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EVALUATION OF COLOR CHARACTERISTICS OF FLOURS OBTAINED FROM VARIOUS TYPES AND VARIETIES OF WHEAT[1]

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ABSTRACT

Colors of flours obtained from various types and varieties of wheat were studied spectrophotometrically. The samples represented western white and dark hard winter wheat from the U.S.A., red spring wheat from Canada, wheat from Western Australia, and some varieties of Japanese domestic wheat. Color characteristics are reported in C.I.E. chromaticity coordinates derived from spectral reflectance curves. At the same levels of ash content, western white flours showed the highest luminosity, and the lowest excitation purity, while Japanese domestic wheat flours showed the lowest luminosity and the highest excitation purity. Differences in hue were also observed among these types of wheat.

Content of yellow pigments, and the amount of residual pigment when bleached, varied with type or variety of wheat. These factors have a major influence on the excitation purity.

Addition of benzoyl peroxide brought little improvement to bran color. Variations in luminosity and hue are caused not only by the different degree of bran contamination but also by the difference in bran color among the various wheat sources.

Two indices, derived from reflectances at some particular wave lengths, were proposed for evaluating flour color: one, for the content of yellow pigments, and the other, for the coloration by the contaminating bran. Using these indices, it is possible to show, regardless of the degree of bran contamination, the color characteristics of flours from different samples of wheat.

A considerable part of the flour milled in Japan is made into "men," or Japanese noodles; that is, dough strings made from flour, salt, and water. The main source of flour for "men" is Japanese domestic wheat, but some types of imported wheat are also blended with it to produce flour for the same use. They are western white and dark hard winter from the United States, and sometimes, red spring wheat from Canada, or wheat from Western Australia. Color is the

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most important factor in assessing the commercial value of "men"; products having satisfactory brightness and whiteness are preferred by consumers. Since "men" is made by a simple procedure and with few ingredients, the color of the product is determined primarily by the color of the flour used. So, color is regarded as the principal criterion of flour quality for "men."

The Kent-Jones & Martin Flour Color Grader (4,5) and some other methods for brightness measurement (1,2) are now in use by millers and processors for this purpose. Unfortunately it cannot be said that these methods give satisfactory indices of the color characteristics of flours made from different types or varieties of wheat; for differences in flour color occur with different types or varieties of wheat, even at the same extraction rate or ash content, and differences are found not only in luminosity or brightness, but also in hue and chroma. For example, Japanese domestic wheat flours have ordinarily less white color than those made from imported wheat, and for this reason, their utilization is considerably restricted. Since differences among wheats, as well as degrees of contamination with bran, play an important role in flour color, precise studies of color characteristics cannot be made with reflectance measurements at only one wave length as is now the common practice.

This paper presents, first, results of color comparisons of flours from different types and varieties of wheat, using a spectral reflectance procedure, and an elucidation of the factors causing color differences. Secondly, indices are proposed for evaluating color characteristics of flour from different wheats, irrespective of their degree of contamination with bran or their ash content.

Materials and Methods

HW ✓
Red Spr.
S White

Wheat and Flour. Imported wheats were represented by: 31 samples of western white (U.S.-Wh.) No. 1; 10 samples of dark hard winter (U.S.-DHW) No. 1 from U.S.A.; 22 samples of red spring wheat No. 2 and No. 3 Manitoba (Can.-Man.) from Canada; and 10 samples of soft white wheat from Western Australia (Austr.-Wh.). As for Japanese domestic wheat, 40 samples, which differed from each other in the variety and/or growth location, were also examined; all of them were of red winter type comprising both soft (Jap.-DSW) and hard wheat (Jap.-DHW). White wheat is not grown in Japan.

Samples were washed and cleaned to eliminate dust adhering to the surface of the kernels, which gives dullness to flour color. All samples were milled on a Buhler experimental mill. Some samples of the flours were bleached with 60 p.p.m. of benzoyl peroxide.

