability (min)	Dough resistance (min)	Degree of softening (FU)	Quality number	Quality group
North Bačka	55.75^{ab}	2.25^{a}	2.0^{cd}	4.25^{c}	85^{a}	58.65^{a}	B1
West Bačka	55.6^{ab}	2.0^{a}	2.5^{d}	4.5^{c}	100^{abc}	55.8^{a}	B1
South Bačka	54.5^{a}	2.0^{a}	0.5^{a}	2.5^{a}	100^{abc}	54.3^{a}	B2
North Banat	56.7^{bcd}	2.0^{a}	1.5^{bc}	3.5^{abc}	95^{abc}	55.8^{a}	B1
Middle Banat	57.9^{d}	2.0^{a}	2.0^{cd}	4.0^{bc}	90^{ab}	57.7^{a}	B1
South Banat	57.725^{c}	2.0^{a}	0.625^{a}	2.625^{a}	106.25^{bc}	50.525^{a}	B2
Srem	57.375^{c}	2.125^{a}	1.0^{ab}	3.125^{ab}	110^{c}	51.575^{a}	B2
Average	56.5	2.1	1.4	3.5	98	54.9	B1/B2

Table 9. Values of Extensograph parameters of flour from wheat crop 2010

2010 Region	Energy (cm^2)	Resistance at 5 cm (EU)	Extensibility (mm)	Ratio R/E
North Bačka	17.5^{ab}	70^{ab}	135.5^{b}	0.485^{ab}
West Bačka	0^{a}	0^{a}	0^{a}	0.00^{a}
South Bačka	42^{bc}	140^{bc}	165^{bc}	0.85^{b}
North Banat	18^{ab}	75^{ab}	161^{bc}	0.46^{ab}
Middle Banat	58^{c}	180^{c}	175^{c}	1.03^{b}
South Banat	33.25^{bc}	132.5^{bc}	150.75^{bc}	0.89^{b}
Srem	31.25bc	120^{bc}	158.25^{bc}	0.77^{b}
Average	29	103	135	0.64

Table 10. Values of Amylograph parameters of flour from wheat crop 2010

2010 Region	Peak viscosity (AU)
North Bačka	262^{b}
West Bačka	380^{c}
South Bačka	340^{c}
North Banat	240^{b}
Middle Banat	245$_{b}$
South Banat	226.5^{b}
Srem	157.5^{a}
Average	264

Decreased values of Amylograph peak viscosity are in relatively narrow ranges and are all under the lower limit of value range considered to be optimal for baking processes. Determined low values of peak viscosity are the consequence of wheat sprouting and activation of α-amylase due to increased rainfall. The accompanying consequence of increased rainfall is activation of proteolitic processes in kernels which results in additional damages of protein component of wheat. Testing of wheat from both examined crops by test baking method indicated result which could be expected regarding final product quality with optimization of technological processes and application of combined improver. In table 11 objective (specific volume) and subjective (sensory properties) parameters of quality of bread obtained in test baking are presented.

Table 11. Baking properties of flour from wheat crops 2008 and 2010

QUALITY PARAMETERS	Flour from wheat crop 2008 – blend with Extensograph energy < 40 cm^2		Flour from whea t crop 2010
	Bread from basic raw materials	Bread with optimised improver	Bread from basic raw materials
Specific volume (ml/g)	4.22	5.71	3.55-4.20
Crumb elasticity	0	4	0-4
	poor	Very good	poor to very good
Crumb grain	1.1	4	1-3
	rugh+	fine	rugh to almost fine
Colour and shinyness od crust	5	5	4-5
	light golden brown, shine	Light golden brown, shine	Golden brown to dark brown
Generl assesment of sensory properties	2.2	4.3	1.7-4

Presented ranges in which values of test baking results in 2010 relate to bread samples produced from flour with different protein content (worst evaluation for lowest protein content and opposite).

Based on obtained results of bread quality evaluation the problems in bread production at which were expected on the basis of flour quality determination were confirmed, but these problems could be overcame with optimization of bread production procedure. Certain problems in bread quality also manifested but the additional possibility for obtaining of much better quality not only through optimized production procedure but also through application of adequate combined improvers was confirmed.

CONCLUSION

Temperature stress to which wheat was subjected before and during harvest of wheat crop 2008 resulted in altered biosynthesis paths of gluten complex proteins and carbohydrate i.e. starch component of wheat kernel. Climatic conditions in 2010 resulted in increased content of irremovable impurities content including fusarious, wheat bug attacked and sprouted kernels. Completely different climatic conditions in two production years resulted in similar decrease in quality level evaluated on the basis of Farinograph, Extensograph and Amylograph parameters. For these reasons it is necessary to determine the real causes of decrease of wheat quality with additional methods in order to enable optimization of wheat processing into final products of the best possible quality in adequate direction.

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REFERENCES

Pravilnik o metodama fizičkih i hemijskih analiza za kontrolu kvaliteta žita, mlinskih i pekarskih proizvoda, testenina i brzo smrznutih testa - Regulation of methods of physical and chemical analysis for quality control of grain, milling and bakery products, pasta and quick frozen dough. Službeni list SFRJ, 74, 1988, 1854-1887.

Pravilnik o kvalitetu žita, mlinskih i pekarskih proizvoda, testenina i brzo smrznutih testa. Regulation on quality of

cereals, flour and bakery products, pasta and quick frozen dough. Sl. list SRJ, br. 52/95 i Sl. list SCG, br. 56/2003 - dr. pravilnik i 4/2004 - dr. pravilnik)

RHZS (2010): (according to date of Republic Hydrometeorological Service of Serbia from 2008 and 2010). /www.hidmet.gov.rs/, pristupljeno 18.02.2011.

