MALTING OF NEW WHEAT CULTIVARS[1]

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ABSTRACT

Hard red winter, hard red spring, durum, soft red winter, soft white, and club wheat cultivars from the 1971 and 1972 crops were selected to represent typical cultivars of the commercially grown wheat classes from major centers of wheat cultivation in the U.S.A. Malts from hard wheats were low in total extract; the hard-textured wheats, generally, modified poorly in malting as measured by a high fine-coarse grind extract. Diastatic power was highest in malts from hard red spring and durum, and lowest in soft white and club wheat malts. Diastatic power of soft red winter wheat malts was higher than that of hard red winter wheat malts. Alpha-amylase was lowest in durum and soft white; highest in hard red spring; and intermediate in hard red winter, soft red winter, and club wheats. Wheat classes were found to rank in a different order in 1971–1972 than in 1940–1960. Increase in total grain N was associated with a decrease in fine-grind extract and ratio of wort N to malt N and increase in amylolytic enzymes. The changes were similar to those reported for barley and rye malts.

Several investigators (1-4) have demonstrated that wheats from various classes and cultivars vary in their ability to produce satisfactory malts. Geddes *et al.* (1), and Dickson and Geddes (4), rated soft white (SW) wheat as the best for malting, followed by soft red winter (SRW), hard red winter (HRW), and hard red spring (HRS) wheats. Fleming *et al.* (5,6) rated wheat classes on the basis of decreasing order of their malt enzyme activity: SW, SRW, HRW, durum, and HRS.

Whereas there have been several recent reports on malting qualities of European wheats (7-9), the report of Fleming *et al.* (6) is, apparently, the most

[1]Cooperative investigations between the Agricultural Research Service, U.S. Department of Agriculture, and the Agricultural Experiment Station, University of Wisconsin, Madison.

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recent study on malting of North American wheats. Reitz (10) reviewed recent progress in wheat breeding and indicated that improved varieties of wheat, including semidwarfs, have made possible unprecedented high levels of yield and have contributed to the worldwide "Green Revolution." These high-yielding wheats comprise at least 50 new varieties. The new wheats have shorter, stiffer straw than standard wheats, some have greater adaptability to the environments where they are grown, and some are more resistant to diseases and insects.

Those developments have prompted numerous surveys and investigations on the functional properties of the new wheats in breadmaking. This report describes malting properties of new wheat cultivars grown in the U.S. The wheat cultivars were selected to represent a wide range of genetic material and to include important commercially grown cultivars in each major wheat class.

MATERIALS AND METHODS

Materials

Wheat samples harvested in 1971 and 1972 were selected to cover typical cultivars from the commercially grown wheat classes from major centers of wheat cultivation in the U.S.A. The six wheat classes, 17 cultivars, and numbers of samples from 1971 and 1972 are given in Table I. There were 142 samples from 1971 and 159 samples from 1972.

Malting

The wheat samples were cleaned on a Hart-Carter Dockage Tester. Lots of 170 g cleaned wheat were malted as described by Dickson *et al.* (11). Steeping times, which were varied to attain a moisture content of 45% at the end of steep, ranged from 22 to 36 hr. Steeped samples were germinated in malting chambers

TABLE I
Sample Identifications and Numbers of Samples Tested

Class	Variety	Year 1971	Year 1972
Hard red winter (HRW)	Kharkof	21	26
	Centurk	18	20
	Scout	17	20
Hard red spring (HRS)	Chris	5	6
	Era	5	6
	Waldron	5	5
Durum	Leeds	4	3
	Wells	4	3
Soft red winter (SRW)	Arthur	15	12
	Blueboy	15	12
	Monon	15	12
Soft white (SW)	Luke	3	6
	Nugaines	3	6
	Yamhill	3	6
Club	Elgin	3	6
	Moro	3	6
	Paha	3	4

TABLE II
Mean Values of Nine Parameters and Duncan's Ranking of Means for Six Wheat Classes from 1971 and 1972