Reflectance Measurement. A Hitachi EPU-II type photoelectric spectrophotometer with reflectance attachment was used. A suspension was prepared from 7.5 g. of flour and 10 ml. of water and poured immediately into a cell; and reflectance, as a percentage of standard magnesium oxide, was read from 360 to 700 mμ at 10-mμ intervals. Preliminary experiments showed that the method gives highly reproducible results, that no darkening by oxidizing enzymes occurs during the few minutes of measurement, and that variations in flour particle size, resulting from the ordinary milling process, have no significant effect on reflectance. When the reflectance of bran powder was measured, 0.5% ascorbic acid solution was used instead of water to prevent darkening by its enzymes.

Color Notation. C.I.E. chromaticity coordinates x, y, and Y were calculated from spectral reflectance curves of the samples (3). From the x,-y diagram, hue (represented by dominant wave length, λ_D) and chroma (represented by excitation purity, P_e) were obtained.

Chemical Analysis. Contents of yellow pigments, protein, and ash were determined by the methods described in *Cereal Laboratory Methods* (1).

Results

Flour Color Obtained from Various Types of Wheat. Figure 1 shows the chromaticity coordinates for the various samples. To minimize the influence of variation of grade upon these color values, flours of approximately the same level of ash content were selected. Among the nonbleached flours, the samples of U.S.-Wh. give lowest P_e, highest Y, and shortest λ_D, while samples of Jap-DSW and Jap.-DHW give the opposite results; this means that U.S.-Wh. has the most desirable flour color and Japanese domestic wheat the least desirable. Austr.-Wh. shows similar value to U.S.-Wh. in Y and λ_D, but differs from it in higher P_e. When bleached, the P_e of every sample is lowered remarkably, but the relations for color characteristics among the types of wheat are identical with those for unbleached flours. Bleaching brings no improvement in Y of flour color.

Factors affecting these differences among flour colors of the several wheats are discussed in the following sections.

Pigments in Endosperm of Wheat. Pure endosperm was separated by hand-dissection from wheat kernels corresponding to samples used for color measurement reported in Fig. 1. The yield from each sample was about 45–50%. These samples were then ground to powder, and spectral reflectance was read immediately. Data for bleached samples were also obtained.

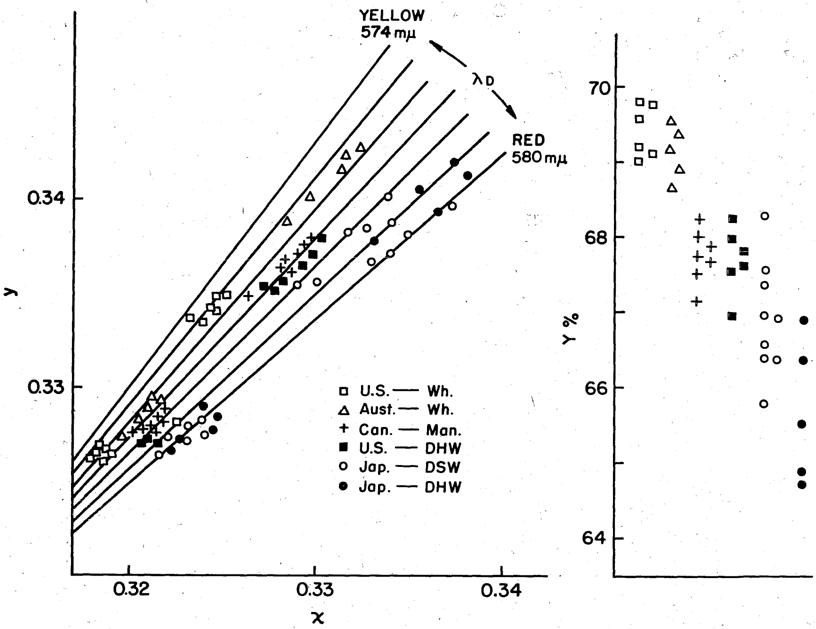

Fig. 1. C.I.E. chromaticity coordinates of flours from various sources. The lower cluster of points in the right-hand graph represents samples bleached with 60 p.p.m. of benzoyl peroxide; upper points represent samples that were not bleached. (Ash contents of all samples are between 0.43 and 0.48%.)

