Journal of Cereal Science 63 (2015) 134–139

Contents lists available at ScienceDirect

Journal of Cereal Science

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

The influence of abiotic stress conditions on dough mixing characteristics of two hard red spring wheat cultivars

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ARTICLE INFO

Article history:
Received 27 August 2014
Received in revised form
11 March 2015
Accepted 29 March 2015
Available online 17 April 2015

Keywords:
Abiotic stress
Mixsmart
Wheat

ABSTRACT

Two commercial hard red spring wheat cultivars were exposed to high and low temperatures, as well as drought stress when the main tiller kernels were at the soft dough stage. The trial was done in the greenhouse for two consecutive seasons to determine the effects of these stress conditions on protein content, SDS sedimentation and selected Mixsmart characteristics. Heat stress had the largest effect on mixing characteristics. Heat and drought stress caused a significant increase in flour protein content of both cultivars and had similar effects on mixing characteristics. The Mixsmart characteristics associated with dough strength were increased by heat and drought stress. Cold stress caused a slight increase in protein content of the cultivars, but in general caused a reduction in dough strength as measured with Mixsmart characteristics. The reaction of Mixsmart characteristics to heat and drought stress was much larger in Duzi than in Kariega, confirming that there is a large genotype effect in rheological characteristics.

1. Introduction

There is an increase worldwide of heat and drought events (IPCC, 2001). These two stresses are often related. In wheat these two types of stress can have severe effects on rheological characteristics of the dough (Li et al., 2013; Zhang et al., 2013).

The mixograph performs certain rheological measurements during dough mixing and is a good predictor of end-use quality (Bordes et al., 2008). In general, strong doughs have long mixing times, high peak values and band widths and low resistance to breakdown (Mao et al., 2013). Peak time is influenced by protein content and associated with the glutenin fraction of the flour. As peak time increases, dough extensibility decreases and dough stability, elasticity and mixing tolerance increase (Hoseney, 1994).

Neacşu et al. (2009) indicated five mixograph parameters to be effective for selecting processing quality in breeding programmes and they are descriptive of all basic rheological aspects of mixing properties. These parameters are the initial slope (indicative of water-absorption), peak time (indicative of mixing requirement), peak height (indicative of dough strength), end-width (indicative of extensibility) and breakdown (indicative of stability). These parameters explained 91% of the variance observed in loaf volume. Wikström and Bohlin (1996) also reported five mixogram parameters namely build-up (the phase after initial build-up, up to the maximum height at the top of the curve), peak time, initial width, area below the mixogram curve and peak height to be effective, when combined with protein content, in predicting loaf volume. These parameters explained 92.8% of the variance in loaf volume.

Using Mixsmart software, 44 parameters can be measured on a single mixogram curve (Pon et al., 1989). The software constructs a midline curve, which divides the mixogram into two envelope curves where both the upper envelope as well as the midline curve are then analysed (Walker and Walker, 1992; Dobraszczyk and Schofield, 2002). The 44 parameters result from measurements made at different heights, widths and slopes as well as areas on the mixogram curve (Walker and Walker, 1992). Curve-height measurements, determined as a percentage of the full scale, are informative about dough consistency. Curve-width measurements are the difference between the top and bottom envelope, and midline-width measurements obtain some information from the top envelope. Curve-widths are indicative of the dough's tolerance to mixing. Slopes are determined by dividing the value by the certain time in question, where small values will be indicative of flat, stable

Abbreviations: AACC, American Association for Cereal Chemists; m.b., moisture base; SDS, sodium dodecyl sulphate.

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http://dx.doi.org/10.1016/j.jcs.2015.03.007
0733-5210/

curves and large values will be indicative of a quick rise and/or breakdown which are undesirable, indicative of poor tolerance to mixing and sensitivity to the mixing time. Areas under the midline curve are indicative of dough strength and exhibit correlations with other parameters.

Variations in dough rheological properties are influenced by genotype but also by environment (Flagella et al., 2010; Li et al., 2013). The aim of this study was to determine the effect of high and low temperatures and drought stress at the soft dough stage of kernel development in two hard red commercial spring wheat cultivars.

2. Materials and methods

Two commercial hard red spring wheat cultivars Kariega (GluA1 2*, GluB1 17 + 18, GluD1 5 + 10) and Duzi (GluA1 2*, GluB1 17 + 18, GluD1 2 + 12) with excellent baking quality, were planted in 3 l pots filled with soil in the greenhouse in a randomized complete block design with two factors (treatments and cultivars) and three replications. Four treatments were applied to the two cultivars where each treatment was applied to 15 pots per replication, three plants per pot. Greenhouse temperatures were set at 15 °C/22 °C (night/day). Fertilization was applied to assure optimal growing conditions. Optimal watering of the pots was done throughout the experiment for the two temperature regimes and the control, and up to the soft dough stage for the drought stress experiment. The trial was done from May to the end of October in 2012 and was repeated in 2013.