Parameter	HRW		HRS		Durum		SRW		SW		Club	
	1971 56[a]	1972 66[a]	1971 15[a]	1972 17[a]	1971 8[a]	1972 6[a]	1971 45[a]	1972 36[a]	1971 9[a]	1972 18[a]	1971 9[a]	1972 16[a]
Plump (%)	52.8 c	69.1 ab	81.3 a	70.1 ab	79.0 ab	78.0 ab	77.0 ab	69.5 ab	83.2 a	74.1 ab	72.9 ab	62.1 bc
Kernel weight (mg)	26.3 f	32.4 ab	29.2 bcde	27.7 cdef	31.4 ab	32.9 ab	29.9 bcd	27.4 def	34.1 a	30.4 bc	30.0 bcd	26.4 ef
Fine grind extract (%)	79.0 cd	79.6 c	80.1 c	77.9 d	78.4 cd	73.7 e	82.0 b	82.8 ab	84.3 a	83.2 ab	84.2 a	82.7 ab
Fine-coarse grind extract (%)	3.5 ab	3.5 a	3.5 ab	2.7 bcd	3.3 abc	2.8 abcd	2.1 de	2.6 cd	1.4 e	2.8 bcd	1.2 e	2.1 de
Wort color[b]	2.3 d	2.4 c	2.6 ab	2.6 a	1.8 f	2.0 ef	2.6 ab	2.6 abc	2.4 cd	2.5 bc	2.2 de	2.1 e
Wheat-N (%)	2.70 b	2.72 b	2.83 ab	2.96 a	2.87 ab	3.19 a	2.43 c	2.35 cd	2.07 d	2.24 cd	2.06 d	2.36 cd
$\frac{\text{Wort}}{\text{Malt}}$ N (%)	29.7 d	30.4 cd	36.0 a	32.3 abcd	32.3 abcd	24.7 e	35.7 a	34.4 abc	34.7 abc	31.4 bcd	35.2 ab	32.4 abcd
Diastatic power[c]	146.1 d	136.3 e	213.8 a	212.1 a	209.1 a	208.7 ab	189.8 b	177.7 c	108.7 gh	131.4 ef	90.0 h	116.1 fg
α-Amylase[d]	42.7 b	33.7 c	47.4 a	49.0 a	20.9 e	21.7 e	42.9 b	34.3 c	28.1 de	25.6 e	33.0 cd	32.2 cd

[a]Number of samples.
[b]Lovibond Tintometer.
[c]Degrees.
[d]20° Units.
(Values with same letter subscript indicate no significant difference at the 0.01 level.)

at 16°C ± 0.5°C for 5 days. Malted samples were kilned in a programmed procedure that employs higher temperatures after most of the moisture was removed at lower temperatures. Final kiln temperature was 65°C.

Analytical Methods

The grains and malts were analyzed according to methods of the American Society of Brewing Chemists (12) except that coarse-grind extract was determined on material obtained by grinding 25-g samples in the Casella mill with sieve holes of 0.125 in. in diameter.

RESULTS AND DISCUSSION

Certain characteristics of wheats and wheat malts from the six wheat classes are compared in Table II.

Malts from the hard wheats (HRW, HRS, and durum) were lower in extract than malts from SRW wheats and especially from SW and club wheats. Generally, the hard-textured wheats (HRW, HRS, and durum) showed poorer modification (as assessed by higher fine-grind coarse-grind extract difference) than the soft-textured wheats (SRW, SW, and club). The worts from malts of durum wheats had less color than worts from malts of the other wheats.

Protein solubility in barley malt (as measured by the ratio of wort N to malt N) increases with increase in proteolytic activity, but decreases with increase in barley protein (13). The latter results from the fact that with increase in total protein content, the prolamines and glutelins generally increase proportionately more than the albumins and globulins. Consequently, in assessing protein solubility on the basis of the wort N : malt N ratio, the effect of total protein must be considered. The soft-textured wheats (SRW, SW, and club) contained less protein than the hard wheats. On the average, protein solubility was higher for SRW than for HRW and durum wheats but was about equal to that of the HRS wheats, despite their high-protein content.

Diastatic power measures sum total of reducing sugars originally present, and reducing sugars produced (under the conditions of the test), by the combined action of the α- and β-amylases. In autolytic methods, production of those sugars depends on the amounts of substrate that are available to enzymatic action. This availability of substrate is affected by the texture of the grain (or malt), the extent of grain structure breakdown, and amounts of damaged starch as the result of milling or grinding. During mechanical treatment, hard wheats form more damaged starch than soft wheats. Consequently, high diastatic power determined by an autolytic method can be attributed, in part at least, to high levels of available damaged starch.

The procedure used in this study (ref. 12, Malt, Method 6, p. 162) provides sufficient Lintner starch so that the substrate is not limiting. Consequently, high-diastatic power is due to high levels of endogenous amylolytic enzymes and/or reducing sugars. The diastatic power of the HRW wheats was relatively low and of the SRW wheats relatively high (only slightly lower than in durum and HRS wheat malts). The SW and club wheat malts were lowest in diastatic power. We might have attributed these low levels to the climatic conditions of the Western U.S. except for the fact that malts from the HRW wheats grown in the Western

U.S. had diastatic power levels comparable to those of malts from HRW wheat grown in the Great Plains.

