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Quality of durum wheat breeding lines: Genetic and environmental effects

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SUMMARY – Quality data of eleven durum wheat genotypes grown under six environments in 1998/99 were evaluated to determine the relative effects of genotype and environment on quality characteristics, associated with protein content, SDS sedimentation test and mixograph parameters. Glutenin composition was also determined. The 11 durum wheat genotypes assessed, represented three Portuguese reference varieties and eight advanced breeding lines. Highly significant effects on quality parameters were detected, with the exception of protein content. One genotype (TE9507) was identified with high quality potential in all the environments studied. The identification of glutenin composition confirms the consistent relation between the low molecular weight glutenin alleles controlled by the *Glu-B3* and the gluten strength evaluated by the SDS sedimentation test and the mixograph development time. Two genotypes with poor quality carry the LMW glutenin *b* allele. Those with allelic variants *a* are associated with superior quality. The relation between the quality parameters shows that the mixograph maximum peak weight (maximum consistency) is one aspect of the dough behaviour influenced by the protein content in opposition to the mixograph dough development time and the resistance breakdown more dependent of gluten strength evaluated by SDS sedimentation test. Environment as well as genotype, had a significant effect on quality parameters, therefore, samples from multilocation trials should be used for quality evaluation, particularly in advanced breeding lines.

Key words: Durum wheat, quality, glutenins, breeding.

RESUME – *"Qualité chez les lignées d'amélioration du blé dur : Effets génétiques et environnementaux". Les résultats de la qualité de onze blés durs cultivés dans six environnements pendant l'année 1998/99 ont été évalués pour déterminer les effets relatifs au génotype et à l'environnement sur les caractéristiques qualitatives associées à la teneur en protéines, test SDS sédimentation et paramètres du mixographe. La détermination de la composition des gluténines a été aussi effectuée. Les onze blés durs représentent trois variétés portugaises et huit lignées d'amélioration. On a détecté des effets très significatifs dans les paramètres de qualité à exception de la protéine. Un génotype est identifié (TE9507) avec une très haute qualité dans tous les environnements étudiés. L'identification de la composition des gluténines confirme la relation consistante entre les allèles des sous-unités gluténines de faible poids moléculaire (LMW) contrôlés par le locus* Glu-B3 *et la force du gluten évaluée par le test SDS sédimentation et le temps de développement du mixographe. Deux génotypes de faible qualité possèdent l'allèle* b *des gluténines de faible poids moléculaire (LMW). Les génotypes avec l'allèle a sont associés à une qualité supérieure. La relation entre les paramètres de qualité montre que la consistance maximale du mixogramme est un aspect du comportement de la pâte influençable par la teneur en protéines en opposition aux temps de développement du mixographe plus dépendants de la force du gluten évaluée par le test SDS. Comme les génotypes, les environnements ont des effets significatifs sur les paramètres de qualité, de cette façon il faut utiliser des échantillons provenant des essais multilocaux pour l'évaluation de la qualité, surtout en lignées d'amélioration avancées.*

Mots-clés : *Blé dur, qualité, gluténines, amélioration génétique.*

Introduction

Improvement of durum wheat quality is one of the main objectives of the National Plant Breeding Station (ENMP, Portugal) programme. Much of the researches focus on improving protein quality and gluten strength to produce pasta with desirable cooked texture. As breeding lines are developed the quality parameters need to be evaluated and the relative influences of genotype and environment must be defined.

The major quality characters include kernel size, vitreousness, protein content, gluten strength assessed by SDS sedimentation volume, rheological mixing characteristics as measured by alveograph and mixograph tests and pigment concentration (Brites *et al.,* 1998).

