The Color and Turbidity of Beer

A White Paper for Brewers
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Abstract

The colors of thirteen beers were measured by the American Society of Brewing Convention's Spectrophotometric Color Method[1] using three i-LAB® spectrophotometers. The results were compared with published values, when available. Reproducibility of both individual i-LAB measurements, as well as unit to unit measurements was determined. The largest variations in readings could be explained as errors due to dilution factors. The SRM (Standard Reference Method) color values obtained from the i-LAB units were in good agreement with literature values.

Beer Color in General

Color is often the first thing that people notice about beer. Beer colors may range from a pale, straw yellow for a wheat beer to an opaque black for an Irish stout. Color depends largely on the roasting of the malted barley, and the type or amount of barley and other additives.

Color is important for at least two aspects. First, color translates into taste. For example, a clear, pale golden beer may have a lighter, grain or bread flavor, whereas a dark stout could have a caramel or slight smoky flavor. Second, a brew master wants to have consistency in the product quality. Batch to batch variations in color, especially light colored beers means an uncontrolled process and/or non-uniform ingredients. This makes the "same" beer vary in taste.

As Jim Koch of Boston Beer Company stated in an interview on consistency and quality[2]:

"I've got a tremendous respect for the large American breweries," Koch continues. "They can make beer better than anyone in the world, and I strive to meet their standards. Anyone could brew a decent stout in their kitchen, but it would be impossible to produce a Budweiser or Miller High Life. If I can make traditional beer to the large national brewer's standards of quality and consistency," he says, "I'll be a happy man."

"As it is," Koch says, "I'm not sure any small-scale brewer in the country has the level of quality control that we do." Koch notes that the lab facilities available to him at his contracting breweries are superior to those available to most microbreweries. "We originally chose Pittsburgh Brewing because of their strong lab facilities," he notes. "PBC can do 102 separate tests for us, running them several times during fermentation. Today quality control is the function of a good lab.

"Quality is consistency," Koch states. "A quality standard must be maintained in brewing just as in any manufacturing operation. And, when an industrial engineer defines quality, he defines it as conformance to specifications. The word "quality" has to have a concrete, specific, objective meaning.

"Quantifying" Beer Color

The history of quantifying beer color goes back to the 1880s with Joseph Lovibond, a brewery owner, creating a colorimeter for beer quality. Lovibond's "tintometer"[3] (Figure 1) was a crude, but relatively accurate instrument that relied on the user "viewing the colour to be measured, and the (calibrated) glasses used as measures". The instrument relied heavily on the user's vision, the sunlight (a northern exposure was preferred), and multiple calibration standards.

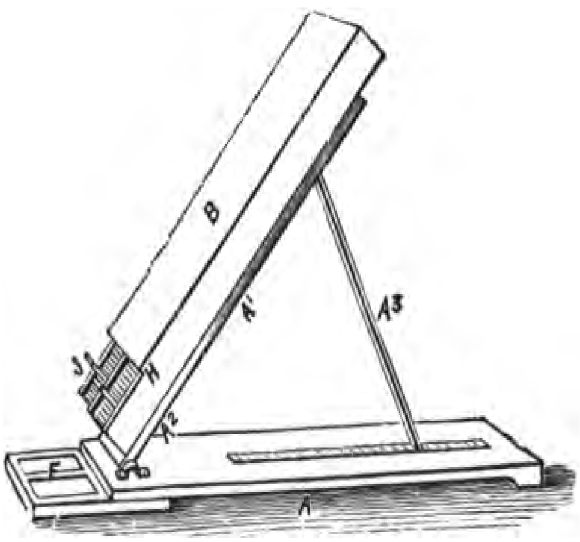

Fig. 1 Lovibond's Tintometer

With the advent of electricity and advanced optics, a spectrophotometer was first developed in 1940 at the National Technical Laboratories Company. Arnold Beckman gets the credit as the inventor, with the project leader being Howard Cary[4]. Both gentlemen went on to form instrument companies that produced high quality spectrophotometers, including the Beckman DU spectrophotometer and the Cary spectrophotometers.