TABLE I

Color Coordinates of Endosperm Powder Obtained from Various Wheat Sources

Sample	Protein	Ash	Y	λ_D	P_e
	%	%	%	$m\mu$	%
U.S.-Wh.	6.0	0.28	75.8	575.0	9.1
	5.4	0.29	76.0	574.8	9.6
	5.5	0.26	75.6	575.0	9.4
Austr.-Wh.	6.5	0.31	74.9	575.0	13.0
	7.0	0.30	75.6	575.0	11.9
	6.8	0.29	75.5	574.8	12.8
Can.-Man.	10.4	0.26	75.0	574.7	10.0
	11.2	0.29	75.2	575.1	10.9
	11.0	0.26	74.9	574.2	10.4
U.S.-DHW	10.0	0.29	75.3	574.9	9.9
	10.8	0.28	75.5	575.3	10.2
	10.8	0.30	75.0	575.0	9.8
Jap.-DSW	7.0	0.28	76.1	575.0	9.9
	8.4	0.30	75.8	574.8	11.7
	8.2	0.30	75.8	575.0	13.1
Jap.-DHW	9.9	0.30	74.8	575.2	13.3
	10.5	0.31	75.2	575.0	11.5
	10.8	0.29	75.0	575.1	12.5

Table I shows that with pure endosperm, as compared with the flours containing some bran, differences in λ_D among various types of wheat disappear almost entirely, and difference in Y also becomes much smaller. A part of the small remaining difference in Y, observed between U.S.-Wh. and Jap.-DSW, on the one hand, and Can.-Man. and Jap.-DHW, on the other, seems to be related to differences in protein content. Only in P_e are significant differences observed for different wheats; and for P_e, the relations between samples are quite similar to those obtained for flours.

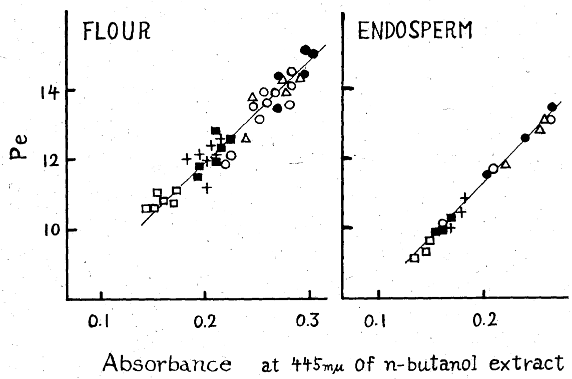

Fig. 2. Correlation between P_e and carotenoid content of unbleached flour.

Figure 2 shows that highly significant correlations exist between P_e and yellow pigment content for both endosperm powder and experimentally milled flour. The carotenoid content of endosperm seems to be the main factor causing differences in P_e. But when flour (i.e., endosperm powder contaminated with some bran) is bleached, the correlation is lowered to a negligible level (Fig. 3). In this case,

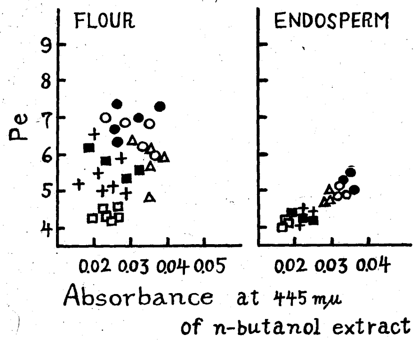

Fig. 3. Correlation between P_e and residual pigment of bleached flour.

the bran color seems to have a major influence on P_e values because of destruction of most of the yellow pigments.

