Color of Sorghum Food Products

L. W. Rooney and D. S. Murty*

Summary

Color of sorghum milled products and foods is an important aspect of quality that must be measured. Color measurements on sorghum grain, roti and tortilla *samples using the Hunter Lab Color Difference Meter and the Munsell Soil Color Charts showed that Munsell Color Charts are effective for a rapid and inexpensive assessment of a large number of samples from quality breeding programs. It would be possible to obtain standardized color schemes to assess a wide array of sorghum food products among laboratories. Sophisticated instruments such as the Hunter Lab Color Difference Meter can be used for fundamental studies to back-up crop improvement programs.*

Color has long been a criterion of product quality and plays a major role in the acceptance or rejection of food products. Flour color was important to the Romans, who prided themselves on making the finest, whitest flours. Even today many people still equate flour color with quality for use in food products. If sorghum is to compete with wheat and maize products in urban areas, highly refined products will be required.

The color of sorghum flour and sorghum products plays an important part in their acceptance. In many cases where traditional foods are concerned, a white color is not required, but in general it is preferred. The accepted color is conditioned by what people are used to, and unaccustomed variability is often viewed with distrust.

In the International Sorghum Food Quality Trials (ISFQT), brown sorghums produced food products that were unacceptable (Murty and House 1980). In general, white sorghum grains produced the most acceptable colored food products, but considerable variation in color of some products was acceptable. For example, *sankati* made from sorghums with a subcoat was acceptable while *rotis* made from sorghums with a subcoat were not acceptable (Murty et al. 1981a b). Thus, it is important to measure color of grain, flour, and the food products in an efficient manner. The purpose of this paper is to review methods to determine color that can be applied in practical breeding programs. Color measurements range from matching the color of the product with that of a standard by subjective evaluation, to measuring the components of color with expensive and sophisticated color analyzers

Subjective Measurements of Color

An effective method used over the years for wheat flour color measurements was a "Slick" or Pekar test, which compared the color of one flour sample with that of a standard flour (Pomeranz 1971). The flour samples are laid side by side and pressed into a thin layer to form a smooth surface. Then, the color is visually compared. The test is more accurate when the flour samples are wetted and compared. For sorghum flour, the test reflects the level of phenols in the product, the granulation of the flour, and the carotenoid pigments in the endosperm. The major factor affecting the color of sorghum flour is the level of polyphenols, which is related to the amount of contamination of endosperm with pericarp and testa (bran in milling terminology). The use of a test like the Pekar test can be effective especially when standard color plates are used to serve as control samples.

Color Meters

A number of colorimeters have been designed to

* Professor, Cereal Quality Laboratory, Texas A&M University, College Station, Texas, USA; Sorghum Breeder, ICRISAT

Proceedings of the International Symposium on Sorghum Grain Quality, 28-30 Oct 1981, ICRISAT Center

measure the color of a sample in terms of the intensity of the three primary colors: red, blue, and yellow. For instance, the Hunter Lab Color Difference Meter measures color in terms of lightness (L), redness (+a) or greenness (−a), and yellowness (+b) or blueness (−b) in a sample. The signs of the 'a' or 'b' readings determine the color value and intensity of the three primary colors. The *Agtron photoelectric colorimeter* works essentially in the same manner. These instruments are calibrated with standard color plate and provide unprejudiced, reproducible results with a minimum of operating skill and training.

Although the instruments are simple to operate, data must be interpreted with an awareness of the factors affecting color. The relatively high cost of these instruments and the need for sophisticated maintenace, constant voltage and other factors, in general, preclude their use in sorghum quality selection except as back-up instrumentation to establish more simple, economical methods.

Sorghum Color Measurements with the Hunter Lab Color Difference Meter

The color of sorghum grain and *tortillas* as measured by the Hunter Lab Color Difference Meter for ISFQT samples grown in 1979, is presented in Table 1. The procedures followed were the same as those described by Johnson et al. (1979). The Hunter Lab Color Difference Meter is not able to distinguish among sorghums with a testa since it only measures surface color. Thus, a person must be familiar with kernel properties of sorghum to evaluate color data on the whole grain. The surface texture of *tortillas* affects color measurements significantly and numerous measurements are required to obtain a reliable reading. This is expecially true when *tortillas* are unevenly cooked. The ΔE values in Table 1 are a way of condensing color measurements into one value. In general, ΔE values were highest for sorghum *tortillas* with the darkest, most unacceptable color.

The Hunter Lab Color Difference Meter has been used to measure the color of fresh and stale (stored 24 hr) *tô* (Akingbala, in press) and *ogi* (Akingbala et al. 1981).

