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Manufacturing & **DISTRIBUTION**

HunterLab Colorflex® colorimetric spectrophotometer measures tomato paste.

Measure to Ensure the Color Stays Right

The association between food appearance and quality is a learned relationship. So color tells consumers a lot about a food product.

BY HAL GOOD

Duke Ellington once said, "If it sounds good, it is good." Similarly, most consumers believe if it looks good, it is good. Strong associations between the consumer's judgement of a product's appearance and its taste are learned through experience. Discolored meat, for example, is recognized as old and lacking in freshness. Consumers' conclusions about some products are based almost totally on color. No wonder the food industry is so concerned with monitoring color. Just as corporate colors identify a company, many foods are associated with specific colors: Granny Smith green, citrus orange and yellow, for example.

Sometimes product color translates directly to economic value, as with tomato color. However, the ability of food processors to achieve desired appearance or color in the final product is limited. Minor color corrections commonplace in other industries are unacceptable in food production. Even where food dyes are permitted to produce a desired color, the variety of dyes available for the purpose is finite. So food processors pay attention to the color of raw materials and to the changes that occur with each step of production. Some also monitor color during storage and distribution.

Keeping the correct food color is quite a challenge. Variations in growing season, ingredients, additives, process variations, storage methods and time can affect food color. Using color measurement instrumentation, an appropriate color scale (or index) and proper sample preparation and presentation techniques provide objective, quantifiable and precise color measurement data for R&D, process control, quality control and in some cases, grading. Color measurement systems are used to measure fresh and processed fruits and vegetables, formulated or compounded foods, dairy products, meats, spices, flavors, grains, flour and cereals, oils, syrups, sugar and beverages.

Instrumentation

Instrumental color measurement is more straightforward and simpler to perform than visual methods, eliminates subjectivity, is more precise and takes less time. Three types of color measurement instruments are used for food and food ingredient color measurement.

- **Monochromatic Colorimeter** This measures not color, but the amount of light reflected in relative units in a narrow area of the red, green, blue or yellow region of color. Monochromatic colorimeters are basically colorblind and see only all red, all green, all blue or all yellow, so can give erroneous results. For example, to measure the "browness" of potato chips, a green filter may be used to measure lightness to darkness. Two different batches of chips—one light brown, another darker brown but with a green cast—would read as the same color, even though visually different. However, a monochromatic colorimeter can view a large area—six inches in diameter—and obtain a good optical average of relatively large coarse samples such as potato chips, corn chips or cereals.
- **Tristimulus Colorimeter** This too, views large areas of sample but also measures true color and correlates to what the eye sees. Using specialized glass color filters and light detectors, eye-brain sensitivity to color is simulated. The human eye can detect up to 10 million different shades of color and the tristimulus colorimeter can quantify all of them. Because of its large area of view, the tristimulus colorimeter is excellent for measuring coarse samples such as cookies, crackers, coarse

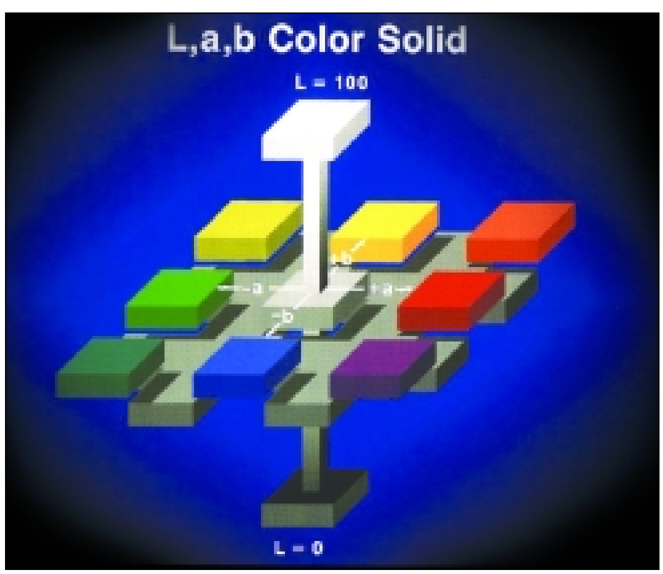
HunterLab D25L Tristimulus Colorimeter sensor shown with snack food sample.

breakfast cereals, extruded snack products, pasta, noodles and tortilla chips. Even "chunky" salad dressings can be measured.

• **Colorimetric spectrophotometer** This measures true color but uses a somewhat different measurement principal than the tristimulus colorimeter. The entire visible spectrum of light (rainbow) reflected from a sample is measured: using mathematical tables representing the human eye's color sensitivity and the color output of different light sources, the result is calculated. This type of instrument is more precise than the tristimulus colorimeter, but does not measure as large an area. The colorimetric spectrophotometer is best for measuring rice, flour, wheat, spices, starch and less coarse breakfast cereal samples. Some instruments can measure transmitted color, so are suitable for measuring samples like brewed tea, clear juices (such as apple and cranberry), vegetable oil, syrup and other clear liquids.

Color Scales

To be useful, a color scale should relate to how we see color, be simple to understand, linear throughout color space and able to quantify color differences. The color scales most widely used by the food industry are the Hunter L,a,b and the CIE L*,a*,b* scales. These three-dimensional scales are based on the opponent-colors theory that states that the red, green and blue human eye cone receptor signals are re-mixed into black-white, red-green, and yellow-blue opponent colors as the signals move from the eye to the brain.



