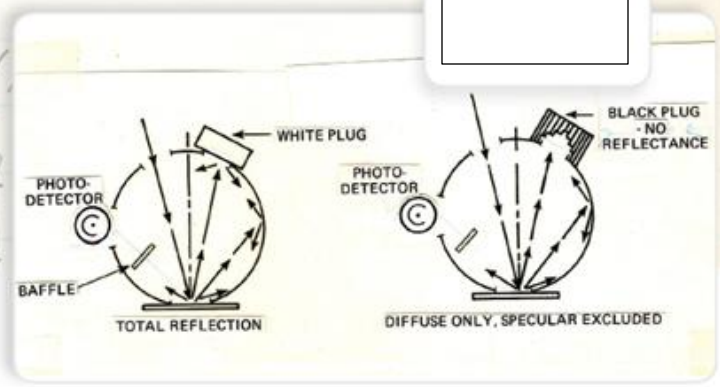
Applications Note

AN 1013



Averaging in Color Measurement

"For most samples, a combination of optical and statistical averaging yields the best quantification of sample color."

Abstract

Averaging is a common colorimetric tool to "even out" the measurement highs and lows that are possible within a single sample or batch. The average measurement best represents the color of the sample or batch as a whole.

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Averaging Can Take Two Forms - Optical and Statistical

Colorimetric instruments optically "average" all spatial detail within the field of view of the sensor to provide a color reading representing the average color within the view. It is recommended that the largest area of sample view possible be measured. The reason is that when you double (2x) the diameter of the sample view, the optical averaging is tripled (3x) based on the sample area.

In addition to optical averaging for a single reading, multiple readings can be statistically averaged for a single measurement that best represents the color of the sample.

This application note further considers statistical averaging as a tool.

Types of Samples for Averaging

The ideal sample for yielding repeatable color measurements is completely opaque or transparent, flat, smooth, and homogenous. However, as few samples meet this ideal, a variety of sample preparation and presentation techniques are employed to make color measurements as repeatable as possible. One technique for reporting the best result is to statistically average multiple readings from the same sample in different areas of the sample (measuring with replacement), or average multiple readings of different samples from the same lot.

To illustrate, shown in Table 1 are five (5) individual readings made on an Aeros using a bag of pretzel pieces placed in a sample pan. The range and standard deviation provide an estimate of the measurement variation on this very non-uniform sample.

In Table 2, five (5) readings were averaged for each measurement, reducing the measurement variability. Between readings, the sample cup was emptied and refilled from the same bag. A single reading alone quantifies the approximate color. The average of the five readings best represents the overall color of the bag.

Examples of samples that benefit from averaging include non-homogenous translucent liquids with suspended particles, samples containing bubbles, scratches, and hazy areas, those with random color or texture distributions and directional samples such as corduroy fabric, ruled paper, and yarn. In each case, the samples should be read at least two to four times, with rotation and/or refills between each readings so that the sample is well presented to the instrument.

The statistical average of the multiple readings, using the largest area of sample view possible, is reported as best quantifying the color of the sample.

Table 1. 5 Individual Readings of Pretzel Bites

Single Reading per Measurement	CIE C/2		
	L*	a*	b*
1	42.79	8.57	38.57
2	42.25	6.88	38.43
3	42.88	8.03	33.83
4	41.03	8.98	33.09
5	43.11	9.62	35.27
Range	2.08	2.74	5.48
Standard Deviation	0.83	1.04	2.55

Table 2. Statistical Average of 5 Readings of Pretzel Bites with Rotating Pan

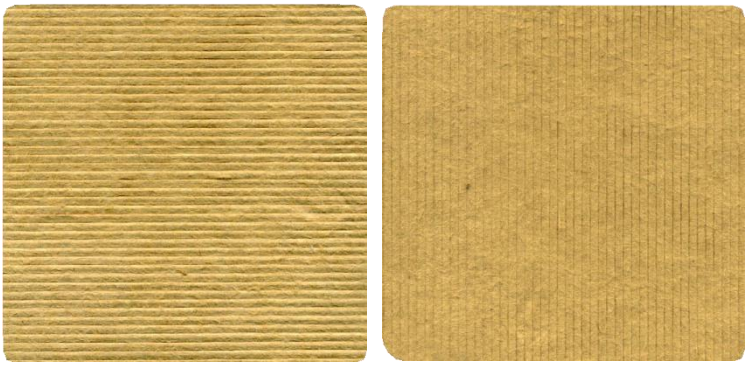
Continuous Average of Readings	CIE C/2		
	l*	a*	b*
	41.55	8.75	37.11
	41.91	9.33	34.70
	42.12	9.33	33.27
	41.96	9.08	33.31
	42.28	8.76	33.28
Range	0.73	0.58	3.84
Standard Deviation	0.27	0.29	1.67

Glass sample cup with pretzel bites ready for color measurement on a HunterLab Aeros with a large diameter area of sample view.

