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Relationship between endosperm proteins and quality in durum wheat (*Triticum turgidum* L. var. *durum*)

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SUMMARY – The influence of gliadins and glutenins, the seed endosperm proteins, on pasta cooking quality is analysed. In the high molecular weight (HMW) glutenin subunits, the negative effect of the HMW 20 is the most outstanding result. The gliadins γ-42 and γ-45 are markers of good and poor pasta quality, respectively. The low molecular weight (LMW) glutenin subunits are the most important prolamins influencing pasta quality. A rank of *Glu-A3* and *Glu-B3* alleles for several tests related to gluten strength is proposed.

Key words: Durum wheat, prolamins, LMW glutenin subunits, gluten strength.

RESUME – *"Relation entre les protéines de l'endosperme et la qualité chez le blé dur". On a analysé l'influence des gliadines et gluténines (les protéines de réserve de l'endosperme) sur la qualité des pâtes alimentaires de blé dur. Le résultat le plus important pour les gluténines de haut poids moléculaire a été l'effet négatif de la sous-unité 20. Les gliadines γ-42 et γ-45 sont des marqueurs pour une bonne et mauvaise qualité de pâte, respectivement. Les gluténines de faible poids moléculaire sont les prolamines qui ont le plus d'influence sur la qualité des pâtes. On propose le rang des allèles des loci* Glu-A3 *et* Glu-B3 *en fonction de leur influence sur des tests technologiques pour mesurer la force du gluten.*

Mots-clés : *Blé dur, prolamines, sous-unités de gluténines de faible poids moléculaire, force du gluten.*

Introduction

Durum wheat is a very important crop in the Mediterranean region, and its uses are very variable. In Western Europe it is mostly used for pasta production.

Pasta cooking quality has been shown to depend on two main parameters: rheological characteristics related to gluten elasticity or strength, and surface conditions, especially absence of such surface deteriorations as stickiness and mushiness. It has been demonstrated that those two parameters are relatively independent (Autran *et al.,* 1986).

The surface state of cooked pasta has been correlated positively with the amount of sulphydril groups and disulphide bonds in some low Mr gluten proteins (Kobrehel *et al.,* 1988). Viscoelasticity of cooked pasta correlates to the seed storage prolamin proteins, to their quantity and specific composition.

Several research groups (Dexter and Matsuo, 1980; Autran and Galterio, 1989) have pointed out a highly positive significant correlation between protein quantity and pasta cooking quality. The genetic improvement of protein content has been particularly hampered, not only by the sharp environmental influence, but also by the fact that a negative correlation was found between the grain yield and seed protein content in segregating populations in all cereals (Cox *et al*., 1985). A high protein content, however, does not always assure the good quality of pasta. It has been ascertained that specific protein components of seed storage prolamin proteins are correlated with the technological properties of durum wheat flour.

Gliadins and glutenins are the seed endosperm prolamin proteins. Gliadins are monomeric protein molecules which have been subdivided into four groups termed: α, β, γ and ω according to their decreasing mobility when separated by electrophoresis on gels at acidic pH. Glutenins contain different polypeptides connected by intermolecular disulphide bonds, the polypeptides are called subunits and are subdivided into low-molecular-weight (LMW) and high-molecular-weight (HMW) according to their molecular weight when separated on sodium dodecyl sulphate polyacrilamide gels.

The genes encoding gliadin components are located on the short arm of chromosomes of the homoeologous groups 1 and 6 of A and B genomes and their loci are name *Gli-1* and *Gli-2*, respectively (Joppa *et al.*, 1983). The genes coding for HMW glutenin subunits are located on the long arm of chromosomes 1A and 1B at the *Glu-1* loci, whereas the most of LMW glutenin subunits are controlled by genes tightly linked to *Gli-1* loci at the *Glu-3* loci (Jackson *et al.*, 1983). More recently a new minor locus for LMW glutenin subunits was found (Ruiz and Carrillo, 1993; Liu, 1995), it is a complex locus named *Gli-B3/Glu-B2*.

HMW glutenin subunits

The relationship between HMW glutenin subunits and durum wheat quality has been analysed in several studies. Earlier studies showed no clear relationships between HMW glutenin subunits and spaghetti quality (du Cros *et al*., 1982; Vallega, 1986). Other authors reported that certain HMW glutenin subunits were correlated with the rheological quality of durum wheats (Boggini and Pogna, 1989; Carrillo *et al*., 1990a; Kovacs *et al*., 1993). The most significant result was that the HMW 20, coded at *Glu-B1*, showed a differential and negative effect on gluten strength and mixing properties. The HMW glutenin subunit genes on chromosome 1A appear to have a negligible relationship to durum quality parameters when compared to genes on chromosome 1B (Pogna *et al.,* 1990).