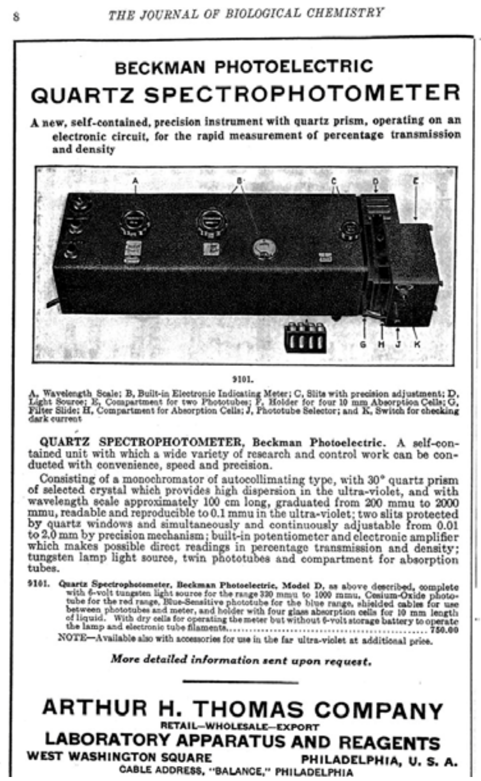

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Fig. 2 An early Advertisement for the Beckman Spectrophotometer

The spectrophotometer removed a great deal of subjectivity (especially the user's depth and color perception, along with the need for glass standards), environmental factors (sun light intensity changes) and other complications (mirror angle and variable sample positioning). However, the spectrophotometer was, and still is, a bulky, bench top unit built for a laboratory environment.

In 1950 the ASBC (the American Society of Brewing Chemists) created the Standard Reference Method (SRM) color system. Independently, the EBC (European Brewing Convention) developed another color system that used visual comparisons, somewhat styled after Lovibond's scales. In the 1970s, the EBC changed to a spectrophotometer system, like the ASBC, but with slightly different calculations[5].

In the latter part of the 20th century and into the 21st century, further advances in electronics, materials, and computers resulted in newer and faster spectrophotometers. Many bench top units actually became larger in size, with the premise of the bigger the unit, the more expensive. Still, the bench top spectrophotometer had its place in the lab, but not on a production floor.

Over the last few years, the i-LAB® visible spectrophotometer was developed to provide high quality measurements (wavelength resolution of ~1 nm), in addition to portability (about the size of an electric razor at half the weight) for various markets- including the beer industry. The i-LAB instrument uses LEDs (light emitting diodes) as a light source and a linear variable filter with multidiode array as the sensor. The instrument was designed to be compact due to this technology and have no moving parts that are subject to mechanical breakdown. Three "AA" batteries are all that is needed to energize the measurement. Software methods were recently added to the i-LAB unit for measuring and calculating beer properties, such as several ASBC (and/or EBC) tests including color and polyphenols. The focus of this paper is color with potential uses that include end-research of new brews, monitoring processes, and quality control.

Materials and Equipment

The materials in the study consist of thirteen beers (Tables 1 and 2), three visible i-LAB® spectrophotometers with cuvette adaptors and 10 mm polystyrene cuvettes (PLASTIBRAND®, Aldrich Cat. No. 75070D, optically matched). Table 1 shows the beer name, type and brewer. Table 2 shows the container or source of the beer (can or bottle), the concentration used for determining color, and the reference color[6]. In theory, the color of beer is uniform, although age, environmental conditions (temperature and light), and preservatives (or lack of) to alter the initial hue.

Procedure

Beer Sample Preparation:

All beers were decarbonated by vigorously shaking and allowed to sit for five minutes, and then the procedure was repeated. No bubbles were observed in the beer after the procedure.

i-LAB® Calibration and Background:

The i-LAB unit was initially calibrated, which accounts for the adaptor optics, using a 10 mm cuvette using distilled water and a black-ink solution. The background Transmission was measured using a cuvette of distilled water. Once the unit was calibrated, and the background measured, no further measurements of standards were needed.

