DETERMINATION OF BREAD CRUMB COLOR AS RELATED TO THE COLOR OF FLOUR USED TO BAKE THE BREAD[1]

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ABSTRACT

Bread color was measured with the Kent-Jones & Martin Color Grader, using a slurry prepared by mixing bread crumb, corn starch, and water in a Waring Blendor. Determinations were made on crumb removed from the center of the loaf and slurried in a 1:1 ratio of starch to bread crumb, for 30 seconds. Delay in color measurement affected the results due to settling of bread crumb solids. The results were unaffected by variations in fermentation and proof time by loaf size and loaf form, and by addition of lactic acid. Storage at elevated temperatures resulted in darkening of bread crumb. The effect of starch employed in bread color determinations was established and a formula for calculating grade color of flour used in a bread under test was determined. The resulting method was applied to a number of flours of varying grade and the breads made from them. The procedure was found to measure that component of bread crumb which is independent of crumb grain and texture; this was shown to be highly correlated with the grade color of the flour from which the bread was baked.

The color of bread crumb depends on a number of factors, the most important of which are the color of flour from which the bread has been produced and the method of bread manufacture. The apparent bread color depends on crumb grain; thus Treloar *et al.* (17) and Graesser (5) have reported correlations between crumb color and texture scores. Properly fermented bread has a fine crumb with soft texture, good sheen, and bright color. The improved color is due to the finer cell walls surrounding small gas cells; this structure tends to reflect the light instead of absorbing it, thus looking much whiter than an improperly fermented bread baked from the same flour. Under normal storage conditions changes in the crumb color of wheat bread are negligible. On prolonged storage at elevated temperature a browning reaction takes place (15). Although the color of bread crumb is of great commercial importance, it has proved rather difficult to measure this property objectively. Markley and Bailey (12) stated that "A practical crumb scoring method which will remove most if not all the personal factors in judgment is very much needed," and that crumb color is one of the most important properties to be ascertained by the baking test.

Measurement of crumb color, employing color charts (14) or Mun-

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sell disks (1,2,6), is difficult and is influenced by pigment content and by crumb grain; hence the values obtained are of little value as an index of flour grade. Geddes (4) measured changes in bread crumb color by a rather complicated procedure, involving careful air-drying of bread crumb, grinding the crumb to a specified fineness, and measurement of the reflectance in comparison with a standard white surface employing a Beckman spectrophotometer, fitted with a reflectance attachment. Larsen *et al.* (10) measured changes in browning of bread crumb with a Hunter color and color difference meter. Wilcox (18) tested the utility of the Photoelectric reflectometer for color crumb measurement and found that the tristimulus values obtained by means of this instrument could be used in an objective differentiation between samples which were visually different. Szalai (16) studied light reflectance from bread slices, pressed bread samples, and frozen bread crumb; satisfactory reproducibility was obtained when measurements were made on vacuum-dried and ground bread crumb.

The Kent-Jones & Martin flour color grader has found a wide use in determination of flour color in cereal laboratories (8,9). The principle of the instrument is the measurement of light reflected by a flour slurry. The instrument uses a filter with maximum transmittance at 530 mμ; the readings reflect primarily the amount of bran present, and are only slightly affected by the color or fineness of bran particles, carotenoid pigments, or by flour particle size. Several workers have found that the reflecting power of flour should be measured at several wave lengths (3,7,13). Though the Kent-Jones & Martin flour color grader measures only one color attribute, it determines the major factor in judging of flour grade: the brightness or dullness which is correlated with the flour extraction rate.

Mackinney (11), while discussing flour color measurement, mentioned the necessity of formulating a relationship between readings of flour color measurement and crumb color of the loaf. In dealing with flours of medium to low quality which produce small loaves with fairly poor texture, grain and texture tend to mask differences in flour grade color. The present study has been undertaken to develop a method for measuring, by means of the Kent-Jones & Martin color grader, that component of crumb color which is independent of crumb grain and texture, and to determine its relation to the grade color of the flour. The method involves mixing corn starch with bread crumb and water to form a slurry, the color of which is measured in the color grader. The influence of a number of variables in analytical procedure, bread storage conditions, fermentation and proof time on the bread color readings was studied and the resulting method

applied to a number of flours of varying grade and the breads baked from them.

