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Changes in bread-making quality attributes of bread wheat varieties cultivated in Spain during the 20th century

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ABSTRACT

Genetic gains in quality traits were assessed in grain samples from 4 field experiments involving 16 bread wheat varieties representative of those most widely cultivated in Spain during the 20th century. The allelic composition at three glutenin loci (*Glu-A1*, *Glu-B1*, and *Glu-D1*) was obtained by PCR-based DNA markers and published references. From 1930 to 2000 grain protein content decreased by $-0.030\%\ y^{-1}$, or in relative terms by $-0.21\%\ y^{-1}$, but the protein produced per hectare increased by $0.39\%\ y^{-1}$. Alveographic tests revealed significant changes in dough rheological properties. Dough strength (W) and tenacity (P) increased at relative rates of $1.38\%\ y^{-1}$ and $0.99\%\ y^{-1}$, respectively, while dough extensibility (L) decreased by $-0.46\%\ y^{-1}$, resulting in an increase of $1.45\%\ y^{-1}$ in dough equilibrium (P/L). The rise in protein quality could be related to the replacement of the null allele by subunits 1 or 2* at *Glu-A1* and the prevalence of subunits 7+8 and 5+10 at *Glu-B1* and *Glu-D1* loci, respectively, in the most recent varieties. Dough extensibility was affected by water input during the crop cycle, this relationship being partially explained by the presence of the 5+10 HMW glutenin subunit. Fermentation tolerance was improved in the most modern varieties. Collapse during fermentation was avoided only in doughs with a $W \geq 159\ J \times 10^{-4}$ and a $P/L \geq 0.56$ mm H_2O mm^{-1}, levels achieved by most of the modern varieties. The over-strong and unbalanced rheological properties of some modern varieties resulted in highly porous doughs, and no clear advances in dough maximum height during fermentation were attained.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is the second most important staple crop in the world, providing 18% of the daily calorie intake worldwide in 2011 (FAOSTAT, 2011). Given its predominance in human diets, cultivated wheat has to meet the specific quality criteria for the manufacture of the wide range of food products derived from it.

During the last century, in many countries including Spain (Royo and Briceño-Félix, 2011), wheat breeding efforts concentrated on yield increases, with grain quality improvement being a secondary breeding objective. Furthermore, studies that assess genetic gains have frequently referred to yield and associated traits, while the enhancement of grain quality has received little attention. These studies, which usually involve historical series of genotypes, allow breeders to evaluate selection efficiency and to identify traits associated with genetic gains. Research into genetic gains in wheat has been conducted in several European countries, such as Italy (Canevara et al., 1994), France (Brancourt-Hulmelet al., 2003), UK (Austin et al., 1989), and more recently Spain (Royo et al., 2007; Sanchez-Garcia et al., 2013; Subira et al., 2014). When addressed, wheat quality is tackled mainly through attributes such as test weight or protein content; however, the evaluation of key end-use quality traits, such as the rheological properties of dough or fermentation performance, are frequently neglected.

Wheat end-use quality is strongly related to the properties of the gluten matrix, which are determined primarily by the quantity and quality of gluten proteins (Finney and Barmore, 1948). High molecular weight glutenin subunits (HMW-GS) are of particular

Abbreviations: TW, test weight; PC, grain protein content; GPpHa, grain protein produced per hectare; P, tenacy; L, extensibility; W, strength; *P*/*L*, configuration ratio; DMH, dough maximum height; DFH, dough final height at the end of the 3 h fermentation; DHL, dough height lost between maximum and final height; T_{DHM}, time to DMH; VP_{CO2}, volume of total CO_2 produced; VR_{CO2}, volume of CO_2 retained by the dough; T_{CO2}, the time to CO_2 release; RQ, retention coefficient.

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interest in bread wheat because of their large influence on the rheological properties of dough (Branlard and Dardevet, 1985; Payne et al., 1987; Vawser and Cornish, 2004) and their involvement in the genotype x environment interaction, particularly regarding gluten strength and extensibility (Blumenthal et al., 1995; Johansson et al., 1999; Panozzo and Eagles, 2000; Hristov et al., 2010). Subunits 1 and 2* encoded at *Glu-A1* loci, and subunit 5 + 10 at *Glu-D1* are considered suitable for promoting dough strength and have contributed to enhancing the quality of bread wheat in a number of countries, among them France and Italy (Mesdag and Donner, 2000). In contrast, other subunits, such as the null allele at *Glu-A1*, is considered to have a negative effect (Payne et al., 1987). Although the relationship between both dough strength (*W*) and Zeleny sedimentation volume and the allelic composition at *Glu-1* was examined in Spanish varieties (Payne et al., 1988), there is still no information regarding changes induced by breeding in the HMW-GS composition and their effect on quality traits.