Beer Measurements:

Turbidity

Decarbonated beers were then poured into cuvettes and the Transmission was measured from 400 nm to 700 nm (Fig. 3) and converted to Absorbance value (Fig. 4). The programming within the unit then calculated the Absorbance values (ABS) at 430 nm and 700 nm for a light path of ½ inch. To convert a path length of 10 mm to that of ½ inch, a factor of 1.27 was used.

$$ABS = -\log(\text{Transmission})$$

$$ABS_{1/2IN} = 1.27 \times ABS$$

$$ABS_{1/2IN}(430\ nm) = 1.27 \times ABS\ (430\ nm)$$

$$ABS_{1/2IN}(700\ nm) = 1.27 \times ABS\ (700\ nm)$$

If $ABS_{1/2IN}(700\ nm) \leq 0.039\ ABS_{1/2IN}(430\ nm)$, ***then beer sample is "free of turbidity".***

The i-LAB color program compares the two values and if the Absorbance at 700 nm was less than or equal to 0.0039 that of the Absorbance at 430 nm it was "free of turbidity" and the i-LAB reported "No Turbidity". Conversely, if the the unit reported "Turbidity" if the value was more than 0.0039, as per the ASBC Color test. "Turbid" beers should be clarified, to get a true color, by centrifugation or filtration. In that case, filtration or clarification value along with free of turbidity value should be reported.

Color

Beer color is defined as the Absorbance at 430 nm for a (calculated) half-inch path length times 10.

$$Beer\ Color = 10\ ABS_{1/2IN}(430\ nm)$$

Beer color is reported on the i-LAB instrument in units of "degrees" and to one decimal point, in accordance with the ASBC test.

Results and Discussion

Figure 3 and 4 show the transmission and absorbance spectrum of beers, respectively, in the visible range. Even though the ASBC color test only uses a couple of wavelengths, the 400 nm to 700 nm wavelength range is inherently measured, and many calculations (e.g., ASBC color, EBC color, L*,a*, b*, etc.,) may be made. Table 3 has the determined color values with the standard deviation for five measurements. In general, the standard deviations are close to each other, indicating that each unit has good reproducibility. Unit to unit measurements vary, but are still in reasonable agreement with each other. Standard deviation generally increases with beer color, as will be explained later. Figure 5 is a histogram of the beer color results for the three i-LAB visible units and literature values. The values shown are an average of five readings for each unit. The color values from the i-LAB instruments are also similar to the referenced values, especially those without dilution. As the dilution increases in order to obtain a meaningful reading (e.g., Sam Adams Boston Lager and Abita Jockamo Pale Ale both at 1:2, and Abita Turbo Dog at 1:10) the calculated error increases. The cause of the error is mainly attributed to the variance in calculations that are multiplied by the dilution factor and the errors in dilution. For example, if a stout beer is diluted 1:10, and the diluted color reading is 5.8 +/-0.2, then the "calculated" color ranges from 56 to 60 degrees. Thus, the darker the beer, the potential for greater error due to dilution factors.

ASBC and EBC

The ASBC SRM (Standard Reference Method) was used in this study. The method used by the European Brewing Convention (EBC) is also measured at 430 nm, but in a smaller cuvette. The EBC color value is approximately 1.97 times that of the ASBC value. The i-LAB instrument can easily measure and calculate the EBC color value, as well as the L*, a*, and b* values for the beer samples (ASBC Color Test C.)

Summary

Thirteen various beers were tested using three i-LAB visual spectrophotometers for ASBC color and turbidity. The color values obtained matched the reference values and were similar for each unit. The units also had low standard deviations in their measurements. The i-LAB instrument inherently measures the full visible spectrum of 400 nm to 700 nm, and may use that data to calculate the ASBC color and turbidity, EBC color, and tristimulus values (L*, a*, b*). The units reported if the beers were turbid or not, as well as the SRM color value.