Among the wheat classes examined, α-amylases of durum wheat malt were lowest and of HRS wheat malt were highest. α-Amylase levels of SW wheat malt were higher than levels in durum wheat. This contrasts with results of previous surveys (1,4-6) in which α-amylase of SW wheat malt was highest among the wheat classes. The difference might be associated with changes in genotypic characteristics of the new high-yielding SW wheat cultivars though annual variation is great due to weather conditions at harvest time. Club wheat malt was intermediate and HRW and SRW wheat malts showed large differences between years in their α-amylase activities.

Table III reports results from analysis of variance on the data from 2 years, 6 classes, 17 cultivars, and for 9 analytical or malting parameters. The high year-to-year variation between classes in kernel weight and plumpness presumably reflected environmental effects on kernel size and development.

Results of Duncan's Multiple Range Test for varietal means are summarized in Table IV. Several consistent and significant differences were found among cultivars within a class. Among the hard winter wheats, Kharkof was characterized by low-protein solubility, α-amylase activity, and diastatic power. Malt from the HRS cultivar Chris was low in protein and yielded more extract than Era and Waldron. Malt from Arthur was lower in protein and diastatic power and higher in total extract and wort color than the other SRW cultivars; Blueboy was high in diastatic power.

TABLE III
Analysis of Variance (Mean Squares) on Data from Wheat and Wheat Malts (2 Years, 6 Classes, 17 Cultivars, 9 Variables)

Source of Variation	D.F.	Plump	Kernel Weight	Fine Grind Extract	Fine-Coarse Grind Extract	Wort Color
Between years	1	611.87	15.64	79.44**	3.26	0.07
Between classes	5	2770.97**	80.40*	246.31**	23.20**	1.70**
Year × class[a]	5	2237.10**	267.06**	31.85**	4.90**	0.08
Variety[b]	16	1352.62**	42.38*	15.02	1.92	0.29**
Error[c]	267	364.79	13.86	6.50	1.33	0.05

Source of Variation	D.F.	Wheat-N	$\frac{\text{Wort N}}{\text{Malt N}} \times 100$	Diastatic Power	α-Amylase
Between years	1	0.88*	393.63**	729.64	390.23**
Between classes	5	3.58**	308.58**	64586.71**	2166.17**
Year × class	5	0.22	71.81	2278.32**	252.43**
Variety	16	0.19	35.83	8232.57**	150.57**
Error	267	0.13	30.68	580.36	48.65

[a]Year-to-year constancy between classes.
[b]Within year × class combination.
[c]Location effect.
(** and * denote significance at the 0.01 and 0.05 levels, respectively).

The large Yamhill kernels yielded deeply colored malts which were high in diastatic power and in α-amylase. No significant differences were found between the two durum and the three club cultivars.

Simple correlation coefficients were calculated among various wheat and wheat malt parameters. Those correlation coefficients were calculated for combined wheat samples within a class for the 2 crop years (Table V). The data in this table indicate only significant correlations at the 1% level (capital letters) or at the 5% level (small letters). The significance level depended on the numbers of samples in the tested classes. Those numbers varied widely and were 122 for HRW (H or h), 81 for SRW (S or s), 32 for HRS (N or n), 27 for SW (W or w), 25

TABLE IV
Mean Values of Nine Parameters and Duncan's Ranking of Means for Varieties within a Class, Pooled Over Two Years