The importance of protein composition for the viscoelasticity of gluten was also considered and studies on gliadin and glutenin identification, inheritance and their influence in durum wheat quality were conducted (Brites *et al.,* 1996; Brites and Carrillo, 1999). The discrimination of LMW-1 and LMW-2 patterns in different allelic variants controlled by *Glu-A3*, *Glu-B2* and *Glu-B3 loci* (Ruiz and Carrillo, 1993; Nieto-Taladriz *et al.,* 1997; Igrejas *et al.,* 1999) permitted to reconfirm that observed associations with gluten strength are more likely caused by LMW glutenins subunits controlled by *Glu-B3 locus* than γ-gliadin bands controlled by *Gli-B1 locus* (Payne *et al.,* 1984; Pogna *et al.,* 1990; Ruiz and Carrillo, 1995). Significant relations were found between HMW glutenin subunits and the gluten strength. Brites and Carrillo, (2000) evaluated the progeny of 4 intervarietal durum wheat crosses segregating for *Glu-B3* (LMW *a*, *b*, *c*, *j* and *k)* and *Glu-B1* (HMW 20, 6+8, 7+8 and 14+15) glutenin alleles. Lines combining HMW 14+15 with LMW *c* alleles are associated with superior SDS sedimentation volume and to better rheological gluten properties in opposition to lines with HMW 20 and LMW *b* or LMW *k* alleles.

The objectives of our study were to determine the glutenin composition and to compare the relative effects of environment and genotype on protein content and gluten strength characteristics in Portuguese breeding lines.

Materials and methods

Grain samples

Eleven durum wheat (*Triticum durum* L.) cultivars comprising three reference varieties ("Celta", "Hélvio" and "Trovador") and eight advanced breeding lines (TE9204, TE9504, TE9506, TE9507, TE9717, TE9718, TE9719 and TE9720) were used in this study. All samples were grown in six environments: Elvas (ENMP), H. Revilheira, Beja, V.F. Xira, Elvas (Comenda) and Abrantes during the 1998/1999 season.

Quality analysis

Samples of grains were tempered at 14% moisture basis and milled using a Cyclotec mill (Tecator, Sweden) equipped with a 1 mm sieve to determine protein content (Prot) by the Kjeldhal method (% N x 5.7, dry matter basis) and SDS sedimentation test (Dick and Quick, 1983). To assess mixing properties, whole-wheat meal was then purified to obtain particle size between 125 to 315 μm and used by the 10 g mixograph AACC method 54-40A with modification for constant absorption water of 6.5 ml, using a spring setting of 8 and based upon the following parameters: maximum peak height (MPH), time to MPH (mixing development time – MDT), height at 3 min after the peak of the curve (H3) and the difference in percentage, between MPH and H3 (resistance breakdown – RB).

Electrophoretic analysis

The glutenins were extracted by the extraction procedure developed by Singh *et al.* (1991) and analysed by SDS-polyacrilamide-gel electrophoresis. The alleles detected for HMW-glutenin subunits were named using the nomenclature of Payne and Lawrence (1983) and the allelic variants for LMW-glutenin subunits were designated by the nomenclature of Nieto-Taladriz *et al.* (1997).

Statistical analysis

Analysis of variance was applied to data considering each location year as an environment and genotypes and environments were treated as fixed effects. Genotype and environment means for quality characteristics were calculated and mean comparisons were performed using Duncan test.

Results and discussion

Electrophoretic separation (SDS-PAGE) of glutenin subunits, present in the same lines, is shown in Fig. 1, which represents the variation of HMW and LMW glutenins detected. The eleven lines were similar concerning the glutenin composition. No HMW glutenin subunits encoded by *Glu-A1 locus* and only three

allelic variants (HMW 6+8, HMW 7+8 and HMW 20) controlled by *Glu-B1 locus* were detected, these results confirm previous data (Brites *et al.,* 1996; Igrejas *et al.,* 1999). Table 1 summarises the LMW glutenin subunits and the correspondence with allelic composition at the *Glu-A3*, *Glu-B3* and *Glu-B2 loci*, at each *locus* only two alleles were identified.