Beer	Type	Brewer
Old Milwaukee	American Lager	Jos. Schlitz Brewing Co. Milwaukee, WI
Corona Light	Light Lager	Grupo Modelo S.A. de C.V., Mexico City, Mexico
Molson Canadian	American Lager	Molson Brewers of Canada, Ltd., toronto, ONT. Canada
Allagash White	Wheat Beer	Allagash Brewing Co., Portland, ME
Sam Adams Light	Light Lager	Boston Beer Co., Boston, MA
Baxter "X"*	Extra Pale Ale	Baxter Brewing Co., Lewiston, ME
Sam Adams Boston Ale	Vienna Lager	Boston Beer Co., Boston, MA
Abita Jockoma IPA	American IndianPale Ale	Abita Brewing Co., Abita Springs, LA
Baxter "I"*	Indian Pale Ale	Baxter Brewing Co., Lewiston, ME
Allagash Dubbel Ale	Dubbel	Allagash Brewing Co., Portland, ME
Geary's Hampshire Special Ale	English Strong Ale	Geary's Brewing Co., Portland, ME
Allagash Black	Belgian Strong Dark Ale	Allagash Brewing Co., Portland, ME
Abita Turbodog	English Brown Ale	Abita Brewing Co., Abita Springs, LA
* Not commercial at this time		

Table 1: Beers Used in the Study- Name, Type, and Brewer

Beer Name	Beer Source (Bottle or Can)	Concentration Measured	SRM Reported Value (6)
Old Milwaukee	C	100%	2.7
Corona Light	B	100%	3.6
Molson Canadian	B	100%	---
Allagash White	B	100%	---
Sam Adams Light	B	100%	11.0
Baxter "X"	B	100%	---
Sam Adams Boston Ale	B	50%	11.0
Abita Jockoma IPA	B	50%	16.0
Baxter "I"	B	50%	---
Allagash Dubbel Ale	B	25%	---
Geary's Hampshire Special Ale	B	25%	---
Allagash Black	B	10%	---
Abita Turbodog	B	10%	60.0

Table 2: Beers Used in Study with Source, Measured Concentration, and Literature Values
(Note: Baxter Beers will be commercial in only cans, but bottles used in this study)

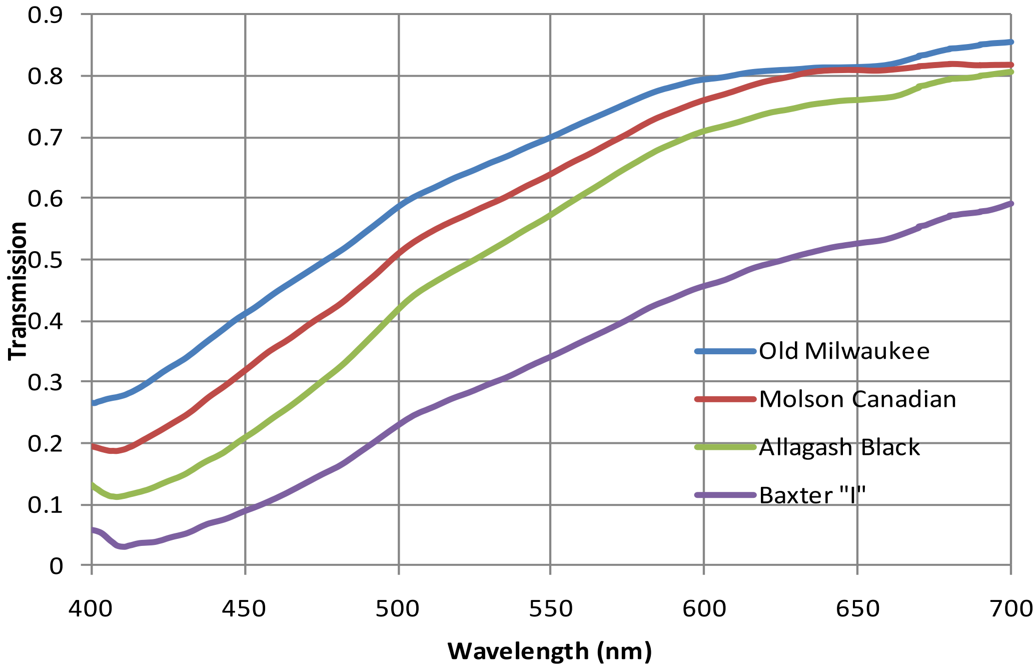

Fig. 3: Visible Transmission Spectrum of Selected Beers from 400 nm to 700nm (Note: Baxter "I" was diluted 1:2 with distilled water, Allagash Black was diluted 1:10)

