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CULTIVAR AND ENVIRONMENT EFFECTS ON DOUGH STRENGTH IN A SET OF WINTER WHEAT CULTIVARS, GROWN IN DIVERSE ENVIRONMENTS AND MANAGEMENT PRACTICES

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ABSTRACT

Dough strength is an important component of wheat baking quality. The aim of this research was to estimate the effects of cultivars and environment on three dough strength parameters, in a set of 23 Romanian and foreign winter wheat cultivars, grown under 21 diverse environments and management practices. Reomixer peak height, time to peak and area below the mixing curves were chosen as possible estimators of dough strength. The effect of years and crop management on the variation of the three indices was much larger than the effect of cultivars, but differences between cultivars were also significant when tested against the Genotype*Environment interaction. Grain protein concentration was significantly correlated with peak height and area below mixing curve, explaining about one third of their variation. Positive deviations from the regression between protein content and the two Reomixer indices identified a few cultivars with intrinsic high dough strength (Josef, Delabrad 2, Capo), while negative deviations identified cultivars with intrinsically weaker gluten. Interesting differences were noticed among cultivars for the stability of all three indices, suggesting possibilities of genetic progress in dough strength stability over environmental conditions. Peak time was not correlated with peak height or area below mixing curve, while peak height and area below the mixing curve were very strongly correlated.

Key words: Dough strength, Reomixer, peak height, peak time, area below mixing curve.

INTRODUCTION

Dough strength has been defined as the property of the flour proteins enabling the dough to retain gas during fermentation to give a higher volume loaf of bread. Strength is considered to result from a balance among three physical dough characteristics: extensibility, elasticity and tenacity (Bender, 2012).

Wheat dough strength can be assessed by several methods, including the Extensigraph test, the Mixograph test, the Alveograph test, the Farinograph test, etc. When using Mixograph type devices, peak height, but also the area below the mixograph curve (torque x minutes) and peak time (minutes), have been used to measure dough strength (Gaines et al., 2006).

Dough strength is significantly influenced mostly by the alleles at genes controlling high molecular weight glutenin subunits (Antes and Wieser, 2001), but also at a smaller extent by alleles at low molecular weight glutenin loci and by certain gliadins (Metakowsky et al., 1997). Other genes could be involved since Arbelbide and Bernardo (2006) also detected QTLs for dough strength on chromosome 5B. Besides genetic factors, dough strength is influenced by nitrogen availability (Johansson et al., 2004), by years (Johansson et al., 2002), and especially by temperature during grain filling (Randall and Moss, 1990).

As high dough strength is an important component of baking quality, the aim of this research was to estimate the effects of cultivars and environment on dough strength in a set of winter wheat cultivars, grown in diverse environments and management practices.

MATERIAL AND METHODS

Grain samples of 18 Romanian (Flamura 85, Dropia, Boema, Crina, Dor, Delabrad 2, Faur, Glosa, Gruia, Izvor, Litera, bred at

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NARDI Fundulea, and Lovrin 34, Alex, Ciprian, Şimnic 30, Şimnic 50, Albota 69, Trivale, bred at other Romanian breeding centers) and 5 foreign varieties (Capo and Josef from Austria, Apache and Exotic from France, Serina from Hungary) from harvest years 2008, 2009 and 2010, tested in yield trials in environments that were widely different in Nitrogen availability and yield potential, were analysed for gluten strength. Environments included:

- NARDI Fundulea and ARDS Şimnic, in three technological systems: organic, conventional, fertilized with recommended doses of nitrogen and conventional without additional nitrogen. Details about crop management in these three technological systems were presented by Neacşu et al. (2010).

- ARDS Albota, fertilized with recommended doses of nitrogen and without additional nitrogen and dough strength was estimated using parameters "peak height", "peak time" and "area below the mixing curve", determined with the Reomixer, a mixograph type device. Details about the device and about estimated parameters were given elsewhere (Neacşu et al., 2009; Stanciu and Neacşu, 2008).

Peak height, time to peak and area below the mixing curves were chosen as possible measures of dough strength.

Protein concentration was determined using a Perten infrared analyzer.

ANOVA was used to analyse the results obtained for all parameters, significance being tested against the interaction between cultivars and environments (years*locations*crop management).