Class and Variety	Plump %	Kernel Weight (mg)	Fine Grind Extract %	Fine-Coarse Grind Extract %	Wort Color[a]	Malt N %	Wort N / Malt N %	Diastatic Power[b]	α-Amylase[c]
Hard red winter									
Centurk	71.1a	31.5a	79.9a	3.3a	2.3b	2.68a	31.6a	141.8ab	39.3a
Kharkof	57.7b	29.0b	78.7a	3.6a	2.3b	2.76a	28.9b	134.1b	34.7b
Scout	56.8b	28.5b	79.6a	3.6a	2.5a	2.67a	29.9ab	148.3a	40.3a
Hard red spring									
Chris	71.1a	28.2a	81.0a	3.4a	2.7a	2.72b	36.2a	193.0b	46.9a
Era	70.0a	27.3a	77.7b	3.2a	2.4b	2.98a	32.7a	218.0ab	46.6a
Waldron	85.8a	30.0a	78.0b	2.6a	2.8a	3.01a	33.2a	229.1a	51.6a
Durum									
Leeds	85.7a	33.8a	76.3a	2.9a	2.0a	3.08a	28.7a	202.3a	19.2a
Wells	71.4a	30.3a	76.6a	3.3a	1.9a	2.93a	29.3a	215.6a	23.2a
Soft red winter									
Arthur	65.2b	29.1ab	84.0a	2.6a	2.7a	2.22b	36.2a	153.4b	36.4b
Blueboy	66.5b	27.4b	81.5b	2.3a	2.5b	2.43a	34.5a	237.0a	39.5a
Monon	89.4a	29.9a	81.5b	2.1a	2.6b	2.55a	34.7a	163.0b	41.1a
Soft white									
Luke	82.9a	30.9b	82.9a	2.2ab	2.4b	2.13a	31.6a	112.2b	25.5b
Nugaines	64.7b	29.2b	84.1a	3.0a	2.2c	2.17a	32.1a	118.2ab	21.1b
Yamhill	83.8a	34.7a	83.7a	1.8b	2.6a	2.26a	33.7a	141.0a	32.7a
Club									
Elgin	64.7a	27.3a	82.9a	1.8a	2.1a	2.38a	33.2a	112.9a	35.1a
Moro	66.3a	28.2a	84.0a	1.5a	2.2a	2.09a	35.1a	106.7a	29.3a
Paha	67.2a	27.5a	82.8a	2.2a	2.1a	2.29a	31.5a	98.6a	33.1a

[a]Lovibond Tintometer.
[b]Degrees.
[c]20° Units.
(Values with same letter subscript indicate no significant difference at the 0.01 level.)

TABLE V
Simple Correlation Coefficients[a] among Certain Wheat[b] and Wheat Malt Characteristics[c]

Wheat or Malt Parameter	K. Wt mg	Plump %	Extract %	F-C %	Wort Color	Malt-N %	S/T	D.P.
K. Wt, mg								
Plump, %	HSNWC							
Extract, %	Hsn	Hnd						
F-C, %	-HWC	-HWC	-C					
Wort Color		-hs	SC	H				
Malt N, %	-h	-H	-HSNWCD	HC	-C			
S/T	N	HN	HSNWCD	-C	HSC	-HSWC		
D.P.	-Hsc	-HScd	-HSNWC	hC	w	HSnWC	-nWC	
α-Amylase	(-H)w	-H	-HSnC	(-w)c	snW	HSWC	-hc	HSNWC

[a]Large letters denote significance at the 1% level; small letters at the 5% level. When a class is missing, the correlation coefficient was not significant.
[b]H = Hard red winter; S = Soft red winter; N = Hard red spring; W = Soft white; C = Club; D = Durum.
[c]K. Wt = Kernel weight. F-C = Fine-coarse grind extract. $S/T = \frac{\text{Wort}}{\text{malt}} \times 100$. D.P. = Diastatic power.

for club (C or c), and 14 for durum (D or d). Consequently, a correlation coefficient of at least 0.661 was required for 1% significance in durum but only 0.231 in HRW.

Correlations were positive and significant (0.01 level) in at least three of the six classes between kernel weight and plumpness, ratio of wort N : malt N and extract or wort color, malt N and diastatic power and α-amylase, and diastatic power and α-amylase. Correlations were negative between kernel weight and fine-coarse grind extract, between extract and malt N or diastatic power or α-amylase, and malt N and ratio of wort N to malt N.

Those correlation coefficients were generally similar to those reported for barley (13) or rye (14). In malts of both of those species, there were positive correlations between diastatic power and malt N or α-amylase, and negative correlations between fine-grind extract and malt N or diastatic power. In addition, in barley there were positive correlations between fine-grind extract and ratio of wort N : malt N and between malt N and α-amylase; and a negative correlation between malt N and ratio of wort N to malt N. Basically, in all cereals studied, increase in total grain N is associated with a decrease in fine-grind extract and ratio of wort N : malt N and increase in activities of enzymes involved in degradation of starch.

Acknowledgment

The authors thank L. P. Reitz, V. A. Johnson, K. L. Lebsock, and F. H. McNeal for making arrangements to obtain, or for providing, samples from plant breeders in 48 locations in the U.S.A. The excellent cooperation of plant breeders is acknowledged.

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[Received November 7, 1974. Accepted December 16, 1974.]