However, with bleached endosperm powder (Fig. 3), P_e is deeply affected by the amount of residual pigment; moreover, since the amount of residual pigment differs for different wheats, the improving effect of bleaching on flour color also differs from wheat to wheat. Generally speaking, samples of high carotenoid content, Austr.-Wh., Jap.-DSW, and Jap.-DHW, also give high values for residual pigment. This residual pigment, probably lipid in nature, is soluble in water-saturated n-butanol. After extraction with this solvent, both bleached and nonbleached endosperm powder gave similar P_e values for different wheats (Table II).

TABLE II
INFLUENCE OF THE PIGMENT EXTRACTION WITH N-BUTANOL ON THE EXCITATION PURITY OF ENDOSPERM POWDER

Sample	Treatment	P_e Untreated	P_e n-Butanol-Extracted Residue
		%	%
U.S.-Wh.	Unbleached	9.1	4.0
	Bleached	4.3	3.8
Austr.-Wh.	Unbleached	13.0	4.2
	Bleached	4.2	3.9
Can.-Man.	Unbleached	10.0	4.0
	Bleached	4.2	3.9
U.S.-DHW	Unbleached	9.9	4.2
	Bleached	4.4	3.8
Jap.-DSW	Unbleached	13.1	4.3
	Bleached	5.1	3.9
Jap.-DHW	Unbleached	12.5	4.1
	Bleached	5.5	3.8

Simple Notation of Flour Yellowness. As described above, the contents, and probably the components also, of flour carotenoid are different for each wheat type or variety. These yellow pigments are usually determined by measuring the absorption of water-saturated n-butanol extract according to the method described in *Cereal Laboratory Methods* (1). However, for quality control in a mill, for example, a simpler method is desirable. For this purpose, the authors adopted the difference between logarithm of reflectance of flour suspension at 554 and at 455 mμ. Reflectance at 554 mμ is selected as the wave length at which the flour reflectance is uninfluenced by bleaching; and 455 mμ, as the one at which a maximum absorption of yellow pigments occurs and thus the largest difference in reflectance between nonbleached and bleached flours. The correlation coefficient for this latter value and yellow pigment content, calculated for 38 samples whose color coordinates are shown on Fig. 1, is 0.959 (Fig. 4). Such a highly significant correlation indicates that reflectance at 455 mμ is a convenient index of yellow pigments, at least for flours of similar grade.

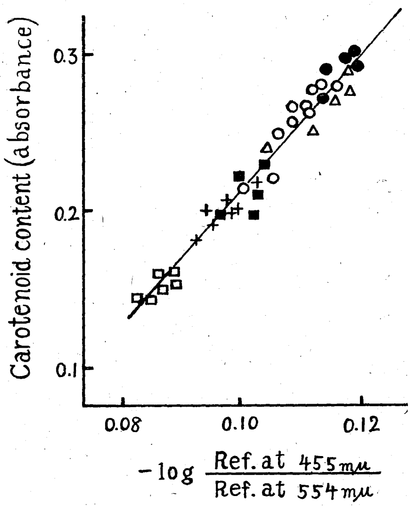

Fig. 4. Simple notation of flour yellowness.

Influence of Bran Color. Figure 5 shows the chromaticity coordinates obtained for some samples of bran, separated from the same set of wheat samples (cf. Fig. 1) and ground to 100–150 mesh. Bran of white wheat gives higher Y and shorter λ_D (which indicates inclination to yellow in hue), while that of red wheat gives lower Y and longer λ_D (which indicates the inclination to red in hue). Bran of Japanese domestic wheat, both hard and soft, showed this red wheat characteristic strongly. These results indicate that the difference in Y and λ_D found between flours may depend on the bran color characteristics of each type of wheat.