Materials and Methods

Flour Samples. Untreated flours of different extraction from 23 commercial mills were used. The flours were milled from a medium-strength wheat grist (about 11.5 to 12% protein) — a mixture of hard red winter, soft red winter, Italian, and Turkish as well as local soft wheats. The range of flour extraction of samples used in this study was between 52 and 95% (calculated as percentage of total products obtained on milling); their ash content varied between 0.55 and 1.35%.

Starch Samples. Commercial corn starch from five sources was used. The grade color of the starches used ranged between −1.2 and +3.0. The grade color of starches employed, except for those used in a series designed to determine the influence of starch color employed on bread color readings, was −0.6 to −0.3.

Analytical Methods. Flour color was determined according to the procedure outlined by the manufacturer, involving measurement of light reflected from the surface of a paste prepared from 30 g. of flour and 50 ml. of water. Starch color was measured on a paste prepared by mixing 40 g. of starch with 40 ml. of water. Unless stated otherwise, bread color was determined by the following procedure: a slurry of bread crumb was prepared from 40 g. of shredded, crust-free bread crumb, taken from the interior part of the bread about 48 hours after baking, and mixed 30 seconds with 40 g. of corn starch and 85 ml. of water in a Waring Blendor. The slurry was poured into the cell of the Kent-Jones & Martin color grader and the color measured. The usual precautions observed during measurement of flour color with the instrument — water temperature, paste consistency, etc. — were also observed in testing bread-crumb color. Minor changes in the ratio of water to solids caused no significant variations in color determinations.

The effect of a number of variables in analytical procedure was studied. These include: delay in color measurement, effect of location in the loaf from which the bread crumb has been taken, effect of starch color, slurry mixing time, and effect of the ratio bread crumb to starch used in making the slurry. Additionally, the effect of variations in bread-baking procedure (fermentation and proof time, loaf size and form, addition of lactic acid) and storage conditions on bread-crumb color has been studied.

TABLE I
BREAD-BAKING METHOD

	White Bread	Dark Bread
Flour (g.)	1000.0	1000.0
Salt (g.)	13.0	20.0
Active dry yeast (g.)	15.0	7.5
Dispersed for 15 minutes in water (ml.)	90.0	50.0
Dissolved with sucrose (g.)	36.0	2.0
Lactic acid, 20% (ml.)	...	25.0
Calcium propionate (g.)	2.0	...
Malt extract (g.)	2.5	....
Potassium bromate (p.p.m.)	20.0	...
Water	variable	variable
Bulk fermentation (minutes)	about 110	about 75
Proof (minutes)	about 75	about 70
Dough temperature (°C.)	30	30
Fermentation temperature (°C.)	30	30
Baking time (minutes)	about 50	about 50
Baking temperature (°C.)	220	220

Bread-Baking Methods. Unless stated otherwise, the bread tested was baked in a testing bakery by the method outlined in Table I.

White bread was baked from flours of grade color below 9.0; for dark bread, darker flour was used. The loaves were scaled (at about 580 g.) so as to weigh 500 g. after baking.

Results and Discussion

Variables Affecting Bread-Crumb Color Determination. The standard error of a grade color determination of the bread crumb was 0.161, based on duplicate analyses of nine typical samples. Increasing the mixing time from 30 to 60 seconds in preparing the slurry in the Waring Blendor had no effect on grade color readings, and a mixing time of 30 seconds was normally employed. Mixing time beyond 30 seconds sometimes gave a stiff slurry, especially in bread made from high-extraction flour and impaired paste consistency, causing difficulties in pouring the slurry into the cell. There is, however, no danger in increasing the mixing time to one minute, if this should be necessary to obtain a slurry of uniform composition.

Though there was a linear relation between the ratio of starch solids to bread crumb solids and grade color (Fig. 1), tests were made with a 1:1 ratio as a matter of convenience in order to be able to measure grade color of various slurries within the working range of the instrument.

The grade color of the bread crumbs, in Fig. 1, was 4.3 and 10.5 (in samples A and B respectively) when tested with a slurry containing a 1:1 ratio of starch to bread crumb.

