LWT - Food Science and Technology 78 (2017) 160–164

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effect of quantity of HMW-GS 1Ax1, 1Bx13, 1By16, 1Dx5 and 1Dy10 on baking quality in different genetic backgrounds and environments

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ARTICLE INFO

Article history:
Received 16 August 2016
Received in revised form
14 December 2016
Accepted 17 December 2016
Available online 20 December 2016

Keywords:
Baking quality
Glutenin subunits
Wheat

ABSTRACT

Four hard red bread wheat cultivars with the same high molecular weight glutenin subunit (HMW-GS) composition (1Ax1, 1Bx13, 1By16, 1Dx5 and 1Dy10), developed for each of two production regions (irrigation and dryland) in South Africa, were tested at two representative locations of each region for two consecutive seasons to determine how different genetic backgrounds, locations and seasons influenced the quantity of the HMW-GS expressed, and how this affected baking quality characteristics. Location contributed the most to the observed variation in the bread making quality characteristics. In the irrigation region, subunit 1Ax1 was correlated significantly to most quality traits, especially flour protein and wet gluten content. In the dryland region, significant positive correlations for similar characteristics were expressed by subunit 1Dx5, showing that the influence of these subunits were not constant across the localities. This also highlighted the importance of the x-type subunits in the bread wheat quality breeding programs of South Africa.

1. Introduction

High molecular weight glutenin subunits (HMW-GS) are a group of gluten proteins that play an important role in the viscoelastic properties essential for the formation of wheat dough (Goesaert, Brijs, & Delcour, 2005). Although they account for a small percentage of wheat storage proteins, they are the most important genetic factor determining flour technological quality. Different combinations of HMW-GS alleles were reported to influence the bread making quality of wheat cultivars. It is generally accepted that subunits 1 and 2* at *Glu-A1*, 7 + 8/9, 13 + 16 and 17 + 18 at *Glu-B1* and 5 + 10 at *Glu-D1* loci are related to higher dough strength and loaf volume, whereas other allelic variations have negative effects on bread quality (Deng, Tian, & Liu, 2004; Jood, Schofield, Tsiami, & Bollecker, 2001; Singh, Donovan, & MacRitchie, 1990). Quantity of the HMW-GS also plays a crucial role in bread-making quality (Bordes, Branlard, Oury, Charmet, & Balfourier, 2008). Variations in dough rheological properties are largely determined by the genotype, but the environment and its interactions with genotype could play an important role in the expression of the end-use quality of a genotype (Souza, et al, 2004). Environmental conditions were reported to contribute largely to the quantitative variation in HMW-GS, while the presence of HMW-GS was generally constant for genotypes across growing seasons and localities (Horvat et al., 2006; Jing, Jiang, Dai, & Cao, 2003).

South Africa has three wheat production regions, the Western Cape region (winter rainfall dryland) where spring wheat is grown; Free State region (summer rainfall dryland) where winter and intermediate wheat is grown; and the Northern region (mainly irrigation) where spring wheat is grown. There are separate breeding programs for each of these regions. Wheat is used almost exclusively for bread production in South Africa. This study was conducted to investigate the effect of quantity of HMW-GS 1Ax1, 1Bx13, 1By16, 1Dx5 and 1Dy10 on bread making quality characteristics in four different wheat cultivars in two representative locations of two production regions of South Africa (irrigation and winter rainfall dryland) over two seasons.

2. Materials and methods

Long term meteorological data for all sites used is given in Table 1. Experimental sites for the irrigation region were Upington and Vaalharts (Table 2). A full irrigation schedule according to standard production practises in the region was applied through centre-pivots and amounts peaked in early to mid-summer from onset of anthesis to end of grain filling. Seeding rate was

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http://dx.doi.org/10.1016/j.lwt.2016.12.031

Table 1
Long-term meteorological data (1995–2013) for the winter rainfall dryland and irrigation regions in South Africa.

	Average maximum temperature (°C)		Average minimum temperature (°C)		Total rainfall (mm)		Total relative evapotranspiration (mm)	
	Dryland winter rainfall	Irrigation	Dryland winter rainfall	Irrigation	Dryland winter rainfall	Irrigation	Dryland winter rainfall	Irrigation
January	28.06	35.97	16.26	18.48	13.23	43.30	150.32	206.02
February	28.11	35.39	16.56	18.15	26.50	32.62	119.96	167.40
March	27.19	33.64	14.92	15.73	27.40	27.94	112.42	156.77
April	23.86	29.24	11.74	10.98	38.59	20.24	72.85	109.61
May	21.69	25.27	9.51	6.11	41.89	15.73	63.62	92.41
June	18.46	21.95	7.28	1.51	47.73	12.78	47.88	65.68
July	18.31	22.65	6.06	1.65	51.24	3.40	46.91	76.73
August	18.72	24.12	5.89	2.88	48.48	1.14	61.87	100.91
September	20.74	28.18	7.30	5.88	19.44	0.28	82.60	133.72
October	22.24	30.75	10.43	10.56	51.14	20.49	104.09	167.95
November	24.21	33.06	12.25	13.11	47.89	15.40	120.01	191.80
December	26.02	35.00	14.62	15.90	20.10	34.76	145.21	209.69
Year	23.13	29.60	11.07	10.08	433.63	228.09	1127.73	1678.68

Compiled from ISCW data (Guidelines for Production of Small Grains in the Summer and Winter Rainfall Areas, 2014).

