INFLUENCE OF WHEAT CULTIVARS AND ENVIRONMENT ON AGTRON VALUES AND FLOUR ASH[1]

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ABSTRACT

Fifty-two wheat samples were milled on a pilot mill and evaluated on a Model M-500-A Agtron to study the influence of variety and environment on flour color reflectance values and flour ash content. They represented 11 different cultivars of hard red spring (HRS) wheat grown at four locations on plots of about 1 acre during the 1973 and 1974 crop years. Inconsistencies were observed between flour extraction and flour ash, flour extraction and flour color value, and flour ash and flour color value among and within cultivars and locations and crop years. Interactions among variety, location, and crop years with flour color value and flour ash made determination of the exact grade or extraction of the flour impossible without prior knowledge of the sample.

Interest of the milling and baking industry in flour color has increased in recent years, particularly in color as measured by reflectance instruments. Color has always been a criterion for flour quality. The early Roman miller prided himself in producing the finest of flours as described by Pliny (1). Today, flour color is associated with quality, especially as related to flour extraction or flour grade.

Gillis (2) described a series of extensive studies with the Agtron. Most experiments were performed with the Model F, Blue Agtron, which measured reflectance at the 436 nm line and was sensitive to yellow. He also used a Model F, Green Agtron, which measured reflectance at the 546 nm line and was sensitive to red. The green model was found to be insensitive to bleaching and could be used to determine ash, since the ash-contributing components of wheat absorbed light in the wavelength of the Green Agtron.

Patton and Dishaw (3) further investigated the Green Agtron as a quality control tool for commercial bakery flours. They concurred with the findings of Gillis and recommended the Green Agtron as "a valuable tool in quality control evaluation of commercial white bread flours." They concluded there was a significant relation between the Agtron value and flour grade, although there was considerable overlapping of the values between the two flour grades studied.

Shuey and Skarsaune (4) computed a regression equation based on the Campbell Taggart (C/T) method (3) to predict percentage flour ash from the flour color reflectance values obtained on a Green Agtron. The equation was valid for a given mill mix and the coefficient of correlation was 0.963** between the predicted and actual ash contents of the flours. Their results generally agreed with those of previous investigators, but they demonstrated that different regression equations were necessary for different mill mixes to obtain greater accuracy in predicting ash content.

Murthy and Dietz (5) were able to determine the percentage composition of a blend by using Agtron readings. In their study, they used simple two-component

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TABLE I
Flour Extraction, Flour Ash, and Agtron Flour Color Data for Nine Varieties Grown at Four Locations

Variety	Year	Crookston, Minn.			Casselton, N. Dak.			Minot, N. Dak.			Plentywood, Mont.		
		Ext. %	Ash[a] %	Color	Ext. %	Ash[a] %	Color	Ext. %	Ash[a] %	Color	Ext. %	Ash[a] %	Color
Bounty 309	1974	67.2	0.401	52.3	64.9	0.404	52.9	67.1	0.363	63.9	66.1	0.388	66.5
Ellar	1973	65.3	0.359	68.5	66.4	0.370	67.5	66.2	0.356	71.5	66.1	0.318	72.0
Era	1974	72.7	0.408	66.3	68.4	0.451	61.0	71.0	0.376	77.8	68.3	0.378	74.8
Prodax	1974	70.6	0.443	56.5	62.6	0.438	52.8	69.1	0.338	63.4	67.9	0.418	66.5
Waldron	1974	69.2	0.442	51.5	66.3	0.406	56.9	69.9	0.355	63.4	69.0	0.351	68.0
Exp. 1	1973	68.0	0.385	66.5	72.0	0.388	70.0	70.8	0.354	72.5	71.3	0.333	71.5
Exp. 2	1973	70.9	0.389	68.5	72.7	0.390	68.0	70.3	0.354	73.0	71.8	0.322	71.0
Exp. 3	1974	71.7	0.349	58.4	70.5	0.342	63.3	71.7	0.307	71.9	70.5	0.308	75.4
Exp. 4	1974	71.8	0.373	65.4	68.0	0.387	61.8	69.9	0.348	71.6	67.8	0.393	74.5

[a] 14% moisture basis.

blends of different flour grades or other ingredients such as first-clear flour and medium rye flour, straight-grade flour and soy flour, and durum flour and egg solids.