In southwestern European countries, bread wheat is consumed mainly as baguette bread, and the dough properties during mixing and fermentation are included in the quality criteria addressed by breeding programs. The study of the response of dough to common constraints that occur during baking is of relevance in order to predict end-use quality (Dobraszczyk and Morgenstern, 2003) since the rheological properties of dough determine product functionality (Dobraszczyk and Morgenstern, 2003). Biaxial extension parameters, such as dough strength or extensibility, usually obtained through Chopin's alveograph procedures, are among the bread-making quality attributes used to characterize wheat samples by official quality classifications (Mesdag and Donner, 2000). All the rheological tests performed on dough seek to predict behavior in response to bread-making processes, such as mixing or fermentation. During the latter, gas cells in the dough expand, causing the final volume of the loaf, which is critical for bread appeal (Dobraszczyk et al., 2000). In spite of this, most fermentation tests are performed on yeast-free doughs at room temperatures, conditions in which the rheological properties of the dough may differ from the fermentation conditions found in commercial bread production lines (Dobraszczyk and Morgenstern, 2003). To reliably determine the fermentation behavior of wheat varieties, recent studies have proposed the use of fermentation monitoring techniques, particularly the rheofermentometer F3 (Ktenoudaki et al., 2010, 2011).

The cataloging of bread wheat varieties on the basis of quality standards is critical not only to establish their compliance with industrial requirements, but also to ascertain the success of breeding programs to address quality improvement. The first classification of bread wheat quality in Spain was implemented in 1945 (Mesdag and Donner, 2000), but it did not include the alveographic parameters already used for quality classification in other European countries (Mesdag and Donner, 2000). Alveographic parameters were first introduced in Spain for wheat quality characterization in the 1970s (Mesdag and Donner, 2000), and not until 2010 was an official classification—similar to those used in neighboring countries and mainly based on alveographic parameters—proposed. This lack of regulation may have contributed to traditionally large imports of bread wheat grain, mainly of high quality, destined to the local milling and baking industries, which in 2012 accounted for up to 51.6% of the total wheat consumption in the country (MAGRAMA, 2012). The enhancement of bread wheat quality in Spain is therefore, a major challenge for present and future breeding programs.

The objectives of the present study were: (i) to investigate the changes caused by bread wheat breeding in Spain during the 20th century on the quality attributes related to bread-making performance; (ii) to assess the relationship between quality improvement and changes in the HMW-GS composition, and (iii) to analyze whether breeders' selection for good rheological attributes led to an improvement in the variety performance during fermentation.

2. Materials and methods

2.1. Plant material

A collection of 16 bread wheat varieties representative of those most widely cultivated in Spain during the 20th century was gathered. These varieties were grouped into three breeding periods (BPs) on the basis of their year of release or cultivation period, as follows: (i) Spanish landraces grown before 1940; (ii) initial varieties

Table 1
Description of the varieties used in the study and their allelic composition at the high molecular weight glutenin subunits (HMW-GS) loci.

Variety	Pedigree	Origin	Year of release in Spain	HMW-GS[a]			References
				Glu-A1	Glu-B1	Glu-D1	
Landraces							
Aragón 03	Selection of the landrace "Catalan de Monte"	Spain	<1940	**Null**	20	4 + **12**	Carrillo et al., 1988
Barbilla	Landrace	Spain	<1940	**?**[b]	NI	NI + **12**	
Candeal	Landrace	Spain	<1940	**Null/1**	NI	**5 + 12**	
Initial varieties							
Impeto	Frassineto-405/Villa-glori	Italy	1950	**1**	7 + 8	2 + **12**	Mesdag and Donner, 2000
Mara	Autonomia/Aquila	Italy	1947	**Null**	7	2 + **12**	Dencic and Borojevic, 1991
Estrella	Mon-desir/Ardito//Mouton-a-epi-rouge/k-3/3/ Mouton-epi-rouge	France	1952	**Null**	7 + 8	2 + **12**	Branlard et al., 2003
Pané 247	L-4/Mentana	Spain	1955	**Null**	7 + 8	2 + **12**	Peña, 2004
Modern varieties							
Yecora	Ciano-67//Sonora-64/Klein-rendidor/3/Siete-cerros-66	CIMMYT	1972	**1**	17 + 18	**5 + 10**	CRC, 1998
Cajeme	Ciano-67//Sonora-64/Klein-rendidor/3/Siete-cerros-66	CIMMYT	1972	**1**	17 + 18	**5 + 10**	CRC, 1998
Anza	Lerma-rojo-64//Norin-10/Brevor/3/3*Andes-enano	CIMMYT/USA	1974	**Null**	7* + 8	2 + **12**	León et al., 2009
Marius	Cadet//Thatcher/Vilmorin-27/3/Ariana/Fundulea	France	1980	**Null**	7 + 9	2 + **12**	Branlard et al., 2003
Rinconada	Unknown	CIMMYT	1981	**1**	7 + 8	**5 + 10**	Peña, 2004
Soissons	Iena/hn-35	France	1990	**2***	7 + 8	**5 + 10**	Branlard et al., 2003
Gazul	Unknown	Spain	1992	**2***	7 + 8	**5 + 10**	Peña, 2004
Isengrain	Apollo/Soissons	France	1998	**Null**	7 + 8	**5 + 10**	Lemelin et al., 2005
Califa Sur	Unknown	Spain	2001	**1**	7 + 8	**5 + 10**	Lucas et al., 2010

NI: Not identified.
[a] In bold-type are identified the HMW-GS characterized in the present study through PCR-based DNA markers.
[b] It is neither the null, the 1 nor the 2* subunit.