Gliadins

Early studies (Damidaux *et al*., 1978; Kosmolak *et al*., 1980; Cros *et al*., 1982) demonstrated the usefulness of two γ-gliadins: γ-45 and γ-42 (encoded at the *Gli-B1* locus) as markers of good and poor pasta quality, respectively.

LMW glutenin subunits

Payne *et al.* (1984) suggested that the LMW glutenin subunits tightly linked to the γ-gliadins were responsible for the determining gluten viscoelasticity differences in durum wheat, while γ-gliadins 42 and 45, coded at *Gli-B1*, were only genetic markers. Two different LMW glutenin patterns, LMW-1 and LMW-2, linked to γ-42 and γ-45 respectively, were described by Payne *et al.* (1984).

Pogna *et al.* (1988, 1990) and Ruiz and Carrillo (1995a) demonstrated that LMW glutenin subunits were responsible for the quantitative differences in quality.

Analysing durum wheat cultivars (Carrillo *et al*., 1990a) and Spanish durum wheat landraces (Carrillo *et al*., 1990b) new patterns of LMW where described besides LMW-1 and LMW-2, showing different associations with sodium dodecyl sulphate sedimentation (SDSS) volumes. The new patterns were nominated LMW-2^- associated with γ-gliadin 45, LMW-2* associated with γ-gliadin 44, and LMW-1^-, null for γ-42 and γ-45. The SDSS values for the different LMW glutenin groups of patterns showed a significant tendency to decrease following the order LMW-2 > LMW-2* > LMW-2^- > LMW-1 > LMW-1^-.

All the LMW glutenin subunits patterns include LMW glutenin subunits encoded by chromosome 1A and 1B, then it was necessary to separate the allelic variants at the *Glu-A3* and the *Glu-B3*. Some allelic variants at the *Glu-A3* and *Glu-B3* loci were determined and reported their effect on pasta making quality (Ruiz and Carrillo, 1995b; Vázquez *et al*., 1996).

The association between gluten quality and LMW-patterns is clearly inadequate or too imprecise because durum quality depends on specific LMW glutenin subunits encoded at the *Glu-3* loci. Therefore, a study of the allelic variation at the *Glu-A3* and *Glu-B3* loci was carried out analysing the B-LMW glutenin subunit composition in ten crosses and in a collection of 88 durum wheat cultivars (Nieto-Taladriz *et al*., 1997). Eight allelic variants were identified at the *Glu-A3* and nine alleles at the *Glu-B3* (Fig. 1).

The equivalence between LMW-patterns described by Payne *et al.* (1984) and Carrillo *et al.* (1990a), and the allelic composition found in the collection of durum wheat cultivars is shown in Table 1.

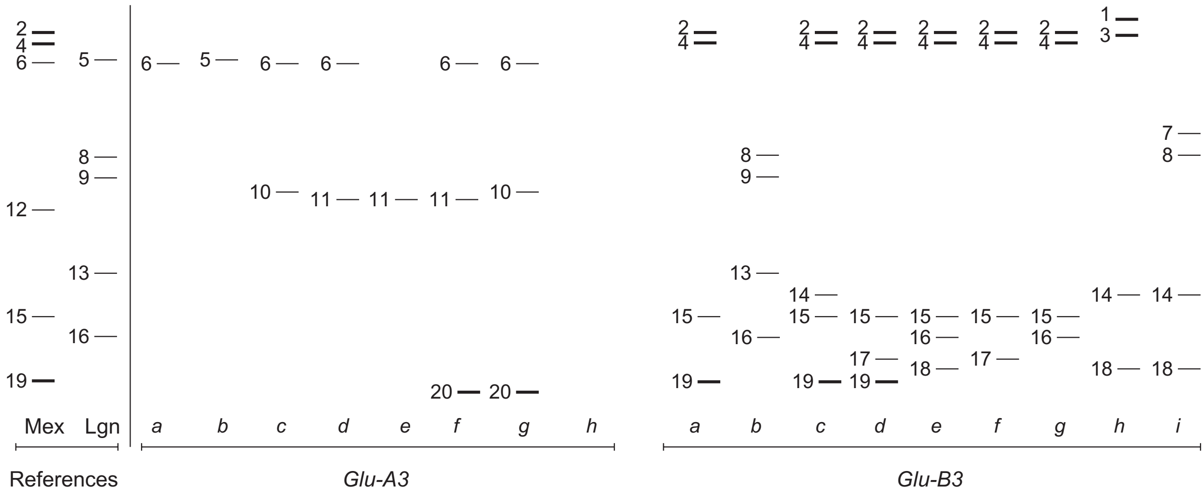

Fig. 1. Diagram showing the *Glu-A3* and *Glu-B3* encoded B-LMW glutenin subunits identified as allelic variants (Nieto-Taladriz *et al.,* 1997).

