NOTE ON THE RELATION BETWEEN BREAD CRUST AND CRUMB COLOR SCORES AND COLOR REFLECTANCE VALUES[1]

MARY EVENSON[2] and B. L. D'APPOLONIA[2]

Cereal Chem. 55(1): 110-114

Color measurement means stating numerically the color of an object. Color measurements have been made on numerous products in the food industry. Croes (1) measured the whiteness of bread crumb according to the tristimulus method with a Photoelectric Reflexímeter (Photovolt). Smak (2) measured the color of the top crust of bread in a similar fashion as that used by Croes for crumb color. Rubenthaler *et al.* (3) determined crumb and crust color on a Photovolt Reflectometer Model 610 with a green filter.

In the present study the Hunter Color Difference Meter, Gardner Digital Color Difference Meter, and Agtron Reflectance Spectrophotometer were investigated for use in bread crust and crumb color evaluations. The relation between visual color and photoelectric measurements of crust and crumb color were examined.

MATERIALS AND METHODS

Bread Samples

Loaves of bread containing 0, 2, 4, 5, 6, 8, and 10% sugar were baked in triplicate on each of three days to obtain a range in crust color. Twelve different loaves of bread containing varying amounts of yellow and black food coloring solution were baked in triplicate on each of three days to obtain a range in crumb color.

[1]Published with the approval of the Director of the Agricultural Experiment Station, North Dakota State University, Fargo, as Journal Series No. 835. Taken in part from a thesis submitted by M. Graven (Evenson) to the North Dakota State University in partial fulfillment of the requirements for the Ph.D. degree.

[2]Respectively: Graduate Research Assistant and Associate Professor.

0009-0352/78/000013$03.00/0

Instrumental Evaluation

Three reflectance spectrophotometers, Hunter Color Difference Meter Model D-25, Gardner Digital Color Difference Meter Model XL-10, and Agtron Model M-500-A were used to measure the reflectance of bread crust and crumb. Each sample was measured twice for color with two readings per measurement, the second reading being taken after the sample was rotated 90°. The Agtron readings for the percentage light reflected by a sample in the red, yellow, green, and blue modes were converted to Hunter's color system (4) with the following equations:

$$L = 10\sqrt{Y}$$

$$a = \frac{17.5\ (1.02X - Y)}{\sqrt{Y}}$$

$$b = \frac{7.0\ (Y - 0.847\ Z)}{\sqrt{Y}}$$

where:

Y = % reflectance in the green mode

Z = % reflectance in the blue mode

X = 0.5440 times % reflectance in the red mode plus 0.2930 times % reflectance in the blue mode.

Bread was evaluated by three experienced judges for crust and crumb color on the two succeeding days following baking. Each factor was scored on a basis of 1–10. A number 10 represented the best possible score and a number 1 the poorest score.

Statistical analyses were performed on an IBM 360 computer utilizing the Statistical Analysis System computer package designed and implemented by Barr and Goodnight (5).

RESULTS AND DISCUSSION

The correlation coefficients between the color parameters for bread crust and bread crumb of the three color meters are shown in Tables I and II, respectively. The corresponding "L", "a", and "b" values of the three instruments were highly significantly correlated. The corresponding "a" values of the three instruments did not have as high correlation coefficients as the other two parameters, although they were significant at the 1% level of confidence. The lower correlations for the "a" parameter may be explained by the difference in the design of the color instruments. The Agtron red mode employs a different wavelength than the Hunter and Gardner.

An average color score designated as Score 1 of the three scores assigned by the judges and designated as Score A, Score B, and Score C was calculated.

The correlation coefficients between instrumental color parameters and visual crust color scores are given in Table III. In all cases, the "L" parameters are

significantly and inversely correlated with the visual crust color scores, while the "a" parameters are significantly and directly correlated with the visual crust color scores.

Table IV shows the correlation coefficients between the instrumental color parameters and visual crumb color scores. The "L" and "a" parameters have shown direct and significant correlation with visual color scores.

SUMMARY AND CONCLUSION

The relation between visual color and photoelectric measurements of crust and crumb color was studied. The Hunter Color Difference Meter, Gardner Digital

TABLE I
Correlation Coefficients Between Color Parameters of the Hunter, Gardner, and Agtron Using Bread Crust[a]

	Hunter			Gardner			Agtron		
	L	a	b	L	a	b	L	a	b
Hunter L	...	0.86**	0.96**	1.00**	0.19**	0.96**	1.00**	−0.69**	0.99**
Hunter a		...	0.96**	0.86**	0.65**	0.95**	0.85**	−0.26**	0.91**
Hunter b			...	0.96**	0.43**	1.00**	0.96**	−0.50**	1.00**
Gardner L					0.18**	0.96**	1.00**	−0.70**	1.00**
Gardner a					...	0.42**	0.16**	0.52**	0.30**
Gardner b						...	0.96**	−0.51**	1.00**
Agtron L							...	−0.72**	1.00**
Agtron a								...	−0.62**
Agtron b									

[a]At 5% level of confidence r = 0.138, 1% level of confidence r = 0.180.