L,a,b type of scales simulate this as:

• L (lightness) axis—0 is black, 100 is white;

• a (red-green) axis—positive values are red; negative values are green and 0 is neutral; and

• b (yellow-blue) axis—positive values are yellow; negative values are blue and 0 is neutral.

All colors that can be perceived visually can be measured in any L,a,b scale. These scales can also measure the *color difference* between a sample and a standard. Color difference is always calculated as SAMPLE minus STANDARD and is frequently stated with a Δ symbol.

• If ΔL is positive, then the sample is lighter than the standard. If negative, it would be darker than the standard.

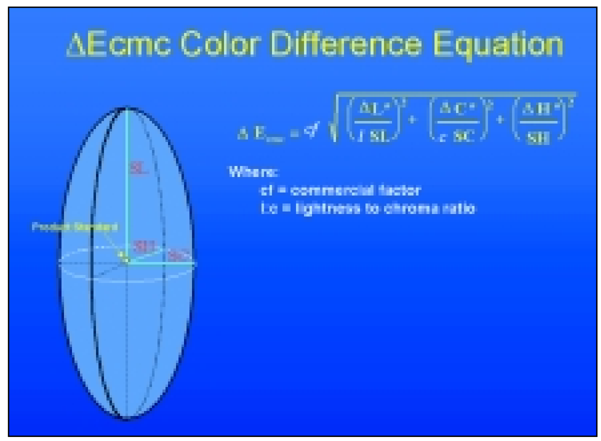
• If Δa is positive, then the sample is more red (or less green) than the standard. If negative, it would be more green (or less red).

• If Δb is positive, then the sample is more yellow (or less blue) than the standard. If negative, it would be more blue (or less yellow).

L,a,b color difference can also be expressed as a single value, ΔE. This value defines the size of the total color difference, but does not give information about how the colors differ. The larger the ΔE value, the larger the color difference. It is defined by the following equation:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

ΔE_{cmc} is a relatively new color difference equation that simplifies the process of setting tolerances. The initials CMC come from the Colour Measurement Committee of the Society of Dyers and Colorists in the UK. A single-number Pass/Fail metric defines a three-dimensional elliptical tolerancing space centered on the product standard. The CMC equation has the unique ability to determine where a particular standard or target color lies in color space. In that particular area, the shape of the tolerance ellipse automatically changes and defines a reasonable volume of acceptance based on three components: ΔL* (lightness difference), ΔC*(chroma difference), and ΔH*(hue difference). SL, SC, SH are weighing functions to correct for non-linearities of CIE L*,a*,b* color space. The general shape of the ellipse can be adjusted to industry parameters by adjusting the l:c (lightness-to-chroma) ratio to accommodate sample differences such as texture. A commercial factor (cf) can be applied to ΔE_{cmc} to increase or decrease the overall size of the ellipse. This results in loosening or tightening the acceptability tolerances set by the edge of the ellipse. Frequently a single ΔE_{cmc} limit value may be set to be used in evaluating the color matches of all the company's products.



Indices

Whiteness is a color index by which a sample's whiteness is measured and expressed as a single numeric value. Observer ratings of whiteness correspond to consumer preferences for products such as sugar, rice and flour. Our visual judgement of whiteness is primarily dependent on how light a sample is and the presence or absence of blue or yellow tint. Of two white samples with the same lightness, the bluer (or less yellow) would be judged to be whiter. A single number— whiteness index (WIE)—is used as a measurement of whiteness and mathematically combines lightness and yellow-blue into a single term. The higher the whiteness index the whiter the sample.

Other indices have been developed for specialized applications. Determination of tomato color according to a specific equation was developed by USDA: Instrumental measurement of color using this equation is widely performed to evaluate the color quality of fruit shipped to tomato canneries. The numerical color value in part determines the price a producer receives for his product. Other similar index scales are used to evaluate processed tomato juice, ketchup, soup paste and puree. Index scales can be used to evaluate other food products. A specific citrus yellowness, redness and equivalent color score has been developed to evaluate the color of orange juice.

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Sample Preparation and Presentation

The ideal sample for color measurement would be flat, smooth, uniform, nondirectional and either totally opaque or totally transparent. Of course, in the real world this is rarely the case, so compromises must be made. To achieve the greatest measurement precision:

- Choose samples representative of the product;
- Prepare the sample in a way that best approximates the ideal sample characteristics;
- Prepare samples the same way each time;
- Present the samples to the instrument in a repeatable manner; and
- Make multiple preparations of the sample and average measurements.

It is common practice to take at least three readings (with sample reload or repositioning) for a non-uniform sample and average the readings. To determine how many readings to average, create one set of averaged readings by reading the same sample three times and averaging the readings. Next, measure the same sample again three times and average. You will now have two averages to compare. If the ΔE between the two averages is less than or equal to 0.11, then three readings are sufficient to provide repeatable results. If the ΔE is greater than 0.11, then try the same procedure again with a greater number of averaged readings until the repeatability is sufficient. The goal of this procedure is to find the lowest possible number of readings that will provide repeatable results.

The benefits of quantitative measurement of food and food ingredient color include consistent product color, reduced waste, consistent package content and improved customer satisfaction. Use of proper instrumentation and measurement protocol ensure high precision and correlation to visual perception.

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