Stability of gluten strength parameters across environments was analysed using:

- amplitude of variation: $Ax = x_{Max} - x_{Min}$

- coefficient of variation: $CV_i = S_i / \bar{x}_i * 100$

Correlation analysis was used to study the relationship between average protein concentration and gluten strength parameters, and among these parameters.

RESULTS AND DISCUSSION

ANOVA showed that the effects of cultivars, for all dough strength indices, were significant when tested against the G*E interaction. However, the environmental effects, which included years, locations and crop management systems, were much more important, being about 9 to more than 20 times higher than cultivar effects (Table 1). Strong influence of the environment has been often reported both on yield (Mustăţea et al., 2009) and on protein content and quality (Triboi et al., 1990 and 2000).

Table 1. ANOVA for dough strength parameters of 23 cultivars in 21 environments

Source of variation	*DF*	F values for			F crit
		Peak height	Peak time	Area below mixing curve	
Cultivars (G)	22	5.53	4.74	4.51	1.57
Environments (E)	20	94.51	36.93	94.31	1.59
Interaction G*E	440				
Total	482				

Peak height varied widely, from 2.13 to 8.36, but most variation occurred between environments. Averaged across environments peak height of cultivars varied from 4.25 to 5.58, but the variation amplitude for each cultivar was between 3.99 and 6.02 (Table 2). Peak height stability, as described by the coefficient of variation (s%) varied between cultivars from 23.11 to 35.96. Some cultivars (such as Josef and Delabrad) combined high average values of peak height and low s% values.

Table 2. Peak height average and some of its stability indices for 23 winter wheat cultivars

Cultivar	Average peak height	Significance*	Variation limits	Amplitude	s%
Josef	5.58	a	2.96….7.78	4.82	23.46
Delabrad 2	5.44	a	3.15….8.08	4.93	25.58
Capo	5.29	ab	2.61….8.36	5.75	29.98
Dropia	4.96	bc	2.87….7.61	4.74	27.71
Flamura 85	4.94	bc	2.89….7.40	4.51	27.13
Gruia	4.89	bc	2.48….8.50	6.02	32.59
Dor	4.88	b-d	2.23….7.45	5.22	35.96
Glosa	4.87	b-d	2.80….7.29	4.49	27.39
Şimnic 50	4.87	b-d	3.05….7.15	4.10	23.95
Lovrin 34	4.81	b-e	2.71….7.60	4.89	31.45
Izvor	4.79	b-f	2.19….6.98	4.79	24.99
Litera	4.79	b-f	2.13….6.86	4.73	28.50
Faur	4.78	b-g	2.17….7.39	5.22	34.12
Şimnic 30	4.78	b-g	2.38….7.09	4.71	33.74
Apache	4.76	b-g	2.21….7.63	5.42	33.31
Crina	4.67	b-g	2.51….6.70	4.19	29.07
Alex	4.65	c-h	2.48….7.69	5.21	33.87
Serina	4.50	c-h	2.82….6.81	3.99	23.11
Boema	4.49	d-h	2.20….6.78	4.58	34.09
Trivale	4.46	e-h	2.63….6.67	4.04	28.50
Albota 69	4.40	f-h	2.41….6.99	4.58	31.24
Exotic	4.38	gh	2.66….7.36	4.70	29.49
Ciprian	4.25	h	2.18….7,01	4.83	31.15

