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Dough quality of bread wheat lacking α-gliadins with celiac disease epitopes and addition of celiac-safe avenins to improve dough quality

Hetty C. van den Broeck [a,*], Ludovicus J.W.J. Gilissen [a], Marinus J.M. Smulders [a], Ingrid M. van der Meer [a], Rob J. Hamer [b]

[a] Plant Research International, Wageningen UR, P.O. Box 16, 6700 AA Wageningen, The Netherlands
[b] Laboratory of Food Chemistry, Wageningen UR, P.O. Box 8129, 6700 EV Wageningen, The Netherlands

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ABSTRACT

Celiac disease is a T-cell mediated immune response in the small intestine of genetically susceptible individuals caused by ingested gluten proteins from wheat, rye, and barley. In the allohexaploid bread wheat (*Triticum aestivum*), gluten proteins are encoded by multigene loci present on the homoeologous chromosomes 1 and 6 of the three homoeologous genomes A, B, and D. The effect of deleting individual gluten loci was analyzed in a set of deletion lines of *T. aestivum* cv. Chinese Spring with regard to the level of T-cell stimulatory epitopes (Glia-α9 and Glia-α20) and to technological properties of the dough including mixing, stress relaxation, and extensibility.

Deletion of loci encoding ω-gliadins, γ-gliadins, and LMW-glutenins located on the short arm of chromosome 1D, reduced the number of T-cell stimulatory epitopes and caused minor deterioration of dough quality by increase of elasticity. Deletion of loci encoding α-gliadins located on the short arm of chromosome 6D, resulted in a significant decrease in T-cell stimulatory epitopes. In parallel, the dough became more stiff and less elastic, which is an improvement for 'Chinese Spring' dough.

We demonstrated that α-gliadins from wheat can largely be compensated by addition of avenins from oat to the flour to meet technological requirements.

1. Introduction

Dough quality for bread making highly depends on the presence and composition of wheat gluten proteins. These gluten proteins are composed of monomeric gliadins and polymeric glutenins, which together determine the bread-making quality (Branlard et al., 2001; Shewry et al., 1997). Glutenins are responsible for the elastic properties of the dough, whereas the gliadins are responsible for the viscous properties. High molecular weight glutenin subunits (HMW-GS) and low molecular weight glutenin subunits (LMW-GS) can form large polymers by inter-molecular disulfide bonds. The LMW-GS can be divided in typical LMW-GS B-subunits that can act as chain extenders because of their ability to form inter-molecular disulfide bonds and in gliadin-like LMW-GS C- and D-subunits that can act as chain terminators because they lack the ability of forming several inter-molecular disulfide bonds (D'Ovidio and Masci, 2004). The amount of large glutenin macro polymers (GMP) is an important quality parameter and strongly relates to dough properties (Don et al., 2003; Gupta et al., 1996; Popineau et al., 1994; Singh et al., 1990; Weegels et al., 1996). Gliadins can be divided into α/β-, γ-, and ω-gliadins (Woychik et al., 1961) which have specific water-retaining capacities important for dough viscosity.

In bread production, the dough mixing process (i.e. the controlled addition of water to the wheat flour) is a very important step (Millar, 2006; Skerritt et al., 1996; Weegels et al., 1996). During mixing, the gluten proteins are rehydrated and homogenously distributed throughout the dough. Upon resting, a three-dimensional gluten network structure is formed that will determine the viscoelastic and gas-holding properties of the dough. Detailed mixing and rheological studies have revealed a direct relationship between gluten composition and structural and dough properties (for a review see Hamer et al., 2009). For example, the ratio between glutenins and gliadins is especially relevant for the viscous vs. elastic properties of dough. A high ratio of monomeric vs. polymeric proteins will lead to a less stiff and more viscous dough (Song and Zheng, 2007, and references therein).

Apart from their role in dough quality, gluten proteins can affect health in genetically susceptible individuals. Many gluten proteins contain T-cell stimulatory epitopes that can cause celiac disease (CD; gluten intolerance) (Sollid, 2002). After consumption of gluten

* Corresponding author. Tel.: +31 317 480974; fax: +31 317 418094.
E-mail address: hetty.busink@wur.nl (H.C. van den Broeck).

