Color Determination of Spaghetti by the Tristimulus Method[1]

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ABSTRACT

The relation between visual color and photoelectric measurements of spaghetti color was studied. Two photoelectric reflectance colorimeters equipped with tristimulus color filters were evaluated by taking quadruplicate readings on 40 spaghetti samples which represented a wide spectrum of colors. Using the CIE system, reflectance data were converted to trichromatic coordinates and related to visual spaghetti color scores. Statistical analysis showed a high correlation between visual and reflectance measurements of colors.

The quality of spaghetti and other pasta products can be attributed to the unique characteristics of durum wheat. Spaghetti made from durum semolina is bright yellow and translucent and loses little solids during cooking. Traditionally, spaghetti color is measured by visual comparison against standard samples. However, errors in visual measurements arise owing to changes in color of standard samples with age, differences in concept of color among judges, and lack of precision in describing the color.

Attempts to eliminate these errors by objectively measuring spaghetti color have met with varying degrees of success. Fifield *et al.* (1) in 1937 and Corneluissen *et al.* (2) in 1962 measured the yellow color of pressed disks of moist durum semolina with the Munsell spinning disk colorimeter. Fifield's results showed a high correlation with semolina pigment content and visual measurement of semolina color. However, the spinning disk method was tedious and lacked precision. Matz and Larsen (3) attacked the same problem and tested the accuracy of several photoelectric instruments for measuring the color of dry durum semolina. They found that the Hunter color difference meter, the Photovolt reflectance meter, and the Densichron reflectance meter gave good results; they reported no measurements of the color of spaghetti or other finished pasta products.

Recently, Matsuo and Irvine (4) reported differences in the reflectance spectra between yellow and brown macaroni, using the ten select ordinates method (5). Their method was accurate but was too time-consuming to be used for screening the numerous samples encountered in durum plant-breeding work.

In the present study, spaghetti color was measured with a tristimulus colorimeter. After a simple calculation, the sample color was located on the CIE chromaticity diagram (5). The results indicated that the method was rapid and convenient and that it correctly identified the color (as determined visually) of all samples tested.

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MATERIALS AND METHODS

Experimentally milled semolinas from 40 randomly selected amber durum, red durum, and hard red spring wheat samples were used in this study. The samples varied in variety and quality and produced a wide spectrum of spaghetti colors.

Spaghetti was experimentally processed from each semolina sample by the micro method of Martin *et al.* (6), which was modified by extruding the pasta through a three-strand, 1/16-in. brass die. The spaghetti was cut in 6-in. lengths, dried, and stored in the dark prior to color measurement.

Visual color was determined by comparing each sample with standards representing the North Dakota durum crop of 1966, under a constant light source (Seedburo North Light), and assigning a numerical visual color score from 1 to 11, with 11 as the best score.

Light-reflectance measurements were made with either the Carl Zeiss Elrepho photoelectric reflection photometer (instrument I) or the Magnuson Engineers' Agtron photoelectric colorimeter model M-500 equipped with an M-300 wide-area viewer (instrument II). Both instruments were fitted with three tristimulus filters to measure the intensity of the three primary colors, red, green, and blue.

The entire 35-mm. viewing area of instrument I was covered with spaghetti strands which were held in place by a 35-mm. black, 0% reflectance, spring-loaded holding stage. Care was taken to ensure that the strands did not overlap. Reflectance readings were taken with each of three tristimulus filters, with instrument I calibrated to compare spaghetti reflectance against a white magnesium oxide 100% reflectance standard.

With instrument II, 16 spaghetti strands were placed in a special holder 1 3/8 by 6 in., covered with a 30-sq.-in., 0% reflectance, black plastic disk, and placed over the 30-sq.-in. wide-area viewer. Care was taken to ensure that the strands did not overlap. Reflectance readings were taken with each of three tristimulus filters; instrument II was calibrated to compare reflectance against a white magnesium oxide, 100%-reflectance standard.

The reflectance readings taken with each instrument were converted to CIE chromaticity coordinates for each sample. Table I shows the method used to convert a typical reflectance reading into CIE chromaticity coordinates.

The chromaticity coordinates, X and Y, were used to locate the sample on the CIE uniform chromaticity diagram (5) shown in upper Fig. 1.