TABLE II
Correlation Coefficients Between Color Parameters of the Hunter, Gardner, and Agtron Using Bread Crumb[a]

	Hunter			Gardner			Agtron		
	L	a	b	L	a	b	L	a	b
Hunter L	...	−0.07	0.32**	0.85**	−0.12*	0.34**	0.92**	0.54**	0.34**
Hunter a		...	−0.86**	−0.13*	0.91**	−0.88**	−0.15**	0.60**	−0.88**
Hunter b			...	0.35**	−0.94**	1.00**	0.40**	−0.44**	0.99**
Gardner L				...	−0.19**	0.38**	0.92**	0.50**	0.38**
Gardner a					...	−0.94**	−0.21**	0.63**	−0.94**
Gardner b						...	0.43**	−0.42**	0.99**
Agtron L							...	0.53**	0.44**
Agtron a								...	−0.43**
Agtron b									

[a]At 5% level of confidence r = 0.118, 1% level of confidence r = 0.146.

Color Difference Meter, and Agtron Reflectance Spectrophotometer were investigated. The color parameters of the three instruments were significantly correlated with each other. The "L" parameters were significantly and inversely

TABLE III
Correlation Coefficients Between Instrumental Color Parameters and Visual Crust Color Scores[a]

	Score[b]			
	A	B	C	1
Hunter				
L	−0.33**	−0.13	−0.29**	−0.30**
a	0.13	0.32**	0.16*	0.21**
b	−0.12	0.08	−0.09	−0.04
Gardner				
L	−0.34**	−0.15*	−0.30**	−0.27**
a	0.73**	0.82**	0.73**	0.79**
b	−0.13	0.07	−0.09	−0.05
Agtron				
L	−0.36**	−0.16*	−0.32**	−0.29**
a	0.81**	0.71**	0.78**	0.80**
b	−0.25**	−0.04	−0.21**	−0.17*

[a]At 5% level of confidence r = 0.138, 1% level of confidence r = 0.180.
[b]Score A, Score B, and Score C are individual crust color scores. Score 1 is the average of Score A, Score B, and Score C.

TABLE IV
Correlation Coefficients Between Instrumental Color Parameters and Visual Crumb Color Scores[a]

	Score[b]			
	A	B	C	1
Hunter				
L	0.41**	0.38**	0.46**	0.46**
a	0.08	0.65**	0.43**	0.47**
b	0.02	−0.53**	−0.31**	−0.34**
Gardner				
L	0.38**	0.34**	0.42**	0.42**
a	0.06	0.66**	0.43**	0.46**
b	0.02	−0.52**	−0.30**	−0.33**
Agtron				
L	0.41**	0.35**	0.44**	0.44**
a	0.40**	0.84**	0.75**	0.75**
b	0.04	−0.51**	−0.29**	−0.32**

[a]At 5% level of confidence r = 0.118, 1% level of confidence r = 0.146.
[b]Score A, Score B, and Score C are individual crumb color scores. Score 1 is the average of Score A, Score B, and Score C.

correlated with the visual crust color and significantly and directly correlated with the visual crumb color score. As the lightness value of the crust increased, the visual crust color score decreased, whereas, with an increase in the lightness value of the crumb, the visual color score increased. The "a" parameters had higher correlation coefficients with the visual crust and crumb color scores than did the "b" parameter. The significant correlations between instrumental color parameters and visual color scores indicate the possibility of establishing color measurements for crust and crumb color.

Literature Cited

1. CROES, A. W. Messung der Brotkrumenfarb. Brot und Gebäck 14: 21 (1960).
2. SMAK, C. New approach to determine the brownness of bread crust. Correlation between crust color and protein content. Cereal Chem. 49: 554 (1972).
3. RUBENTHALER, G., POMERANZ, Y., and FINNEY, K. F. Effects of sugars and certain free amino acids on bread characteristics. Cereal Chem. 40: 658 (1963).
4. HUNTER, R. S. Photoelectric color difference meter. J. Opt. Soc. Amer. 48: 985 (1958).
5. BARR, A. J., and GOODNIGHT, J. H. Statistical analysis system. Sparks Press: Raleigh, NC (1972).

[Received July 21, 1977. Accepted October 11, 1977]