ICC Standard No. 121: Method for Using the Chopin Alveograph

ICC Standard No. 106/2: Working method for the determination of wet gluten in wheat flour

ICC Standard No. 155: Determination of wet gluten quantity and quality (Gluten Index ac. to Perten) of whole wheat meal and wheat flour (Triticum aestivum).

Baking test according to internal procedure of Institute for Food technology in Novi Sad

Torbica A., Antov M., Mastilović J., Knežević D. (2007). The influence of changes in gluten complex structure on technological quality of wheat (Triticum aestivum L.). Food Research International, 40, 1038-1045.

Triboïhttp://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-WU-MsSAYWW-UUA-U-AAVDYDZDUV-AAVCVCDCUV-YUVWCUAWE-WU-U&_rdoc=17&_fmt=summary&_udi=B6T67-410D1VC-5&_coverDate=07%2F31%2F2000&_cdi=5023&_orig=search&_st=13&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7b6ca2909cf280dc6158f185e63c0cf3 - m4.cor*mailto:triboi@clermont.inra.fr E., Abad A., Michelena A., Lloveras J., Ollier J.L., Daniel C. (2000). Environmental effects on the quality of two wheathttp://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-WU-MsSAYWW-UUA-U-AAVDYDZDUV-AAVCVCDCUV-YUVWCUAWE-WU-U&_rdoc=17&_fmt=summary&_udi=B6T67-410D1VC-5&_coverDate=07%2F31%2F2000&_cdi=5023&_orig=search&_st=13&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7b6ca2909cf280dc6158f185e63c0cf3 - hit2 genotypes: 1. quantitative and qualitative variation of storage http://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-WU-MsSAYWW-UUA-U-AAVDYDZDUV-AAVCVCDCUV-YUVWCUAWE-WU-U&_rdoc=17&_fmt=summary&_udi=B6T67-410D1VC-5&_coverDate=07%2F31%2F2000&_cdi=5023&_orig=search&_st=13&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7b6ca2909cf280dc6158f185e63c0cf3 - hit1proteins.http://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-WU-MsSAYWW-UUA-U-AAVDYDZDUV-AAVCVCDCUV-YUVWCUAWE-WU-U&_rdoc=17&_fmt=summary&_udi=B6T67-410D1VC-5&_coverDate=07%2F31%2F2000&_cdi=5023&_orig=search&_st=13&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7b6ca2909cf280dc6158f185e63c0cf3 - hit3 European Journal of Agronomy, 13, 47-64.

Triboï E., Martre P., Girousse C., Ravel C., Triboï -Blondel AM. (2006). Unravelling environmental and genetic relationships between grain yield and nitrogen concentration for wheat. European Journal of Agronomy, 25, 108–118.

Altenbach B.S., DuPont M.F., Kothari M.K., Chan R., Johnson L.R., Lieu D. (2003). Temperature, Water and Fertilizer Influence the Timing of Key Events During Grain Development in US Spring Wheat. Journal of Cereal Science, 37, 9-20.

Dupont M.F., Altenbach B.S. (2003). Molecular and biochemical impacts of environmental factors on wheat grain development and protein synthesis. Journal of Cereal Science, 38, 133–146.

Triboïhttp://www.sciencedirect.com/science?_ob=ArticleURL&_aset=V-WA-A-W-WU-MsSAYWW-UUA-U-AAVDYDZDUV-AAVCVCDCUV-YUVWCUAWE-WU-U&_rdoc=17&_fmt=summary&_udi=B6T67-410D1VC-5&_coverDate=07%2F31%2F2000&_cdi=5023&_orig=search&_st=13&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=7b6ca2909cf280dc6158f185e63c0cf3 - m4.cor*mailto:triboi@clermont.inra.fr E., Martre P., Triboï-Blondel A. (2003). Environmentally-induced changes in protein composition in developing grains of wheat are related to changes in total protein content. Journal of Experimental Botany, 54, 1731-1742

Jamieson P.D., Stone P.J., Semenov M.A. (2001). Towards modeling quality in wheat-from grain nitrogen concentration to protein composition. Aspects of Applied Biology, 64, 111-126.

Goesaert H., Brijs K., Veraverbeke S.W., Courtin M.C., Gebruers K., Delcour A.J. (2005). Wheat flour constituents: how they impact bread quality, and how to impact their functionality. Trends in Food Science & Technology, 16, 12-30.

Fido J.R., Bekes F., Gras W.P., Tatham S.A. (1997). Effects of α-, β-, γ- and ω-Gliadins on the Dough Mixing Properties of Wheat Flour. Journal of Cereal Science, 26, 271-277.

Peña R.J. (2002). Wheat for bread and other foods, Bred wheat Improvement and Production, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, Rome, 567 pg.

Radovanovic N., Cloutier S., Brown D., Humphreys G.D., Lukow M.O. (2002). Genetic variance for gluten strength contributed by high molecular weight glutenin proteins. Cereal Chemistry, 79 (6), 843-849.

Blumenthal C., Barlow R.W.E., Wrigley W.C. (1993). Growth environment and wheat quality: the effect of heat stress on dough properties and gluten proteins. Journal of Cereal Science, 18, 3-21.

Gibson L.R., McCluskey P.J., Tilley K.A., Paulsen G.M. (1998). Quality of hard red winter wheat grown under high temperature conditions during maturation and ripening (1). Cereal Chemistry, 75 (4,) 421-427

Cressey P.J., McStay C.L. (1987). Wheat bug damage in New Zealand wheats. Development of a simple SDS sedimentation test for bug damage. J. Sci. Food Agric. 38, 357–366.

Aja S., Perez G., Rosell C.M. (2004). Wheat damage by Aelia spp. and Erygaster spp.: effects on gluten and water-soluble compounds released by gluten hydrolysis. Journal of Cereal Science, 39, 187–193.

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