Munsell Soil Color Charts

The Munsell Soil Color Charts (Anon. 1975) display different standard color chips systematically arranged according to their Munsell notations, on cards carried in a loose leaf notebook. The arrangement is by three simple variables that combine to describe all colors and are known in the Munsell system as Hue, Value, and Chroma. The Hue notation of color indicates its relation to red, yellow, green, blue, purple, yellow-red, green-yellow, blue-green, purple-blue, and red-purple; the Value notation indicates its lightness; and the Chroma notation indicates strength (or departure from a neutral of the same lightness). The colors displayed on individual cards are of constant Hue, designated by a symbol. Vertically, the colors become successively lighter from the bottom of the card to the top by visually equal steps; that is, their Value increases. Horizontally they increase in Chroma to the right and become grayer to the left. The Value notation for each individual column and row are indicated on the chart.

As arranged in the notebook, the charts provide three scales: (1) radial, or from one chart to the next in Hue, (2) vertical in Value, and (3) horizontal in Chroma. The charts provide color names as well as the Munsell notation of color. The Munsell notation is used to supplement the color names wherever greater precision is needed. The Munsell notation is especially useful for international correlation, since no translation of color names is needed.

The Munsell notation for color consists of separate notations for Hue, Value, and Chroma, which are combined in that order to form the color designation. The symbol for Hue is the letter abbreviation of the color of the rainbow (R for red, YR for yellow red, Y for yellow) preceded by numbers from 0 to 10. Within each letter range, the Hue becomes more yellow and less red as the numbers increase. The middle of the letter range is at 5; the zero point coincides with the 10 point of the next redder Hue. Thus 5YR is in the middle of the yellow red Hue, which extends from 10R (zero YR) to 10YR (zero Y).

The notation for Value consists of numbers from 0 for absolute black, to 10 for absolute white. Thus a color of Value 5/ is visually midway between absolute white and absolute black. One of Value 6/ is slightly less dark, 60% of the way from black to white, and midway between Values of 5/ and 7/.

The notation for Chroma consists of numbers beginning at 0 for neutral grays and increasing at equal intervals to a maximum of about 20. For

Table 1 Grain, *roti*, and *tortilla* color measured with the Hunter Lab Color Difference Meter and the Munsell color charts.

Sorghum samples	Apparent grain color description	Grain color[a] L	Grain color[a] a	Grain color[a] b	Grain color[a] ΔE[c]	Grain[b] color Munsell	*Roti* color Munsell	*Tortilla* color[a] L	*Tortilla* color[a] a	*Tortilla* color[a] b	*Tortilla* color[a] ΔE[c]
P721	White	59.1	3.1	19.1	20	2.5Y 8/2	5Y 6/4	49.9	−0.4	15.8	29
E35-1	White	58.8	2.2	17.4	20	5Y 8/2	5Y 8/2	53.8	−0.3	15.2	25
IS158[d]	White	62.2	2.3	19.1	17	5Y 8/2	5Y 7/3				
Market-1	White	62.2	2.6	17.6	17	5Y 8/2	5Y 8/2	49.7	−1.1	14.3	30
S29	White	61.1	3.3	18.1	18	2.5Y 8/2	5Y 8/2	48.6	1.6	12.0	31
IS2317	Light gray	58.9	0.8	14.4	21	5Y 7/1	2.5Y 5/2	29.7	0.4	4.7	51
WS1297	Light gray	59.3	1.0	12.6	21	5Y 7/1	2.5YR 5/2	33.9	0.85	5.3	44
IS7035	Light gray	56.4	1.0	12.6	24	5Y 7/1	2.5YR 4/2	36.0	0.38	6.9	45
M35-1	Pale yellow	56.6	3.7	19.6	22	5Y 8/3	5Y 8/2	46.4	−2.0	15.2	33
CSH-5	Pale yellow	56.0	3.9	19.8	23	5Y 8/3	5Y 8/2	49.4	−2.4	16.6	29
M50009	Pale yellow	52.2	3.6	18.2	26	2.5Y 8/4	5Y 8/3	48.1	−2.0	15.4	31
M50013	Pale yellow	52.7	3.9	18.9	26	2.5Y 8/4	5Y 8/2	48.1	−1.4	16.0	30
M35052	Pale yellow	52.3	4.0	18.1	27	2.5Y 8/4	5Y 7/3	49.9	−1.1	14.3	29
M50297	Pale yellow	56.5	3.2	19.1	22	2.5Y 8/4	5Y 8/3	54.3	0.7	15.4	25
Mothi	Pale yellow	53.3	3.2	17.8	25	5Y 8/3	5Y 8/3	51.1	−1.8	16.8	27
Segaolane	Pale yellow	51.8	4.5	17.0	27	2.5Y 8/4	2.5Y 8/2	51.0	−0.6	14.2	28
Swarna	Pale yellow	54.2	4.4	19.2	25	2.5Y 8/4	2.5Y 8/2	52.2	−0.8	15.3	27
S-13	Pale yellow	53.7	4.0	18.2	25	2.5Y 8/4	5Y 7/3	54.3	−0.7	15.4	25
CS3541	Pale yellow	52.0	4.8	19.2	27	2.5Y 8/4	5Y 8/4	46.0	1.2	15.3	33
Patcha Jonna	Yellow	43.7	6.1	19.3	35	5Y 7/8	5Y 6/6	41.5	5.8	17.3	37
IS9985	Yellow	50.6	5.9	19.9	28	10YR 7/6	2.5Y 8/2	52.0	0.23	15.8	27
CO-4	Light red	41.6	16.4	17.2	37	10R 6/8	10YR 6/4	46.8	3.0	14.1	32
IS8743	Dark reddish gray	34.4	14.0	12.6	45	10R 4/1	5YR 5/4	35.6	2.9	10.7	44
IS7055	Reddish brown	38.0	8.6	14.0	42	5YR 4/4	2.5YR 5/4	26.6	5.5	4.6	55
Dobbs	Pinkish gray	44.4	7.8	16.8	35	7.5YR 7/2	2.5YR 5/4	26.9	4.7	4.1	54