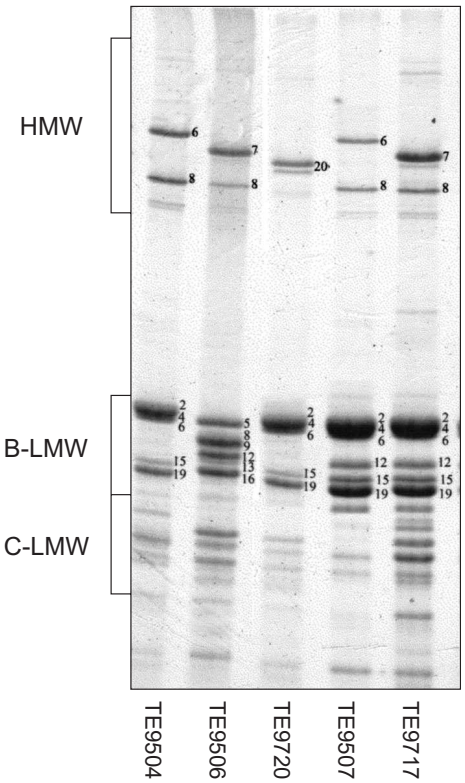

Fig. 1. SDS-PAGE patterns of glutenin subunits of some durum wheat lines.

Table 1. LMW glutenin subunits present and their allelic classification at *Glu-A3, Glu-B3* and *Glu-B2 loci*

Locus	LMW subunits	Allelic variant
Glu-A3	6	*a*
	5	*b*
Glu-B3	2+4+15+19	*a*
	8+9+13+16	*b*
Glu-B2	12	*a*
	null	*b*

The line TE9719 showed a mixture of grains with two types of HMW glutenins: null, 20 and null, 7+8.

Effects of genotypes and environments on the quality characteristics were evaluated by analysis of variance (Table 2).

Environmental and genetic effects were very highly significant with the exceptions of genotype in protein content and the environment in mixograph resistance breakdown. The strong influence of environment on grain protein agrees with other studies (Mariani *et al.,* 1995; Ames *et al.,* 1999). Unable to separate the interaction term in the analysis of variance unfortunately in this case we cannot compare

the relative magnitude of genotype, environment and interaction variances. Genotype glutenin composition and mean values for quality parameters over the six environments are presented in Table 3.

Table 2. Mean squares for the analysis of variance across environments[†]

Source of variation	df	Protein	SDS	Mixograph parameters			
				MDT	MPH	H3	RB
Genotype	10	1.6*	1197***	3.7***	133***	144***	31***
Environment	5	52***	376***	1.4***	669***	414***	14^{ns}
Residual	50	0.7	44	0.2	27	15	7.6

[†]SDS = sedimentation volume; MDT = development time; MPH = maximum peak height; H3 = height at 3 min after the peak; RB = resistance breakdown.
*,***Significant at 5% and 1% levels, respectively; ns = non significant.

Table 3. Genotype means of parameters used in quality tests, their comparisons using Duncan test and HMW and LMW glutenin composition

Genotype	Protein (%)	SDS[†] (mm)	Mixograph parameters[††]				Glutenin composition	
			MDT (min)	MPH (mm)	H3 (mm)	RB (%)	HMW *Glu-A1, Glu-B1*	LMW *Glu-A3,Glu-B3, Glu-B2*
1-Celta	14.6^{a}	25^{c}	1.75^{d}	82.3^{cde}	64^{c}	21.9^{a}	N,7+8	*b, b, a*
2-Hélvio	13.9^{ab}	67^{a}	4.29^{a}	83.5^{bcde}	71^{b}	14.7^{bc}	N,6+8	*a, a, a*
3-Trovador	13.9^{ab}	42^{b}	2.77^{bc}	84.7^{bcd}	71^{b}	15.8^{bc}	N,6+8	*a, a, a*
4-TE 9204	13.3^{b}	67^{a}	3.27^{b}	86.0^{abc}	73^{b}	14.6^{bc}	N,7+8	*a, a, a*
5-TE 9504	14.9^{a}	49^{b}	3.23^{b}	86.3^{abc}	75^{ab}	13.5^{c}	N,6+8	*a, a, b*
6-TE 9506	13.9^{ab}	26^{c}	1.90^{d}	78.2^{de}	64^{c}	17.5^{b}	N,7+8	*b, b, a*
7-TE 9507	14.4^{a}	62^{a}	4.11^{a}	91.5^{a}	78^{a}	14.5^{bc}	N,6+8	*a, a, a*
8-TE 9717	13.1^{b}	45^{b}	2.63^{c}	77.3^{e}	66^{c}	14.5^{bc}	N,7+8	*a, a, a*
9-TE 9718	13.8^{ab}	46^{b}	2.75^{bc}	77.5^{e}	66^{c}	15.3^{bc}	N,7+8	*a, a, a*
10-TE 9719	14.0^{ab}	46^{b}	2.62^{c}	84.2^{bcd}	71^{b}	15.5^{bc}	N,7+8/20	*a, a, a*
11-TE 9720	14.0^{ab}	42^{b}	2.76^{bc}	89.7^{ab}	76^{ab}	15.5^{bc}	N,20	*a, a, b*