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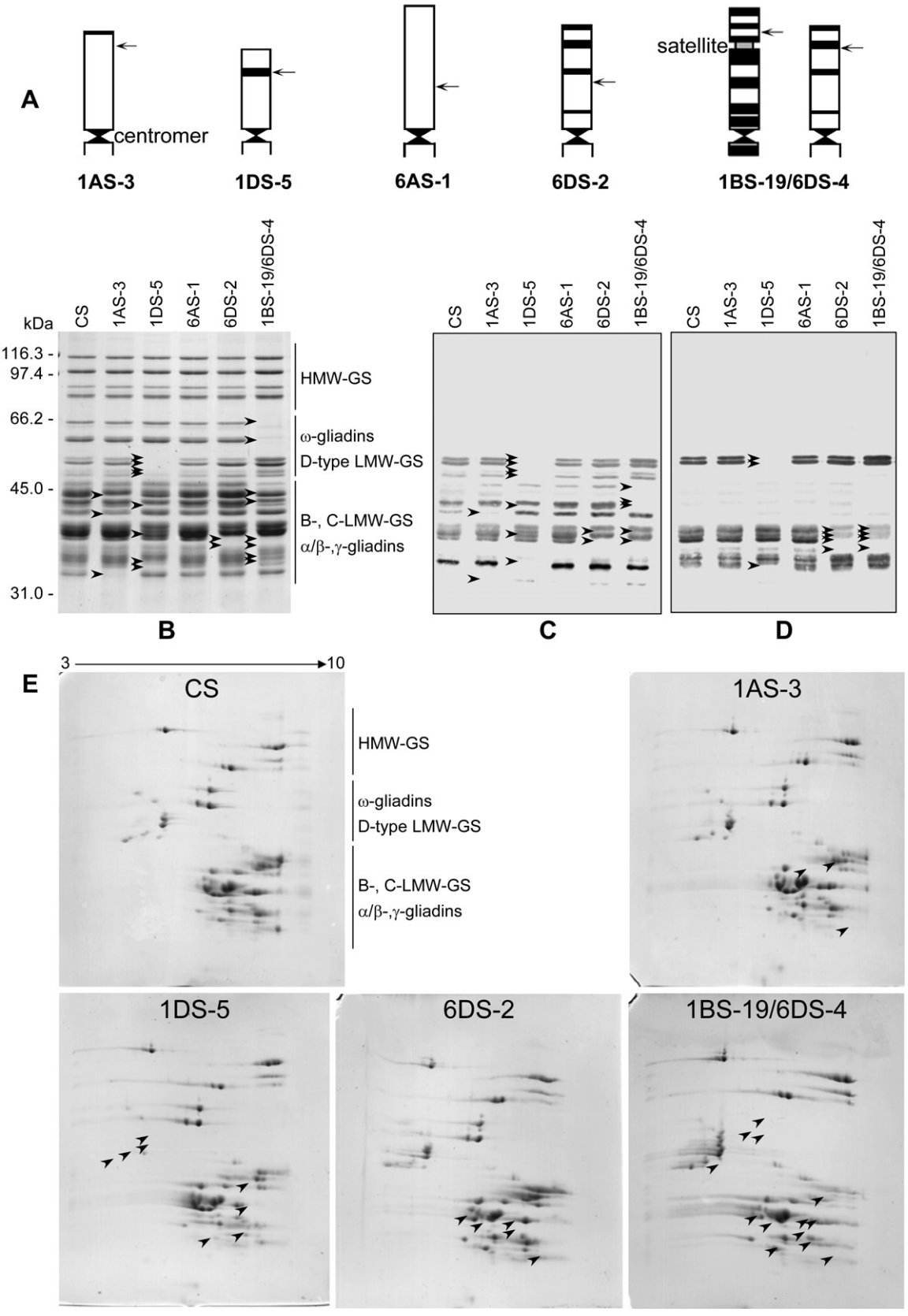

Fig. 1. Analysis of 'Chinese Spring' deletion lines of the short arm of chromosome 1 and 6. (A) Physical maps of the short arms of wheat chromosomes 1A, 1B, 1D, 6A, and 6D from centromer to telomeric ends (Wheat Genetic and Genomic Resources Centre, Kansas State University, USA). Arrows on the right of each chromosome indicate the deletion lines with their breakpoint (indicated as fraction length from the centromer). The banding patterns within the chromosomes are according to Gill et al. (1991). Gluten protein extracts from flour analyzed by: (B) SDS-PAGE (10%) stained with PageBlue. (C) Immunoblot using mAb Glia-α9. (D) Immunoblot using mAb Glia-α20. (E) 2-DE gels stained with PageBlue. CS: Chinese Spring wild type. Arrow heads indicate absent gluten protein bands.