Skarsaune and Shuey (6) further demonstrated that fine grinding significantly lowered the flour color, especially for shorter patent, lower ash flours, as determined by the C/T slurry method.

The objective of this study was to determine the influences of cultivar and environment on Agtron color readings. Location and crop year were both considered to be environmental factors for the experiments.

MATERIALS AND METHODS

Fifty-two wheat plots about 1 acre each in size were grown at four locations (Crookston, Minn., Casselton and Minot, N. Dak., and Plentywood, Mont.). Twenty plots were grown in 1973 and 32 in 1974. Chris and Kitt were the only cultivars grown both crop years. Ellar, Exp. 1, and Exp. 2 were grown during the 1973 crop year, while Bounty 309, Era, Prodax, Waldron, Exp. 3, and Exp. 4 were grown during the 1974 crop year. Each cultivar or experimental line was planted at each location.

The milling, analytical, and Agtron procedures were described previously (4,7). All analytical and Agtron determinations were done in duplicate.

RESULTS AND DISCUSSION

The flour extraction, flour ash, and Agtron flour color data for the 36 wheat lots are given in Table I. The data for the other 16 lots are in Table II, representing the two cultivars that were grown both crop years.

TABLE II
Flour Extraction, Flour Ash, and Agtron Flour Color Data for Two HRS Wheat Varieties, Four Locations, and Two Crop Years

	Extraction		Ash[a]		Color	
Variety and Location	**1973**	**1974**	**1973**	**1974**	**1973**	**1974**
CHRIS						
Crookston, Minn.	68.1	64.4	.368	.370	65.5	60.5
Casselton, N. Dak.	65.7	65.8	.369	.388	72.0	63.4
Minot, N. Dak.	63.6	68.8	.379	.337	72.0	67.5
Plentywood, Mont.	67.0	68.7	.332	.345	73.5	73.8
Average	66.1	66.9	.362	.360	70.8	66.3
1973–74 Average	66.5		.361		68.5	
KITT						
Crookston, Minn.	66.5	68.9	.395	.409	67.5	58.9
Casselton, N. Dak.	66.8	65.6	.379	.422	70.5	57.1
Minot, N. Dak.	60.3	68.7	.387	.358	73.0	70.1
Plentywood, Mont.	65.7	67.2	.344	.413	74.0	68.0
Average	64.8	67.6	.376	.401	71.3	63.5
1973–74 Average	66.2		.388		67.4	

[a]14% moisture basis.

Cursory observation of the data showed inconsistencies in the different determinations among varieties within or between stations. For example, the Bounty 309 samples grown at Crookston, Minn. and Minot, N. Dak. have essentially the same flour extraction, yet the Minot, N. Dak. sample had a lower flour ash and higher flour color value, which is consistent with former data (2–6). In contrast, the Ellar samples grown at Minot, N. Dak. and Plentywood, Mont. had essentially the same flour extraction and flour color value, but the Minot, N. Dak. sample had higher flour ash. The Prodax samples grown at Minot, N. Dak. and Plentywood, Mont. had different flour extractions, flour ashes, and flour color values, and the Minot, N. Dak. sample had the higher flour extraction but the lower flour ash and flour color value. The lower flour ash and color value would be expected but the inverse relations between flour ash and flour extraction or flour ash and flour color disagreed with published data (2–4,6).

Table II further reflects these inconsistencies. For Chris, the average flour extraction and flour ash were essentially the same between years, but flour color value differed. For Kitt, the crop year averages for ash and flour color were in general agreement with published data (2–4,6), yet the Minot data were inconsistent with these averages.