This assumption was confirmed by observing the deterioration in color caused by adding bran powder of U.S.-Wh., Can.-Man. and Jap.-DSW, respectively, to endosperm powder of U.S.-Wh. (Fig. 6 and Table III). Figure 6 also shows that a greater ratio of color deterioration occurred when a smaller amount of bran was blended. This indicates that flours of higher grade require more careful control for color.

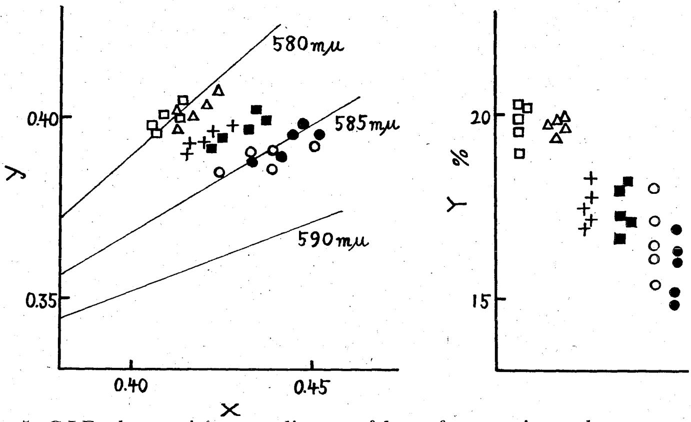

Fig. 5. C.I.E. chromaticity coordinates of bran from various wheat sources.

TABLE III
COLOR COORDINATES OF BRAN USED FOR BLENDING

SAMPLE	Y	λ_D	P_e
	%	mμ	%
U.S.-Wh.	20.6	579.5	45.8
Can.-Man.	17.9	583.2	46.6
Jap.-DSW	16.2	586.2	47.8

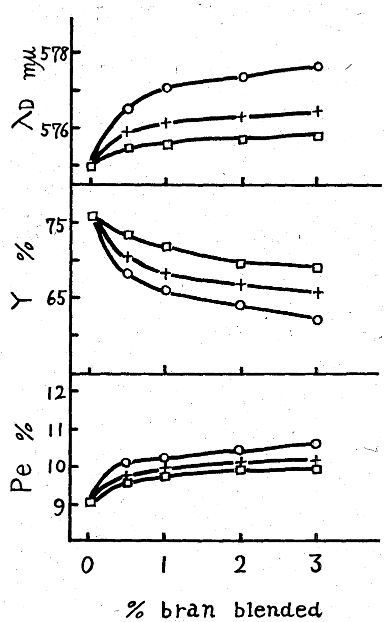

Fig. 6. Influence of bran on the flour color. (Each bran is blended with a sample of endosperm of U.S.-Wh.)

Bleaching with benzoyl peroxide made substantially no improvement in the reflectance curve for bran powder. Observations mentioned above show that bran color may have a serious effect on the commercial value of flour; so, it is a matter of significance to estimate color characteristics of bran. However, measurement of the apparent color of wheat kernels does not give a satisfactory prediction of the influence of bran on flour color; because not only the color of kernel skin itself, but also other conditions of kernels such as vitreousness or kernel size, may affect the color value obtained. Moreover, preparation of bran powder for the purpose of color measurement takes much time and labor for separating and grinding to approximately the same level of particle size. Accordingly, it is of great convenience if we can take account of the color characteristics of bran by suitable reflectance measurements on the experimentally milled flour used for other quality tests.

Flour brightness can be evaluated by the Kent-Jones & Martin Flour Color Grader, and the brightness reading according to *Cereal Laboratory Methods*. Though these one-point methods give results which correlate fairly well with sensory evaluation of flour brightness, they give no information on the other attributes of flour color such as hue or chroma. Moreover, the values obtained are always affected by two factors combined: the color characteristics of each type of bran, and the degree of bran contamination. For this reason, another method is required to demonstrate bran color characteristics only, which vary widely among types and varieties of wheat, regardless of the degree of bran contamination. A simple method of estimating the effect of bran is proposed here.