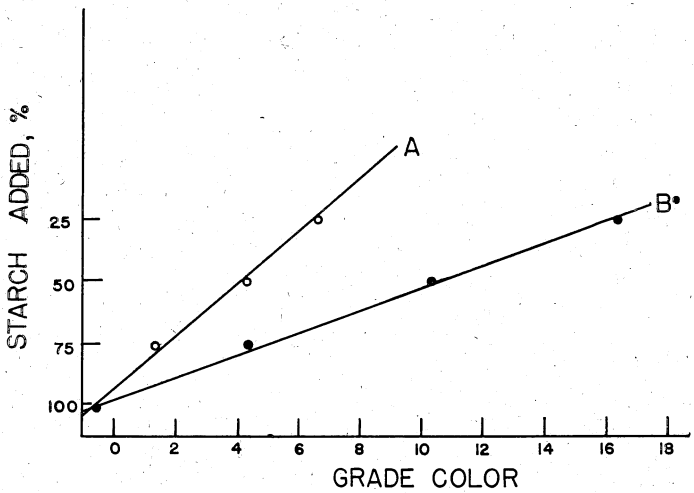

Fig. 1. Effect of various amounts of starch (as percent of total solid ingredients) on grade color.

Readings of color grade were made immediately after completion of mixing, because delay in the color measurement had a significant effect on results, caused by settling of bread solids (see table below).

Sample No.	*Effect of Delay (minutes) in Color Measurement on Bread Grade Color*			
	0	*5*	*15*	*30*
1	5.1	5.4	5.6	5.8
2	8.3	8.8	9.0	9.3

Bread crumb was generally removed from the interior of the loaf. The effect of including also some part of the exterior (care being taken not to include crust) is given in Table II.

The results show that the place from which the bread crumb was removed had a significant effect (5% level) on grade color. Subse-

TABLE II

EFFECT OF PLACE FROM WHICH BREAD CRUMB WAS REMOVED ON GRADE COLOR

SAMPLE NO.	INTERIOR ONLY	EXTERIOR INCLUDED
1	7.5	7.5
2	7.5	7.7
3	9.4	9.4
4	10.2	10.4
5	10.7	11.1
6	11.3	11.4
7	11.4	11.4

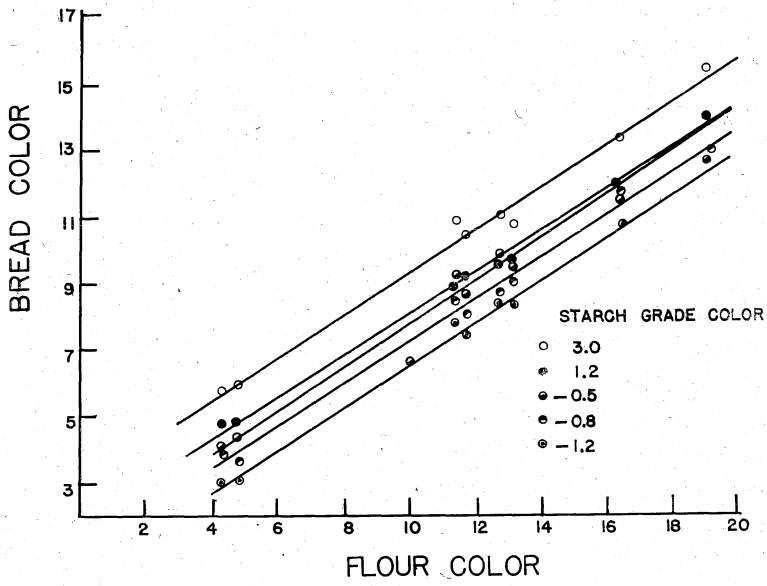

Fig. 2. Effect of starch color on relation between flour color and bread color.

quently, only the interior crumb was used for color measurement.

Relation between Bread Color and Flour Color. Figure 2 shows the relation between flour color and bread color, with the use of five different starches in preparing the slurry. Bread was baked from 16 flours, ranging in grade color from 4.3 to 19.0, and duplicate crumb color determinations were made using each of the starches.