a Grain and *tortilla* color was measured with a Hunter Lab Color Difference Meter with L = 78.2, a = −2.3, b = 22.4 as standard. "L" measures color intensity. Increasing "b" = increasing yellow color. Decreasing "b" = increasing blue color. Increasing "a" = more red. Decreasing "a" = more green.

b The number and letters describe the Hue, Value, and Chroma of standard Munsell color plates that matched the *roti* and grain color.

c $\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ where Δ indicates the difference between observed and standard L, a and b values, respectively.

d Hunter Lab Color Difference Meter data were not collected for *tortillas* of IS158.

absolute achromatic colors (pure grays, white, and black) which have 0 Chroma and no Hue, the letter N (neutral) takes the place of a Hue designation. In writing the Munsell notation, the order is Hue, Value, Chroma with a space between the Hue letter and the succeeding Value numbers, and a virgule between the two numbers for Value and Chroma. If expression beyond the whole numbers is desired, decimals are always used. Thus the notation for a color of Hue 5YR, Value 5, Chroma 6, is 5YR 5/6, a yellowish red. Thus, the Munsell values can be related to values obtained with the Hunter Lab Color Difference Meter. But, the Munsell color can be evaluated without an instrument by selecting the best match of product color with standard Munsell plates.

The color plates can be purchased at low cost to provide the range in color values expected for a product. It is estimated that the human eye can perceive several million different colors under optimum color-matching conditions. It is economically impractical to match every possible color. Thus visual interpolation is required.

Sorghum Color Measurements with Munsell Color Charts

Color measurements obtained on grain samples of 25 sorghum cultivars of ISFQT-1979 are presented in Table 1 in comparison with those obtained with the Hunter Lab Color Difference Meter. It was observed that apparently the white gray and pale yellow group of grain samples could be further distinguished by different Hue, Value, and Chroma values of Munsell charts. Variation in a, b, and ΔE values of the Hunter Lab Color Difference Meter was associated with variation in the Hue, Value, and Chroma values of Munsell. The white grain samples P721 and E35-1 showed different a and b values while the Munsell Color Chart also distinguished them by different Hue values. Even minute differences among a and b values of Market-1 and S-29 were reflected in different Hue values of Munsell. Light gray sample IS-7035, which has a testa, showed the least a and b values while the Munsell chart distinguished its color as 5Y 7 1. Among the pale yellow samples, the b values of M35-1 and CSH-5 were the highest while the Munsell Color Chart also distinguished these samples with 5Y 8 3. Similarly, differences in a, b and ΔE values among the two yellow samples were adequately reflected in the Munsell notation. Higher ΔE values were associated with darker shades in the Munsell system. Thus, the Munsell Color Charts are as effective in color description as is the Hunter Lab Color Difference Meter.

At ICRISAT, Munsell Soil Color Charts were used to measure the color of several hundred sorghum grain and *roti* samples (Murty et al. 1981b). Repeated color measurements on grain samples drawn from check cultivar bulks over several weeks showed that color comparisons with Munsell Charts are highly repeatable within ± 1 limits of Chroma. This was also true with *roti* color observations made on samples drawn from the same cultivars replicated in the field in various experiments (Table 2).