* Values with same letters are not significantly different

Table 3. Peak time average and its stability for 23 winter wheat cultivars

Cultivar	Average peak time	Significance*	Variation limits	Amplitude	s%
Boema	4.83	a	1.38….9.98	8.60	50.09
Dropia	4.68	ab	2.38….9.98	7.60	44.14
Lovrin 34	4.65	a-c	1.60….9.37	7.77	45.90
Faur	4.64	a-d	1.93….9.28	7.35	42.16
Gruia	4.64	a-d	1.83….9.18	7.35	44.18
Dor	4.60	a-e	1.65….9.98	8.33	48.64
Flamura 85	4.28	a-e	2.10….9.73	7.23	42.11
Ciprian	4.28	a-f	1.35….8.80	7.45	46.33
Serina	4.24	a-f	2.13….8.05	5.92	44.95
Delabrad 2	4.20	a-f	2.53….8.73	6.20	34.98
Alex	4.05	b-f	1.28….6.87	5.59	39.49
Litera	4.03	b-f	1.48….7.12	5.64	41.85
Izvor	4.01	b-f	1.90….7.63	5.73	38.84
Capo	3.97	c-g	2.15….7.23	5.08	33.24
Josef	3.95	d-h	2.00….7.33	5.33	34.93
Glosa	3.78	d-h	2.10….8.28	6.18	39.69
Apache	3.76	d-i	2.12….7.05	4.93	43.10
Şimnic 50	3.74	d-i	2.47….6.72	4.25	32.21
Crina	3.73	d-i	1.63….7.13	5.50	44.38
Albota 69	3.32	e-i	1.28….9.23	7.95	52.19
Trivale	3.23	h-i	1.78….6.35	4.57	47.47
Exotic	3.11	h-i	1.83….5.42	3.59	36.63
Şimnic 30	3.08	i	1.02….7.12	6.10	51,74

* Values with same letters are not significantly different

Peak time stability, as described by the coefficient of variation (s%) varied between cultivars from 32.21 to 52.19 (Table 3).

Area below the mixing curve synthetically describes dough behaviour during the whole mixing test, being influenced by the initial slope of the curve, the peak height and dough breakdown. It varied from 13.34 to 50.82, with most variation occurring between environments. Averaged across environments, area below mixing curve varied among cultivars from 25.13 to 32.38, with the variation amplitude for each cultivar varying between 14.62 and 36.40 (Table 4). The stability of the area below mixing curve, as described by the coefficient of variation (s%), varied between cultivars from 24.21 to 36.88.

Cultivars Josef and Delabrad 2 had the highest average areas below the curve (above 30) and also good stability (low s%). Average areas under 26 were found in cultivars Ciprian, Serina and Exotic.

Table 4. Average of the area below mixing curve and some of its stability indices for 23 winter wheat cultivars

Cultivar	Average area below mixing curve	Significance*	Variation limits	Amplitude	s%
Josef	32.38	a	15.80….46.22	14.62	24.34
Delabrad 2	31.01	ab	17.51….43.16	25.65	24.91
Capo	29.93	bc	14.42….50.82	36.40	32.18
Simnic 50	28.77	bcd	18.45….42.15	23.70	24.21
Gruia	28.73	bcd	15.79….50.60	34.81	33.04
Simnic 30	28.59	bcd	16.31….44.57	28.26	33.13
Flamura 85	28.29	bcde	17.08….43.94	26.86	27.72
Dropia	28.00	bcdef	16.37….41.87	25.50	27.68
Glosa	27.94	bcdef	17.40….41.89	24.49	27.87
Izvor	27.93	bcdef	15.21….41.95	26.74	27.73
Dor	27.88	cdef	13.34….44.63	31.29	36.88
Lovrin 34	27.53	cdef	14.86….45.25	30.39	32.70
Alex	27.24	cdefg	15.01….40.78	25.77	32.35
Faur	27.23	cdefg	14.07….43.02	28.95	34.26
Litera	26.95	cdefg	15.09….39.14	24.05	27.04
Apache	26.85	cdefg	13.71….41.80	28.09	32.21
Trivale	26.50	defg	14.84….37.78	22.94	26.90
Crina	26.19	defg	15.19….38.96	23.77	28.84
Albota 69	26.16	defg	15.44….40.37	24.93	28.87
Boema	26.14	defg	14.73….42.13	27.40	32.73
Exotic	25.98	efg	14.02….43.61	29.59	32.76
Serina	25.81	fg	14.52….41.55	27.03	28.27
Ciprian	25.13	g	14.35….42,12	27.77	32.38

* Values with same letters are not significantly different

Table 5. Correlations between dough strength indices and protein concentration

	Protein concentration	Peak time	Peak height	Area below mixing curve
Protein concentration	1.00	0.15	0.57**	0.60**
Peak time	0.15	1.00	0.21	0.08
Peak height	0.57**	0.21	1.00	0.96**
Area below mixing curve	0.60**	0.08	0.96**	1.00

**Correlation significant at $P<0.01$

Protein concentration was significantly correlated ($P<0.01$) with peak height (Table 5, Figure 1).