This is the instrument view through the bottom of the dish. The instrument optically averages all colors within the field of sample view.

Directional Samples

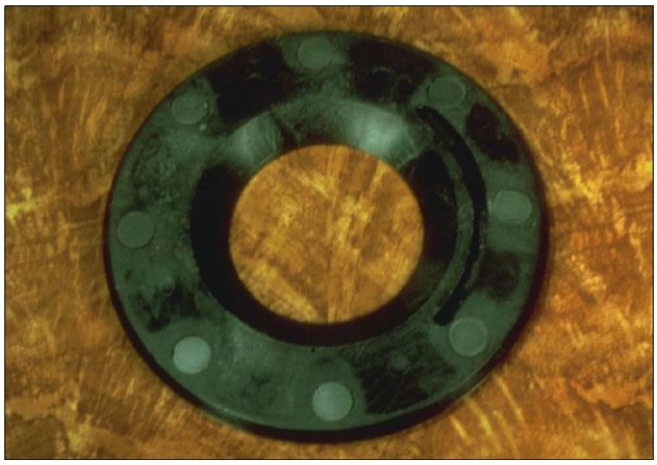
Examples of directional samples are corduroy fabric, ruled paper, and yarn. These types of samples look different to both the instrument and the eye depending on which direction they are turned. Therefore, directional samples should be read two to four times, with the sample rotated 90° between the readings ("with rotation") so that each orientation is presented to the instrument. The readings should then be averaged for the final, reported result.



Grooved Kraft board showing directionality effect with 90° rotation.

Non-Homogenous Samples

Non-homogeneous samples could include unshaken liquids with suspended particles, samples containing bubbles, scratches, or hazy areas, or ones with random color or texture distributions. In general, non-homogeneous liquids should be read several times and the readings averaged. In between the readings, the liquid should be dumped out of its container and the container refilled, so the sample readings are made "with replacement." Non-homogenous solids can either be rotated between readings like directional ones, or the sample can simply be moved so that a different area is read each time.



Example of a Non-Homogenous Sample

Batches of Samples Irregular in Size and/or Shape

These types of samples, where groups of individual pieces are measured together, include items like pieces of cereal, small plastic parts, and pretzels. You should read several containers full of this type of sample, emptying the container and refilling it with sample between readings.

Example of an Irregularly Shaped Sample

Define the Measurement Method

Six parameters are important for any good color measurement method and optical and statistical averaging is a key part of that method. Changing any of the following parameters will affect the color values.

1. **Color Scale** - Select the color or color difference scale. If unsure, use CIE L*, a*, b* or Hunter L, a, b.
2. **CIE Illuminant** - Select the illuminant. If unsure, use CIE D65.
3. **CIE Standard Observer** - Select the observer. If unsure, use the 1964 10 degree Standard Observer.
4. **Instrument Geometry** - This parameter is fixed by the choice of instrument model which can be a directional 45°/0° or diffuse d/8° sphere. Typically an instrument with a directional 45°/0° like the Aeros is used to measure the very non-uniform samples.
5. **Sample Preparation** - Sample preparation must be consistent with technique es that support making the sample more uniform leading to a more repeatable reading.
6. **Sample Presentation** - Presentation techniques use optical (largest area of sample view) and statistical (multiple readings with replacement per measurement) to ensure a repeatable and representative color measurement of the sample.

Conclusion

The variation between measurements can be lowered by averaging multiple readings per measurement with replacement, using the largest area of view possible with each reading. It is important to document the measurement methodology for the purpose of effectively replicating and communicating color values.

About HunterLab

HunterLab, the first name in color measurement, provides ruggedly dependable, consistently accurate, and cost effective color measurement solutions. With over 6 decades of experience in more than 65 countries, HunterLab applies leading edge technology to measure and communicate color simply and effectively. The company offers both diffuse/8° and a complete line of true 45°/0° optical geometry instruments in portable, bench-top and production in-line configurations. HunterLab, the world's true measure of color.

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