The Munsell Soil Color standards have been

Table 2. Grain color of six sorghum cultivars grown in a split plot experiment with four treatments replicated three times.[a]

	Replication 1	Replication 2	Replication 3
P-721	2.5Y 7/2[b]	5Y 7 2	5Y 7 3
	5Y 6 3	5Y 7 2	5Y 7 2
	5Y 6 2	5Y 6 2	5Y 6 3
	5Y 6 3	2 5Y 7 2	5Y 6 3
CS3541	5Y 8 3	5Y 8 2	5Y 8 2
	5Y 8 3	5Y 7 3	5Y 8 3
	5Y 8 3	5Y 8 2	5Y 8 3
	5Y 8 3	5Y 8 2	5Y 8/2
SPV351	5Y 8 2	5Y 8 2	5Y 8/2
	5Y 8 3	5Y 8 3	5Y 8 3
	5Y 8 2	5Y 8 2	5Y 8 2
	5Y 8 2	5Y 8 2	5Y 8 2
E35-1	5Y 7 3	5Y 8 2	5Y 8 2
	5Y 8 3	5Y 8 2	5Y 8 3
	5Y 7 2	5Y 8 3	5Y 8 2
	5Y 8 2	5Y 8 3	5Y 8 2
SPV393	5Y 8 2	5Y 8 3	5Y 8 3
	5Y 8 2	5Y 8 2	5Y 8 3
	5Y 8 3	5Y 8 2	5Y 8 3
	5Y 8 3	5Y 8 3	5Y 8 2
M35-1	5Y 8 3	5Y 8 2	5Y 8 3
	5Y 8 2	5Y 8 3	5Y 8 3
	5Y 8 3	5Y 8 2	5Y 8 3
	5Y 8 3	5Y 8 3	5Y 8 3

a. Grain color observations are according to Munsell notation.
b. Each observation pertains to a sample from a treatment.

used to designate color of *tortillas* (Bedolla and Rooney, unpublished data 1981) and *tô* (Akingbala and Rooney 1981, unpublished data). The Munsell color values for *tortilla* and *tô* were obtained by using tristimulus values measured with the Hunter Lab Color Difference Meter to produce Munsell Color notations. *Tortilla* colors ranged from 10Y to 10YR, lightness Values of 7 to 8, to Chroma of 1 to 6. The yellow and yellow red Hues described *tortillas* Hue very well.

We have accumulated sufficient data on color measurements of sorghum and sorghum products to permit accurate acquisition of Munsell plates (Anon. 1975). A set of standard plates can be purchased for as little as $10 per set provided 20–30 sets are purchased, or the whole soil color classification manual can be purchased for about $30–40. Therefore, we recommend to those who want to determine color in sorghum food products to try the Munsell standard charts as an inexpensive practical method of evaluating color.

Acknowledgment

This research was supported in part by grant AID DSAM XII 6-0149 from the Agency for International Development, Washington, D C. 20523, USA.

References

Akingbala, J. O. (in press) The properties of starch in relation to *tô* quality. Ph.D dissertation Texas A&M University, College Station, Texas, USA

Akingbala, J. O., Faubion, J. M., and Rooney, L. W., 1981 Physical, chemical and organoleptic evaluation of *ogi* from sorghum of differing kernel characteristics Journal of Food Science 46 1527.

Anonymous. 1975 Munsell Soil Color Charts Baltimore, Maryland 21218, USA.. Macbeth Corporation.

Johnson, B A., Rooney, L. W., and Khan, M. N. 1979 *Tortilla* making characteristics of micronized sorghum and corn flours. Journal of Food Science 45(3): 671-674.

Murty, D. S., and House, L. R., 1980. Sorghum food quality, its assessment and improvement. Report presented to the Joint Meeting of UNDP-CIMMYT-ICRISAT Policy Advisory Committee, 14-18 Oct 1980, Patancheru, India.

Murty, D S., Patil, H. D., and House, L. R., 1981a. *Sankati* quality evaluation of sorghum cultivars. These Proceedings.

Murty, D S., Patil, H. D., and House, L. R., 1981b. Sorghum Roti II. Genotypic and environmental variation for *roti* quality parameters. These proceedings.

Pomeranz, Y. (ed). 1971. Chapters 4, 5 and 10 *in* Wheat chemistry and technology. St. Paul, Minnesota, U.S.A.: American Association of Cereal Chemists

Shuey, W. C 1975 Flour color as a measurement of flour quality. Bakers Digest 28: 18-22.