Table 1. Equivalence between LMW-models (Payne *et al.,* 1984; Carrillo *et al.,* 1990a) γ-gliadin and the allelic composition found by Nieto-Taladriz *et al.,* 1997

Model	γ-gliadin	*Glu-A3*	*Glu-B3*	*Glu-B2*
LMW-1	42	*b*	*b*	*a*
	42	*b*	*b*	*b*
	Null	*b*	*i*	*b*
LMW-1^{-}	Null	*e*	*i*	*b*
	42	*h*	*b*	*b*
LMW-2	45	*a*	*a*	*a*
	45	*c*	*a*	*a*
	45	*d*	*a*	*b*
	45	*c*	*c*	*b*
	45	*f*	*a*	*b*
	45	*c*	*f*	*a*
	45	*g*	*g*	*a*
LMW-2^{-}	45	*h*	*a*	*a*
	45	*h*	*c*	*b*
	45	*e*	*d*	*a*
	45	*e*	*e*	*a*
	45	*e*	*f*	*a*
LMW-2*	44	*d*	*h*	*b*

An experiment of 25 durum wheat cultivars was carried out during two years in three different locations. All the allelic variants at *Glu-A3* and *Glu-B3* described by Nieto-Taladriz *et al.* (1997) were present in the 25 cultivars. The viscoelasticity of the flour was evaluated by several tests: (i) SDSS test; (ii) two parameters of the mixograph – mixing time (MT) and maximum peak height (PH); and (iii) two parameters of the alveograph – strength (W) and extensibility (L).

As result of the experiment, a rank of the *Glu-A3* alleles and *Glu-B3* alleles was obtained in relation with the viscoelasticity. In the *Glu-A3* alleles rank (Table 2), it was possible to group the alleles in two classes, the alleles *h*, *c*, *d* and *a* related with higher values of elasticity in the four tests, and the alleles *g*, *f*, *e* and *b* related with lower values of viscoelasticity.

Table 2. Rank of *Glu-A3* alleles (from higher to lower values) for several quality tests: sodium dodecyl sulphate sedimentation (SDSS), mixing time (MT), maximum peak height (PH), strength (W) and extensibility (L)

	Glu-A3 alleles rank							
SDSS	*h*	*c*	*d*	*a*	*g*	*f*	*e*	*b*
MT	*a*	*h*	*c*	*d*	*g*	*f*	*e*	*b*
PH	*h*	*d*	*f*	*c*	*a*	*g*	*e*	*b*
W	*h*	*d*	*c*	*a*	*e*	*g*	*b*	*f*
L	*g*	*f*	*d*	*h*	*c*	*a*	*b*	*e*

The effect of LMW glutenin subunits controlled by *Glu-B3* loci on quality was the more significant effect among the different types of prolamins. In the *Glu-B3* alleles rank (Table 3), the alleles *c* and *a* showed association with the highest values for the four tests evaluating quality, other four alleles: *g*, *d*, *f* and *h* showed intermediate values, and the alleles *b*, *i* and *e* were related to the lowest values for the viscoelasticity. In the last group, the alleles *b* and *i* were placed within the pattern LMW-1, but the allele *e* belongs to the LMW-2 pattern.

Table 3. Rank of *Glu-B3* alleles (from higher to lower values) for several quality tests: sodium dodecyl sulphate sedimentation (SDSS), mixing time (MT), maximum peak height (PH), strength (W), and extensibility (L)

	Glu-B3 alleles rank								
SDSS	*c*	*a*	*g*	*d*	*f*	*h*	*b*	*i*	*e*
MT	*a*	*c*	*g*	*d*	*f*	*h*	*b*	*i*	*e*
PH	*c*	*a*	*h*	*f*	*g*	*d*	*b*	*i*	*e*
W	*c*	*a*	*f*	*d*	*g*		*b*		*i*
L	*g*	*c*	*a*	*f*		*d*	*b*		*i*

The parameter of the alveograph evaluating L seems to be influenced by different alleles or in a different way than the viscoelasticity.

Selection based on alleles at *Glu-3* associated with positive effects can improve durum gluten quality. The knowledge of the different association of *Glu-3* alleles with quality could help plant breeders to select in early generations lines with the best allelic combinations for improved quality in new durum wheat cultivars.

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