Correlations among flour extraction, flour ash, and flour color value showed that the effects of all combinations of variables were significant for the 1974 crop year, probably because of the wide range in values of the three variables (Table III). The ash-color data appeared to be the most consistent because they were all significantly negatively correlated. Some of the correlations were unexpected (Table IV) for the varieties Chris and Kitt. The negative correlations for flour ash *vs.* flour color value were expected; an increase in ash is normally associated with a decrease in color value. However, the negative correlations for flour extraction *vs.* flour ash (Table III) were contrary to the traditional concept that flour ash increases with flour extraction. This reversal demonstrated the genetic × environmental interaction on ash distribution within the kernel and on the milling characteristics (7).

Analysis of variance (AOV) of the data was made to determine the causes for the observed inconsistencies (Table V). Because all of the entries were not

TABLE III
Correlation Coefficients between Flour Extraction, Flour Ash, and Flour Color Value for 1973 and 1974 Crop Years

Variables	Year	Number of Samples	Correlation Coefficient
Ash *vs.* extraction	1973	20	−0.11
	1974	32	−0.38*
	1973 + 1974	52	−0.21
Extraction *vs.* color	1973	20	−0.22
	1974	32	0.39*
	1973 + 1974	52	0.12
Ash *vs.* color	1973	20	−0.51*
	1974	32	−0.48**
	1973 + 1974	52	−0.54**

replicated at each location, an estimate of the plot error was computed from the data obtained on the check or control variety, which was grown in replicate at each location. The error term used in the analysis was derived by pooling the plot errors from each location and designated as a "pooled error," and would be an estimate of the error term.

Analyses of variance were determined on Agtron color score and ash content data for each crop year. All the variances were highly significant for 1974 for both color scores and ash content, but only the locations for 1973 for both, while entries were significant for ash content (Table V). This would indicate that the two measurements do not appraise the flours exactly the same.

It was possible to use Agtron color scores from the 1973 crop to distinguish among locations but not among entries. Examples of the 1973 crop year data (Fig. 1A) show the inability to select by color score a flour blend of individual entries composed of the four locations, since the average color scores were: Chris, 70.8; Kitt, 71.3; Ellar, 69.8; Exp. 1, 70.1; and Exp. 2, 70.0. Conversely, Fig. 1B illustrates that two individual locations (Crookston, Minn. and Casselton, N.

TABLE IV
Correlation Coefficients between Flour Extraction, Flour Ash, and Flour Color Value for HRS Wheat Varieties, Chris and Kitt, for Two Crop Years (1973 and 1974)

Variables	Variety	Number of Samples	Correlation Coefficient
Ash *vs*. extraction	Chris	8	−0.68*
	Kitt	8	0.02
Extraction *vs*. color	Chris	8	−0.21
	Kitt	8	−0.99**
Ash *vs*. color	Chris	8	−0.48
	Kitt	8	−0.77*

TABLE V
Entry × Location Analysis of Variance for the Agtron Flour Color Values and Flour Ash Content

Source of Variance	df	Agtron Values MS	Ash MS
1973 Crop Year			
Entry	4	2.54	0.00068*
Location	3	82.33**	0.00547**
Entry × location	12	3.97	0.00022
"Pooled error"	(20)	(2.22)	(0.00014)
1974 Crop Year			
Entry	7	146.64**	0.00599**
Location	3	669.92**	0.01097*
Entry × location	21	10.66**	0.00076**
"Pooled error"	(32)	(2.22)	(0.00014)

Dak.) might be distinguished from either Minot, N. Dak. or Plentywood, Mont., as the average color scores were: Crookston, Minn., 67.3; Casselton, N. Dak., 69.6; and Minot, N. Dak., and Plentywood, Mont., 72.4. The 1974 crop year data suggested that two locations (Minot, N. Dak. and Plentywood, Mont.) might be differentiated from either Crookston, Minn. or Casselton, N. Dak., and that six of the entries (Bounty 309, Chris, Era, Kitt, Exp. 3, and Exp. 4) might be differentiated from each of the others. The average color scores for the locations were: Crookston, Minn., 58.7; Casselton, N. Dak., 58.7; Minot, N. Dak., 68.6; and Plentywood, Mont., 70.9, and for the entries: Bounty 309, 58.9; Chris, 66.3; Era, 69.8; Kitt, 63.5; Prodax, 59.9; Waldron, 60.0; Exp. 3, 67.3; and Exp. 4, 68.3.