[†]SDS = sedimentation volume.
[††]MDT = development time; MPH = maximum peak height; H3 = height at 3 min after the peak; RB = resistance breakdown.
^{a,b,c,d,e}Means with the same letters are not different at 5% level.

Overall quality was good in the 1998/1999 season, grain had high protein content. Significant differences among genotypes were detected, concerning SDS sedimentation and mixograph development time. Cultivar “Celta” and TE9506 advanced line were the poorest in all environments for the quality traits considered (except protein content). TE9507 advanced line exhibits high quality potential with highest mean values for all the quality tests.

Environment mean values for the quality parameters are presented in Table 4. Samples from Elvas (Comenda) had a higher protein content in opposition to V.F. Xira and also higher gluten strength evaluated by SDS and mixograph mixing development time than Elvas (ENMP) samples. The differences observed in the two trials at Elvas (Comenda and ENMP) were probably due to soil fertility.

Table 5 shows correlation among quality parameters where significant correlations were found between protein content and the mixograph maximum peak eight and height at 3 min. after the peak; SDS sedimentation values and mixograph mixing development time and resistance breakdown. There is no correlation between the protein content and the sedimentation values.

Table 4. Environmental means of parameters used in quality tests and their comparisons using Duncan test

Location	Protein (%)	SDS† (mm)	Mixograph parameters			
			MDT (min)	MPH (mm)	H3 (mm)	RB (%)
1-Elvas (ENMP)	15.6^{ab}	36^{c}	2.9^{b}	88^{ab}	74^{b}	16.2^{ab}
2-H.Revilheira	13.8^{c}	47^{ab}	2.8^{b}	85^{b}	70^{c}	17.5^{a}
3-Beja	13.1^{c}	44^{b}	3.5^{a}	84^{b}	72^{bc}	14.6^{b}
4-V.F.Xira	10.2^{d}	51^{a}	3.0^{b}	69^{c}	59^{d}	14.4^{b}
5-Elvas (Comenda)	16.0^{a}	51^{a}	3.0^{b}	92^{a}	77^{a}	16.1^{ab}
6-Abrantes	15.2^{b}	51^{a}	2.4^{c}	85^{b}	71^{bc}	15.6^{ab}

†SDS = sedimentation volume; MDT = development time; MPH = maximum peak weight; H3 = height at 3 min after the peak; RB = resistance breakdown.
^{a,b,c,d}Means with the same letters are not different at the level.

Table 5. Pearson correlation coefficients between quality tests†

	Prot	SDS	MDT	MPH	H_3	RB
Prot	1.00					
SDS	-0.11	1.00				
MDT	-0.10	0.61**	1.00			
MPH	0.76**	0.11	0.30*	1.00		
H_3	0.69**	0.26*	0.44**	0.93**	1.00	
RB	0.21	-0.40**	-0.36**	0.22	-0.14	1.00

†SDS = sedimentation volume; MDT = development time; MPH = maximum peak height; H3 = height at 3 min after the peak; RB = resistance breakdown.
*,**Significant at 5% and 1% levels, respectively.

Conclusions

Genetic and environmental effects accounted for differences in the results of durum wheat quality parameters. SDS sedimentation test and mixograph mixing development time were traits with an important genetic component, consequently, they are the most indicated parameters to establish the variation in varietal end-use quality characteristics.

The good performance of the TE9507 genotype seems to be an evidence of the potential to improve the quality of the new Portuguese durum wheat germplasm.

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