After a number of samples had been measured, it became apparent that spaghetti color fell in the area bounded by the chromaticity coordinates X = 0.32 to 0.40 and Y = 0.34 to 0.41. To detect small differences in color, chromaticity coordinates were plotted on an expanded portion of the CIE uniform chromaticity

TABLE I. CALCULATIONS TO CONVERT REFLECTANCE TO CIE CHROMATICITY COORDINATE

Tristimulus Filter	Reflectance Reading	Tristimulus Value		Chromaticity Coordinates
Red	$Rx = 40.1$	$x = 0.782\ Rx + 0.198\ Rz$	$=34.76$	$X = \frac{x}{x+y+z} = 0.3812$
Green	$Ry = 36.1$	$y = Ry$	$= 36.10$	$Y = \frac{y}{x+y+z} = 0.3959$
Blue	$Rz = 17.2$	$z = 1.181\ Rz$	$= 20.31$	

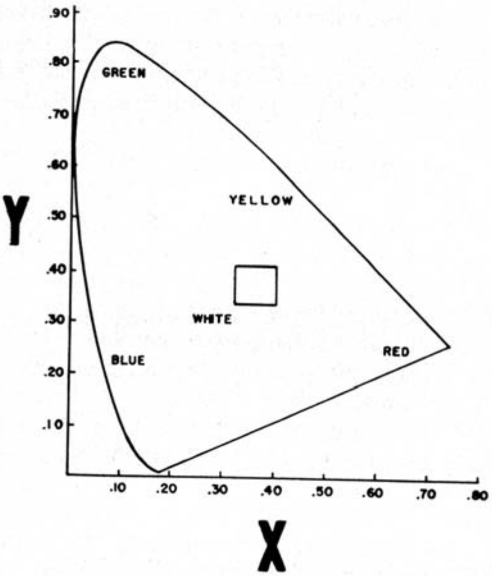

Fig. 1. Above, uniform chromaticity diagram; below expanded portion of uniform chromaticity diagram bounded by X = 0.32 to 0.40, Y = 0.34 to 0.41.

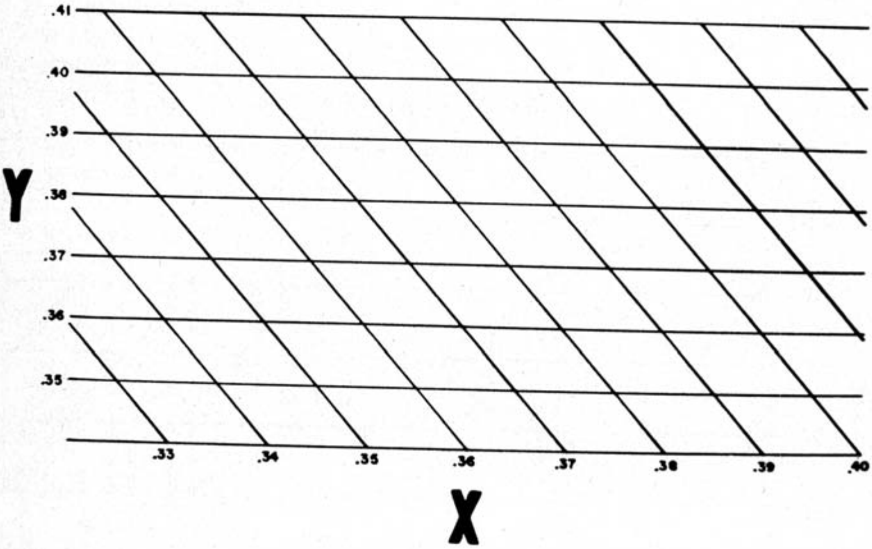

diagram bounded by X = 0.32 to 0.40 and Y = 0.34 to 0.41, according to the method of Simon and Goodwin (7) shown in lower Fig. 1.

To express photoelectric color readings in terms of single values (photoelectric color scores), areas of the expanded chromaticity diagram were assigned numbers corresponding to the visual color scores. Areas were assigned for each instrument as ±1 standard deviation on either side of the mean X and Y chromaticity coordinates of standard samples of known visual color score. Samples having X and Y values falling inside numbered areas were assigned a photoelectric color score which corresponded to the number of the area. Samples falling outside or between two areas were assigned a photoelectric color score by linear interpolation between the two nearest numbered areas.

RESULTS AND DISCUSSION

The results obtained by plotting the average chromaticity coordinates obtained from quadruplicate readings of 40 samples are shown in Fig. 2 for instrument I and Fig. 3 for instrument II.

Figure 2 showed a wide spread along the yellow-white axis and very little spread along the green-red axis for values obtained with instrument I.

Figure 3 showed a wide spread along the red-green axis as well as the yellow-white axis for values obtained with instrument II. This indicated that instrument II was more sensitive to differences between gray and brown spaghetti than instrument I, but both instruments distinguished differences between yellow and pale-yellow.

A calculation of the regression equation and correlation coefficient between X and Y values showed the dependence of chromaticity coordinates upon each other. For instrument I (Elrepho), the coefficient of correlation was +0.9764 with a regression equation $Y = 1.03X + 0.003$. The high correlation coefficient and slope of the regression line indicated that little improvement in accuracy was achieved by taking three tristimulus readings as opposed to taking only the green reading.