Similar data were also found for ash content as that for color scores, except for the significant F-value for the entries in 1973. The average ash contents by entry for 1973 were: Chris, 0.362; Kitt, 0.376; Ellar, 0.351; Exp. 1, 0.365; and Exp. 2, 0.364; and the average ash contents by location were: Crookston, Minn., 0.379;

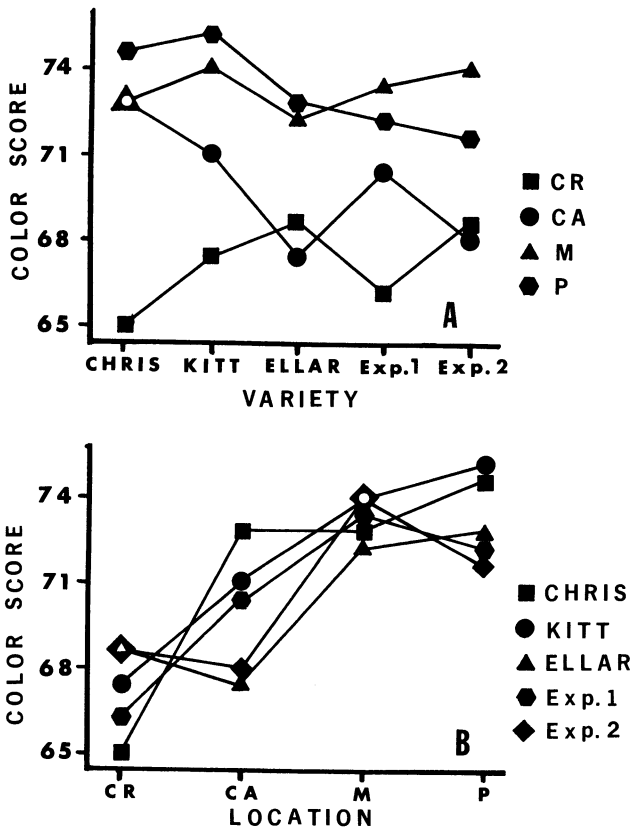

Fig. 1. Interaction diagrams of the 1973 crop year data. A = Varieties with respect to the locations; B = locations with respect to the varieties. Color scores are the averages of duplicate readings.

Casselton, N. Dak., 0.379; Minot, N. Dak., 0.366; and Plentywood, Mont., 0.330. These data show the possibility of distinguishing either Ellar or Kitt from the other three cultivars, Chris, Exp. 1, and Exp. 2, and also that the Minot, N. Dak. and Plentywood, Mont. stations might be differentiated from the Crookston, Minn. or Casselton, N. Dak. locations. The 1974 data showed that all four locations can be distinguished from each other and that two pairs of entries (Bounty 309 and Waldron or Era and Kitt) along with the other entries might be selected from each other. The average ash content in 1974 for locations was: Crookston, Minn., 0.399; Caselton, N. Dak., 0.405; Minot, N. Dak., 0.348; and Plentywood, Mont., 0.374; and for the entries: Bounty 309, 0.389; Chris, 0.360; Era, 0.403; Kitt, 0.401; Prodax, 0.409; Waldron, 0.389; Exp. 3, 0.327; and Exp. 4, 0.375.

An AOV was computed for Agtron color value and ash content for the varieties Chris and Kitt, which were grown in 1973 and 1974 (Table VI). Mean squares were significant for each source of variation except the interaction of year × location × variety for both measurements and location × variety for ash content.