For the five corn starches used, the following formulas for linear regression lines were obtained.

Starch Color	*Linear Regression*[a]
−1.2	$y = 0.652x + 0.143$
−0.8	$y = 0.642x + 0.892$
−0.5	$y = 0.654x + 1.306$
+1.2	$y = 0.618x + 1.895$
+3.0	$y = 0.647x + 2.954$

[a] y = Grade color of bread slurry; x = grade color of flour.

The multiple regression was calculated: $Y = 0.640X + 0.554Z + 1.202$, where Y = grade color of bread slurry, X = grade color of flour, and Z = grade color of starch. The flour and bread color had a high over-all positive linear correlation: $r = +0.948^{xxx}$ from a total of 72 pairs of observations, using five different starches. The correlation between flour color and bread color was increased to a partial correlation of $r_{yx.z} = 0.987^{xxx}$, when starch color was held fixed.

The multiple correlation between the observed flour color and those calculated from the multiple regression equation given previously was 0.988^{xxx}, which is larger than either simple correlation with bread color.

These data enable one to calculate from bread color data the grade color of the flour from which the tested bread was baked, provided the color of starch is known.

Effect of Variations in Bread-Baking Procedure and Bread Storage on Bread Color. In a series of experiments it was found the neither the loaf size (500 to 1,000 g.) nor the form (panned or open hearth; oblong or round) had any significant (at 5% level) effect on color of the crumb.

Table III shows the grade colors of bread crumbs baked from doughs fermented and proofed for various times.

TABLE III
EFFECT OF FERMENTATION AND PROOF TIME ON GRADE COLOR

	Fermentation Time	Proof	Loaf Volume	Color Ranking (Visual)[a]	Color Grade
	hours	*minutes*	*cc*		
Dark bread	1	60	1,175	3	10.3
	2	75	1,300	2	10.4
	3	90	1,300	1	10.1
	1	60	1,300	3	10.9
	2	75	1,375	2	11.0
	3	90	1,475	1	11.2
White bread	1	60	1,500	3	4.3
	2	75	1,600	1	4.0
	3	90	1,225	2	4.4
	1	60	1,575	3	4.6
	2	75	1,675	1	4.5
	3	90	1,225	2	4.6

[a] Samples were sorted into three classes and labeled 1, 2, and 3, in order of decreasing color preference.

The results show no significant differences in grade color readings, in spite of rather wide variations in fermentation and proof times. When the same crumbs were scored visually, the differences in color were quite pronounced. This is in agreement with reported observations that variations in fermentation and proofing have a definite effect on visual appearance of loaf crumb color. These differences could not be measured by the proposed method after the crumb texture was destroyed by slurrying.

The addition of lactic acid (at levels varying between 0.2% and 0.8% on flour basis) had no significant effect on the color of the

crumb, as measured by the proposed method.

The determinations of grade color were made, generally, 48 hours after baking. Bread stored at room temperature showed no significant change in crumb color of bread within 48 hours.

Storing bread for 1 week at 28° to 30°C. affected the grade color of crumb; pronounced differences (significant at 5% level) were determined on storage at elevated temperatures after 48 hours.

	Crumb Color of Bread Stored at 28° to 30°C.				
After 48 hours	3.4	6.7	8.5	10.8	12.7
After 1 week	3.6	7.3	9.1	11.6	14.5
	Crumb Color of Bread Stored for 48 Hours				
At 20°–30°C.	2.2	2.7	9.9	10.0	
At 65°–68°C.	3.8	4.9	11.2	10.6	

These results show that the method does detect changes in color due to bread crumb browning caused by either elevated temperatures or prolonged storage.

While under normal conditions the color of flour determines to a very large extent the color of bread crumb, several additional factors may influence the visual perception of bread color by the consumer. Though the effect of browning seems to be of rather minor importance (and is measured by the proposed method), texture has a definite effect on bread color score as judged by visual comparison of crumbs. By slurrying the bread, the differences in color due to these texture differences are avoided. The method seems attractive because of its simplicity and rapidity. It enables one to estimate the degree of extraction of the flour used in the bread, and to use a common basis for estimating color in both flour and bread.

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