From Figure 1 it is obvious that, despite the significant correlation, several cultivars showed large deviations from the regression line.

Cultivars Josef, Delabrad 2 and Capo had large positive deviations, suggesting high dough strength, irrespective of protein concentration, while Ciprian, Exotic and Albota 69 had large negative deviations, suggesting low intrinsic gluten strength.

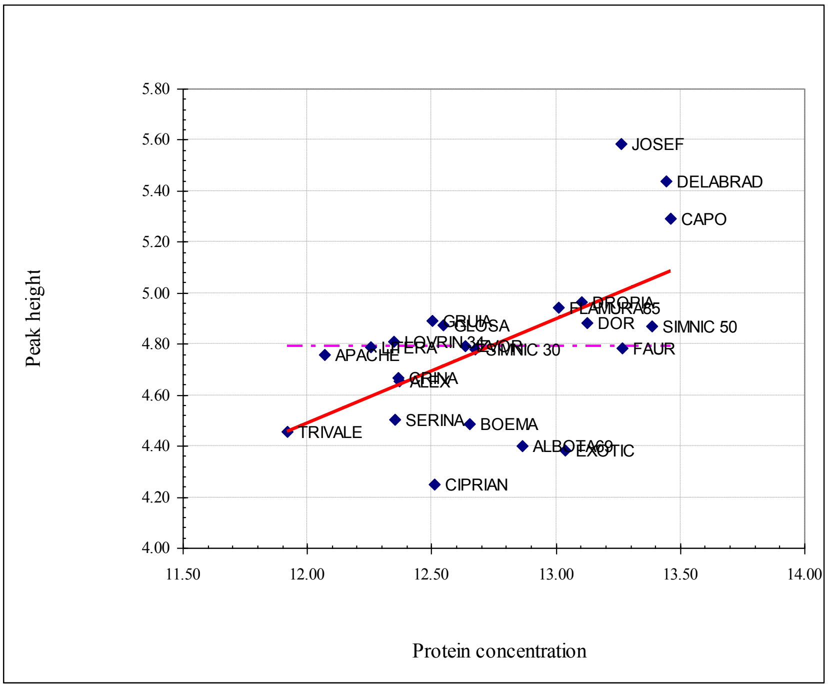

Figure 1. The correlation between peak height and protein concentration

Protein concentration was also significantly correlated with area below mixing curve (Figure 2), but not with mixing time (peak time).

Peak time was not correlated with peak height or area below mixing curve (Figure 3), suggesting that it is not directly related with the other measures of dough strength.

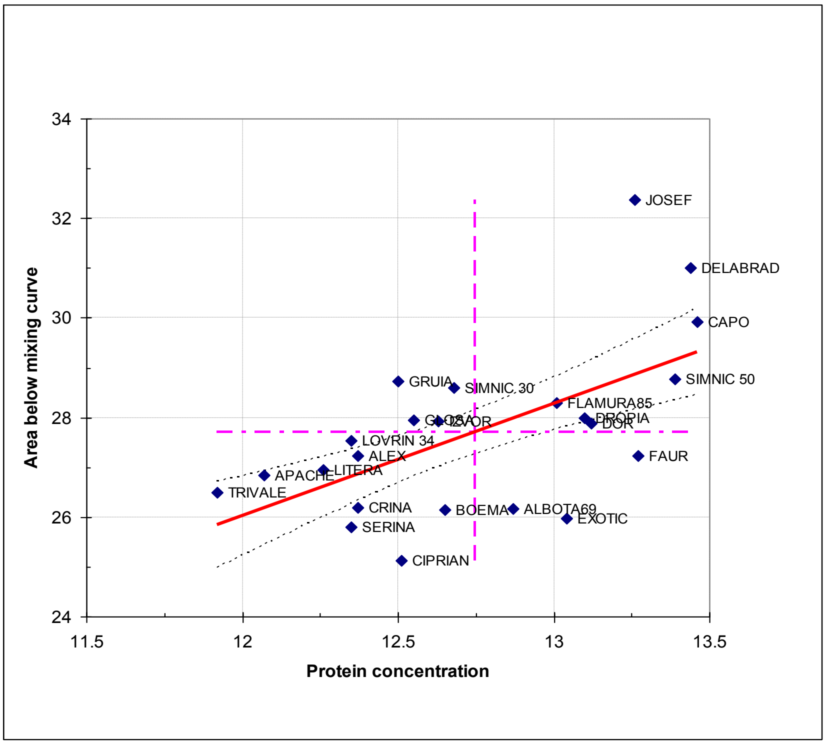

Figure 2. The correlation between protein concentration and area below mixing curve