Estimation of Bran Color Characteristics in Flour. Figure 7 shows typical spectral reflectance curves obtained from bran of three types of wheat. A remarkable difference is found between red wheats and the white one, especially for the slope of the curves at wave lengths longer than 530 mμ. The curves for two types of bran cross in this range, where yellow pigments and bleaching have little influence on the spectral reflectance curve of flour. Accordingly, it should be possible to detect this difference of slope between reflectance curves for flour contaminated with these brans; a red wheat flour should give larger difference of reflectance between 530 mμ and 700 mμ than a white one. Of course, among samples from the same wheat, the slope of reflectance curves in this range will differ according to extraction rate or degree of bran contamination; i.e., the lower the grade of flour, the steeper the slope of reflectance curve and the larger the difference of reflectance between the two wave lengths. So, when

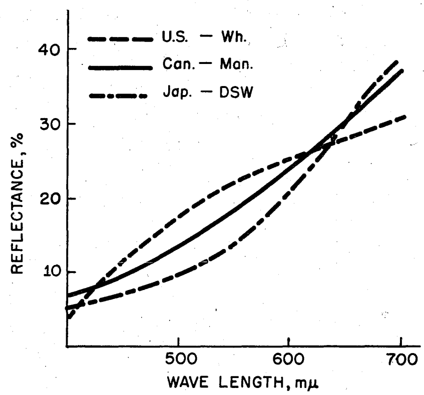

Fig. 7. Spectral reflectance curves of bran powder.

comparisons of slopes of reflectance curves are made in this range, it is also necessary to take into account the grade of the flour. Following this reasoning, a method of estimating the bran color characteristics of flour color was devised.

In Fig. 8, flour colors of various samples are represented by plotting the difference between the logarithm of reflectance at 700 and at 554 mμ against the logarithm of reflectance at 554 mμ. Instead of 530 mμ, 554 mμ is adopted, since the reflectance value is closer to Y, and is less influenced by yellow pigments or bleaching.

The characteristics of each type of wheat are obviously shown by the slope of the regression lines. Both the fact that these regression lines tend to originate at one point, and the fact that points representing pure endosperm of various types of wheat are closely grouped, provide satisfactory confirmation of the suitability of this method for evaluating flour color in terms of the color characteristics of bran included in the flour, irrespective of the degree of bran contamination.

For reporting flour color according to this method, the following index, K_B, is calculated:

$$K_B = \frac{\{\log(\text{ref. at } 554\ \text{m}\mu) - \log(\text{ref. at } 700\ \text{m}\mu)\} - 0.021}{\log(\text{ref. at } 554\ \text{m}\mu) - 0.119}$$

In this equation, 0.021, and 0.119 are the ordinate and the abscissa, respectively, of the assumed point for color of pure endosperm calculated statistically from results shown in Fig. 8. High values of K_B are always obtained from red wheat flours and low values from white wheat flours; in other words, high value of K_B corresponds to a flour color of relatively long λ_D and low Y, i.e., the more undersirable characteristics of red wheat (such as Japanese domestic wheat), while low K_B represents more desirable color.

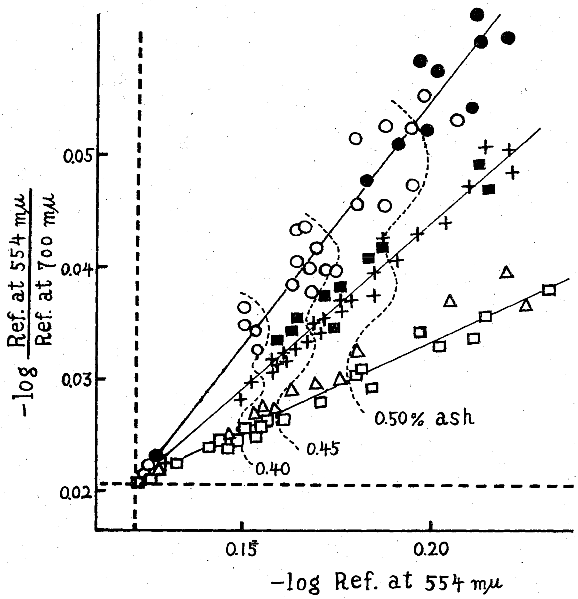

Fig. 8. Notation of bran color characteristics of flour.