For instrument II (Agtron), the coefficient of correlation was +0.8548 with a regression equation $Y = 0.789X + 0.085$. This lower correlation coefficient and slope of the regression line indicated that accuracy was improved significantly when

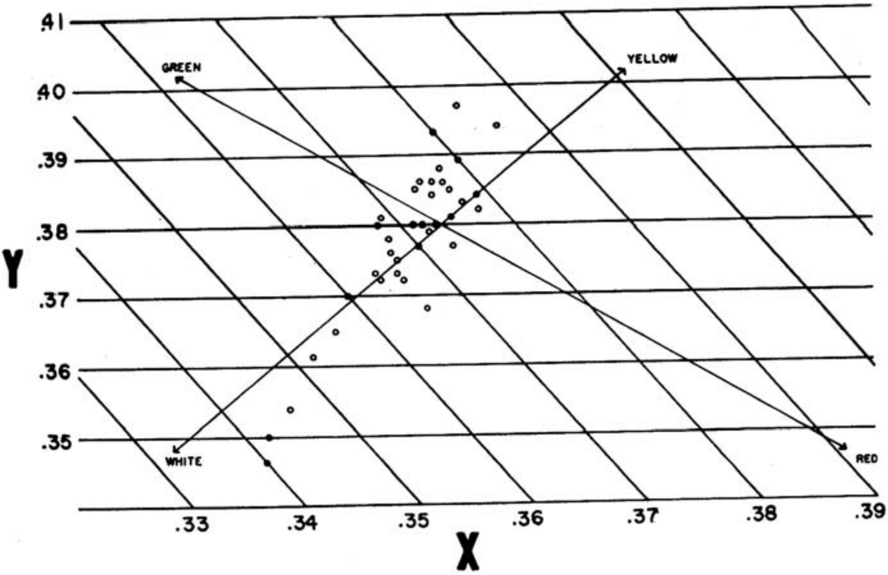

Fig. 2. Average chromaticity coordinates for quadruplicate readings of 40 spaghetti samples taken with instrument I.

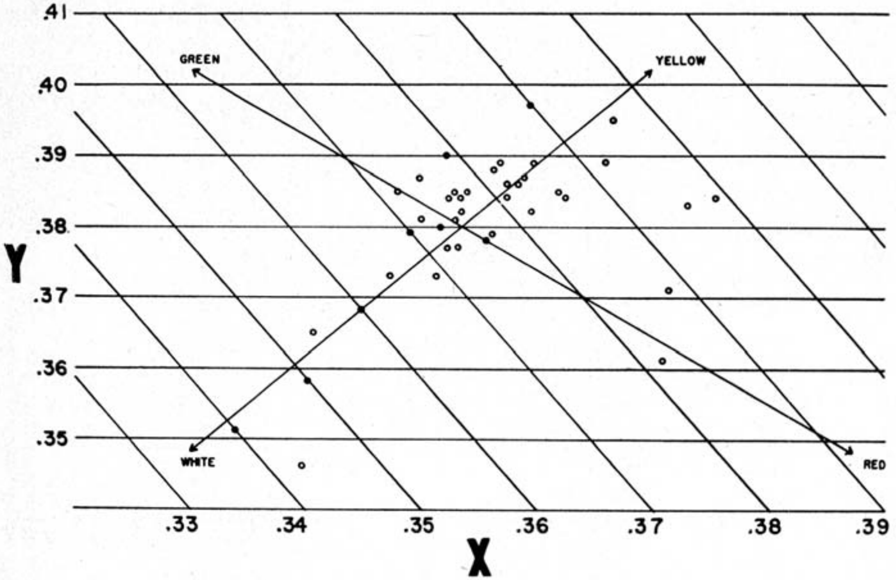

Fig. 3. Average chromaticity coordinates for quadruplicate readings of 40 spaghetti samples taken with instrument II.

all three tristimulus readings were taken, as opposed to taking only the green tristimulus reading.

An analysis of variance (AOV) was made with a split-plot arrangement and completely random design (CRD) on the data from the two instruments. The AOV of the data is shown in Table II.

The estimated mean square (EMS) of the replications (Table II) was significantly higher for instrument II than for instrument I. This indicated that instrument II had a significantly higher variation in replications and was less precise than instrument I. However, there was a larger range between the means of the sample readings of instrument II than of instrument I. This indicated that instrument II showed greater differences among samples, which in part compensated for the greater variation. The standard error of the determination was ±0.03 for instrument I and ±0.08 for instrument II.