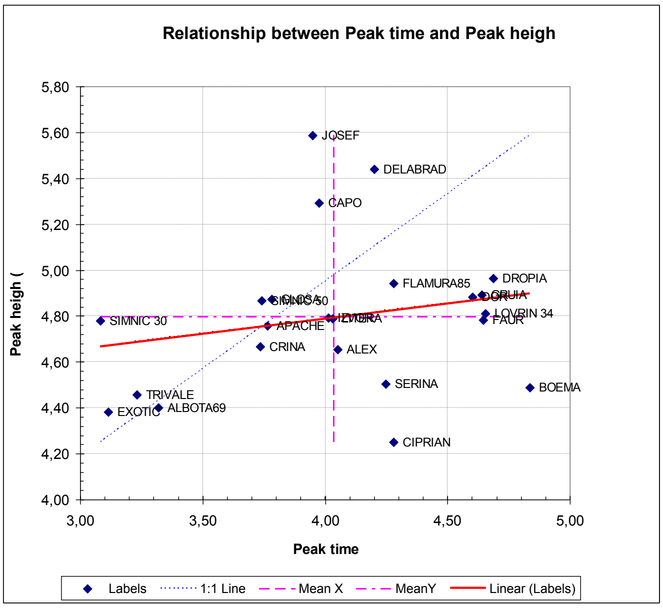

Figure 3. Relationship between peak height and peak time

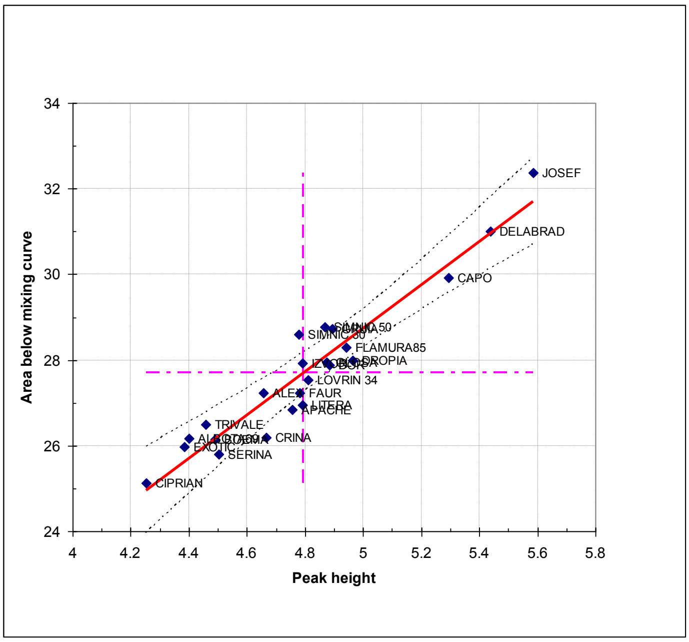

Figure 4. Relationship between area below mixing curve and peak height

On the contrary, peak height and area below the mixing curve were very strongly correlated (r = 0.596) (Figure 4), suggesting that these two indices reflect mostly the same dough traits.

CONCLUSIONS

The effect of years and crop management on the variation of three indices related to dough strength (peak height, peak time and area below the mixing curve) was much larger than the effect of cultivars. However, the differences between cultivars were also significant when tested against the Genotype*Environment interaction.

Grain protein concentration was significantly correlated with peak height, explaining about one third of its variation. Positive deviations from the regression between protein content and peak height identified a few cultivars with intrinsic high dough strength (Josef, Delabrad 2, Capo), while negative deviations identified cultivars with intrinsically weaker gluten. Protein concentration was also significantly correlated with area below mixing curve, but not with peak time.

Peak time was not correlated with peak height or area below mixing curve, while peak height and area below the mixing curve were very strongly correlated.

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