TABLE IV

FREQUENCY DISTRIBUTION OF K_B

K_B SAMPLE	U.S.-WH.	AUSTR.-WH.	CAN.-MAN.	U.S.-DHW	JAP.-DSW	JAP.-DHW
1.1–1.2						
1.3–1.4	6					
1.5–1.6	9					
1.7–1.8	6	2				
1.9–2.0	6	6				
2.1–2.2	1	2				
2.3–2.4						
2.5–2.6						
2.7–2.8	3		3	1		
2.9–3.0			8	1		
3.1–3.2			7			
3.3–3.4			4			
3.5–3.6			2	3		
3.7–3.8				4	1	
3.9–4.0				1	3	
4.1–4.2					6	1
4.3–4.4					3	1
4.5–4.6					1	1
4.7–4.8					6	2
4.9–5.0					2	2
5.1–5.2					4	
5.3–5.4					3	1
5.5–5.6						2

A frequency distribution for K_B values for various types of wheat is presented in Table IV. According to their type, imported wheats and Japanese domestic wheats show different K_B values. The relatively small fluctuation among samples of each type of imported wheat indicates reasonable uniformity in the blends of various wheats represented in imported parcels. Samples of Japanese domestic wheat, both soft and hard, show higher K_B values, and thus more undesirable color than imported ones. The greater fluctuation of K_B, observed for these wheats, may be due to the fact that they represent a relatively wide range of different varieties and/or of wheats from different growth locations.

Discussion

Flour color is affected not only by its grade, or extraction rate, but also by color characteristics of the endosperm and the skin of the wheat kernel from which the flour is obtained. The aim of this study is to obtain basic information for evaluating the color of flour from each type or variety of wheat, taking these factors into account.

When flour is bleached, its color improves owing to oxidation of yellow pigments, carotenoids. It has generally been considered that yellow pigments of wheat have no significant effect on the color of bleached flour. However, results obtained here showed that there is some varietal difference of P_e among bleached samples of wheat endosperm caused by differences in the amount of residual pigment. In flour milled by the usual procedure, it is probable that the ground germ supplies some amount of yellow pigment to the flour, so the effect of residual pigment may be the more marked. Our results, though not described here, also indicated a possible correlation between the amount of residual pigment and of original yellow pigments of nonbleached flour. It thus seems pertinent to determine yellow pigments of flour as one of the factors affecting the color improvement of flour when bleached. The composition of yellow pigments of each flour, or wheat, is considered to be closely related to the degree of bleaching effect, and further studies on this point are now in progress.

Bran is the main factor causing deterioration in flour color, and, as is also the case with endosperm, its effect varies among different types or varieties of wheat. When wheat kernels are sufficiently clean, and flour obtained from them has been little affected by dust or other extraneous materials, K_B is suitable for denoting the bran color characteristics of flour; for, with K_B, it is possible to obtain substantially the same values for flours extracted from one sample of wheat, irrespective of extraction rate or flour grade.

Results described above lead to the conclusion that when wheat quality is evaluated from the viewpoint of color of flour, it is important to have information on the color characteristics of the wheat (the source of flour) in addition to the milling quality, i.e., the tendency of bran particles to contaminate flour. Indices proposed above may also have some other uses: for example, as a rapid screening test to select lines of good flour color from collections of hybrid lines of widely varying origins.

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