The chromaticity coordinates of spaghetti samples measured with each instru-

TABLE II. ANALYSIS OF VARIANCE OF QUADRUPLICATE COLOR READINGS ON 40 SPAGHETTI SAMPLES

		Estimated Mean Square	
Source of Variation	Degrees of Freedom	Instrument I	Instrument II
Replications (R)	3	0.51	7.60**
Samples (S)	39	205.90**	257.25**
R x S (error)	117	0.11	0.75
Filters (F)	2	19,829.57**	27,734.54**
Samples x filters	78	4.79**	9.72**
R x S x F + R x F (error)	240	0.10	0.32
Total	479		

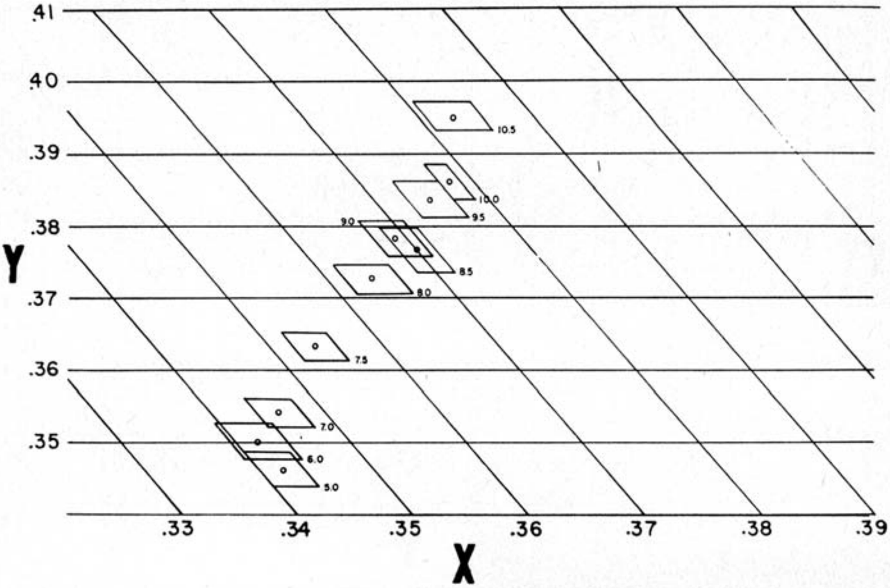

Fig. 4. Numbered areas of chromaticity diagram for instrument I corresponding to visual color scores of spaghetti.

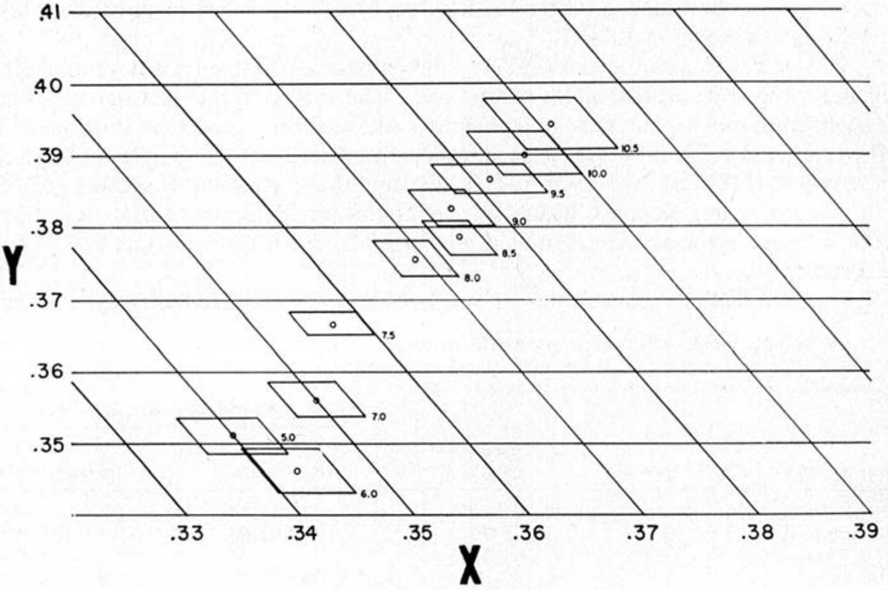

Fig. 5. Numbered areas of chromaticity diagram for instrument II corresponding to visual color scores of spaghetti.

ment were converted to single-value photoelectric color scores with the use of the graphs shown in Figs. 4 and 5.

The photoelectric color scores in most cases agreed with the visual color scores. The correlation coefficient was +0.948 between visual color scores and photoelectric color scores for instrument I, with a regression equation: Visual color score = Photoelectric score (1.067) − 0.499. The correlation coefficient was +0.971 between visual scores and photoelectric color scores for instrument II with a regression equation: Visual color score = Photoelectric score (1.037) − 0.3360. These high correlation coefficients indicated favorable agreement between photoelectric and visual spaghetti color scores for both instruments. However, because of the higher correlation coefficient and the ability of instrument II to distinguish between the grays and browns, it was more accurate than instrument I, though not so precise.

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