As soon as the main tillers in each pot reached soft dough stage, treatments commenced. The soft dough stage is when wheat kernels contain approximately 50% moisture and is classified as a value of 85 on the Zadoks scale (Zadoks et al., 1974).

For the cold treatment, plants were placed in climate cabinets in the following cycle: 5 °C for 30 min then 1 °C less every 30 min until it reached −5.5 °C, then it was left for three hours after which it was reduced to −2 °C for 30 min, then 0 °C for 30 min; then 2 °C for 30 min; then 5 °C for 30 min; then back to green-house to optimal conditions. This treatment was structured in such a way to closely resemble field conditions in the spring wheat planting areas where cold spells are often experienced after anthesis. For the heat treatment, plants were placed in climate cabinets at 32 °C/15 °C (day/night) temperatures for 72 h and then returned to the green-house.

To induce drought stress, watering was withheld until severe wilting was visible and then watering was resumed. All stress treatments were only applied once. The control treatment was left in the green-house under optimal conditions until harvesting. At harvesting the seed of plants of the 15 pots per replication were bulked for each of the treatments and cultivars. After harvesting, wheat samples were conditioned for 18 h according to AACC procedure 26–95 (AACC, 2000) after which they were milled on a laboratory, pneumatic mill, Bühler model MLU-202.

A 35 g-mixograph was applied with Mixsmart software. Protein content (AACC procedure 46–30, 2000) and moisture content of the white flour samples (AACC procedure 44–15A, 2000) were used for the mixogram analyses in order to determine the flour weight and water volume required. The following formulas as developed by Walker et al. (1997) were used to determine the required weight of flour and the required volume of water:

Table 1
Mean square values of some quality and Mixsmart characteristics measured on two wheat cultivars for four treatments and two seasons.

	Cultivar	Season	Treatment	CultxSeason	CultxTreat
Flour protein content	0.91	371.42**	6.33*	0.81	0.25
SDS sedimentation	875.52**	2625.52**	31.52	2.52	49.08
Envelope left slope	154.13	35,766.82**	256.74	705.59	2173.02**
Envelope left value	798.56*	2303.55**	139.92	907.49*	89.65
Envelope left width	28.27	1889.64**	90.91	385.44**	200.93**
Envelope peak integral	1085.73**	523.89**	40.39	332.49**	3.74
Envelope peak time	1.24**	4.50**	0.08	0.61**	0.03
Envelope peak value	13.63	3377.03**	15.95	6.13	22.18
Envelope peak width	233.44	3602.65**	15.50	10.97	120.18
Envelope right integral	3924.83**	73.16	235.72*	641.09**	93.58
Envelope right slope	482.22**	28,486.97**	188.48*	19.89	25.40
Envelope right time	2.27**	16.54**	0.43*	0.43	0.15
Envelope right value	344.25**	348.97**	9.66	35.41*	9.71
Envelope right width	258.47**	229.92**	4.26	177.81**	2.77
Envelope tail integral	6433.66**	66.58	554.77*	925.39*	224.81
Envelope time × integral	8257.81**	918.99**	213.41**	1906.49**	12.38
Envelope time × value	423.44**	18.40**	9.94**	20.42**	2.14
Envelope time × width	139.34**	112.29**	9.09**	26.35**	1.22
Envelope Tail Value	431.02**	41.24**	9.51*	30.44**	0.33
Envelope tail width	160.22**	230.68**	1.33	75.41**	2.52
Midline left integral	3816.31**	1897.16**	34.90	259.56*	20.71
Midline left slope	204.47**	579.18**	65.91*	55.00	52.64
Midline left time	2.47**	3.58**	0.04	0.21*	0.03
Midline left value	624.44**	19.27	7.43	0.02	3.23
Midline peak integral	5920.33**	551.75*	73.94	141.31	17.82
Midline peak time	2.52**	3.63**	0.05	0.20*	0.03
Midline peak value	13.68	2290.60**	29.46	15.23	11.83
Midline peak width	247.04*	594.08**	182.40*	693.77**	245.94**
Midline right integral	8415.04**	213.49	100.37	481.01**	4.50
Midline right slope	17.22**	116.58**	3.25	1.43	3.29
Midline right time	2.94**	4.14**	0.02	0.30**	0.05
Midline right value	147.04**	0.00	13.45**	4.16	3.76
Midline right width	304.25**	617.17**	11.58**	180.87**	4.04

$^*P \leq 0.05$, $^{**}P \leq 0.01$.