Table 2
Site, planting and harvesting data of the locations used within the two production regions.

Trial	Test site	GPS coordinates	Elevation (masl)	Planting	Harvesting
Dryland winter rainfall	Riversdale	34°6′37.31″ S 21°15′16.89″ E	209	End May	Mid November
	Moorreesburg	33°8′60″ S 18°40′0″ E	151	Mid May	End November
Irrigation	Upington	28°27′0″ S 21°15′0″ E	801	Early May	End November
	Vaalharts	27°56′47.96″ S 24°48′12.001″ E	1141	Early May	Mid November

200 kg ha^{-1}. Irrigation plots were seeded with a Wintersteiger Plotman (Wintersteiger AG, Austria). A balanced soil fertility status was achieved through application of a commercial fertilizer mixture of 2N (nitrogen):3P (phosphorous):4K (potassium) (28) bought from the local cooperation and Koch Advanced Nitrogen (KAN) (28) to a total amount of 280 kg N ha^{-1} in split applications of 160 kg N ha^{-1} at seeding, 60 kg N ha^{-1} between tillering and stem elongation and 60 kg N ha^{-1} between flag leaf to anthesis.

The dryland winter rainfall region is located along the southern and western regions of the Cape Province. It has a Mediterranean-type climate with mild minimum and maximum temperatures (Table 1) throughout the growing period of wheat and allows cultivation of spring-type varieties. Approximately half of the annual rainfall occurs from May to August and coincides with the seeding period for the region.

The two experimental sites planted in this region were Moorreesburg and Riversdale (Table 2). Seeding density was sufficient for establishing 250 to 300 plants per m^2. A total of 130 kg N ha^{-1} was applied through a commercial mixture of 4N:1P:1K (31). Fertilizer application was split between 100 kg N^{-1} during seeding and the remaining 30 kg N ha^{-1} applied as KAN (28) between tillering and stem elongation.

Cultivars PAN3489 and SST822, were both planted in each of the irrigation sites (Upington and Vaalharts) whereas cultivars SST027 and SST047 were both planted in each of the dryland sites (Mooreesburg and Riversdale). These cultivars were selected due to their common HMW-GS composition (HMW-GS 1Ax1, 1Bx13, 1By16, 1Dx5 and 1Dy10).

All trials were planted as randomized complete block designs with three replications. Trials were planted with six-row commercial Wintersteiger seeders adapted for planting yield plots, and field plots of experiments in each region were harvested with Wintersteiger Plot combines (Wintersteiger AG, Austria). The seed was air-dried, cleaned and quality analysis done at the Agricultural Research Council - Small Grain Institute (ARC-SGI) in Bethlehem. Wheat samples were conditioned for 18 h prior to milling, according to AACC method 26–95.01 and milled on a laboratory pneumatic mill (Bühler model MLU-202, Bühler-Miag, Uzwil, Switzerland). The resistance of dough to extension was measured with the approved method described in AACC 54–30.02, using a Chopin Alveograph (Chopin Technologies, Villeneuve-la-Garenne Cedex, France) (AACC, 2010). The SDS sedimentation value was determined using a modification of the AACC 56–70.01 method, where 5 g of flour samples were used and results recorded in ml. Flour (10 g) was washed with 20 g/L NaCl solution and used on a glutomatic system (Glutomatic 2100, Perten Instruments, Springfield, USA) for the measurement of wet gluten content using AACC method 38–12.02. The percentage break flour yield (AACC method 26–21.02) was also determined (AACC, 2010). Flour protein content was established with AACC method 46–30.01. Loaf volume was determined by rapeseed displacement following the optimised, straight dough baking procedure (AACC 10–10.03). Alveograph analyses (AACC method 54–30.02) were performed on a Chopin alveograph (Chopin Technologies, Villeneuve-la-Garenne Cedex, France). Mixographs (35 g fixed-bowl model. National Manufacturing Corporation of Lincoln, Nebraska, USA) were constructed as two envelope curves and one midline curve and Mixsmart software (Mixsmart for Windows) was used to measure the mixograph peak value.

Reverse phase high performance liquid chromatography (RP-HPLC) was done according to the modified method of Vawser and Cornish (2004). Deionised water (Elix® Millipore, Molsheim, France) was used to prepare solvents and eluants. Flour samples (200 mg) were extracted twice in 500 μl of freshly prepared 500 ml l^{-1} propanol containing 10 g l^{-1} dithiothreitol (DTT) followed by vortexing for 30 s. Samples were incubated at 60 °C for