The interactions of years, locations, and variety for the Agtron color values are illustrated in Fig. 2. There was a definite trend for the samples originating further west (Minot, N. Dak. and Plentywood, Mont.) to yield flours with higher reflectance values (Fig. 2A). The average rate of increase of the two cultivars between Crookston, Minn. and Plentywood, Mont. was more pronounced for 1974 (59.7 to 70.9) than for 1973 (66.5 to 73.8). The figure also shows that it was impossible to distinguish by color score between the two cultivars in 1973 (Chris, 70.8 and Kitt, 71.3) but possible in 1974 (Chris, 66.3 and Kitt, 63.5). The average decrease in Agtron color value from 1973 to 1974 was greater for Kitt than for Chris and the rank was reversed (Fig. 2B and 2C). These data indicate that the flour color value of Kitt responded differently to environments than that of Chris.

The intricate relations between the factors help explain the apparent inconsistencies of the data. Because the responses differed in magnitude as well as direction, high ash or low extraction flours could have high or low Agtron color values, or *vice versa*. This, too, would explain why previous investigators obtained straight line responses on blends made from two components, but found considerable overlap of flour grades that originated from different mills.

TABLE VI
Crop Year × Location × Variety Analysis of Variance for the HRS Chris and Kitt Varieties' Agtron Color Values and Ash Content

Source of Variance	df	Agtron Values MS	Ash MS
Year	1	291.61**	0.0010*
Location	3	144.96**	0.0018**
Variety	1	11.28*	0.0060**
Year × location	3	25.93**	0.0023**
Year × variety	1	22.78**	0.0014**
Location × variety	3	14.32**	0.0003
Year × location × variety	3	6.13	0.0002
"Pooled error"	(16)	(2.22)	(0.00014)

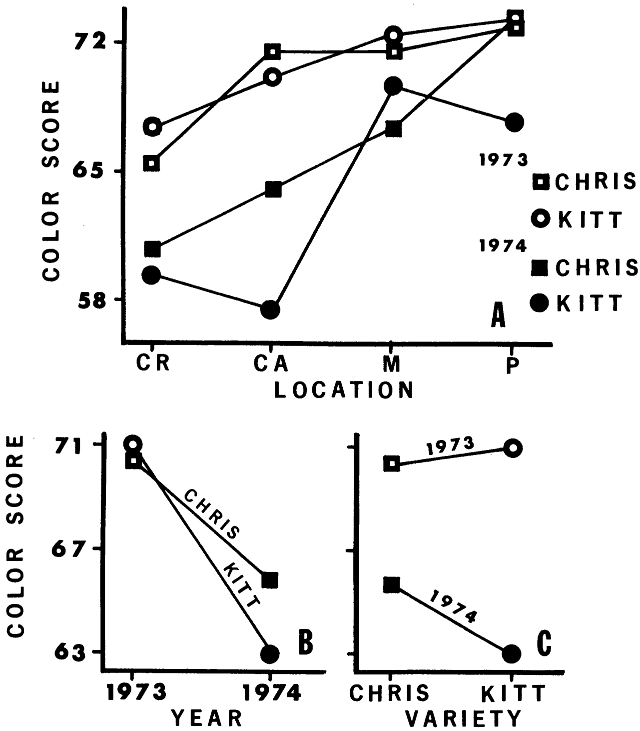

Fig. 2. Interaction diagrams of the two varieties, Chris and Kitt, for the two crop years, 1973 and 1974. A = Locations with respect to varieties and years; B = years with respect to varieties over locations; C = varieties with respect to years over locations. Color scores are the averages of duplicate readings.

These data demonstrate it can be misleading to conclude that flours having the same color values or ash contents are the same grade or extraction. Yet, there are certain advantages when flour color is used as a controlling flour quality factor instead of ash content. Some of the advantages are speed, nondestructiveness, continuous monitoring, and electronic sensing of the test, as well as a direct measurement of a consumer's requirement for a product with a pleasing eye appeal. Although these data do not completely explain the resultant flour color, they do indicate that the year, location, entry, or cultivar and the interaction of these factors can influence flour color as well as flour ash. For an accurate evaluation of flour quality either by color reflectance instruments or ash content, the origin of the test sample should be known.

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