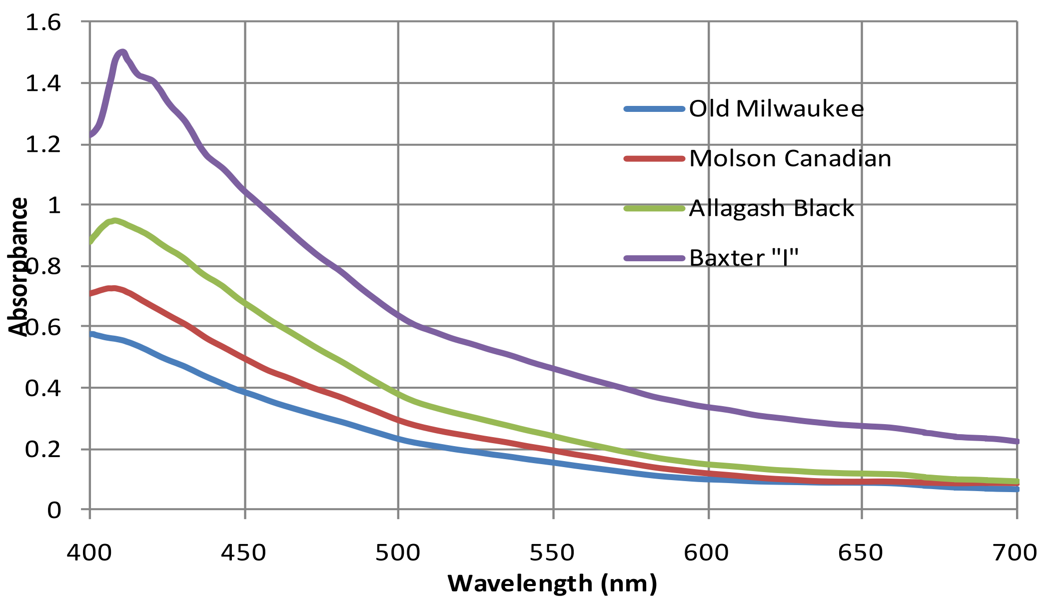

Fig. 4: Visible Absorbance Spectrum of Selected Beers from 400 nm to 700nm (Note: Baxter "I" was diluted 1:2 with distilled water, Allagash Black was diluted 1:10)

Beer	Concen-tration Measured	Unit 637		Unit 670		Unit 671		*Three Unit Average*
		Average	Std Dev	Average	Std Dev	Average	Std Dev	
Old Milwaukee	100%	2.9	0.01	2.8	0.00	2.9	0.01	2.88
Corona Light	100%	3.3	0.01	3.6	0.00	3.2	0.01	3.33
Molson Canadian	100%	3.7	0.03	3.6	0.01	3.7	0.00	3.68
Allagash White	100%	5.5	0.02	5.7	0.01	5.5	0.03	5.56
Sam Adams Light	100%	10.0	0.06	11.4	0.06	9.4	0.06	10.23
Baxter "X"	100%	9.6	0.07	11.0	0.10	10.9	0.08	10.49
Sam Adams Boston Ale	50%	13.6	0.04	14.0	0.13	14.4	0.12	13.97
Abita Jockoma IPA	50%	17.0	0.03	17.7	0.13	17.3	0.15	17.33
Baxter "I"	50%	18.6	0.11	21.5	0.09	19.2	0.18	19.75
Allagash Dubbel Ale	25%	23.4	0.02	24.4	0.11	23.4	0.09	23.72
Geary's Hampshire Special Ale	25%	23.2	0.06	23.7	0.06	23.1	0.18	23.30
Allagash Black	10%	53.6	0.05	55.1	0.11	54.2	0.19	54.30
Abita Turbodog	10%	54.4	0.08	54.9	0.06	54.5	0.20	54.60

Table 3: Color Values for the i-LAB® units with standard deviation for five measurements

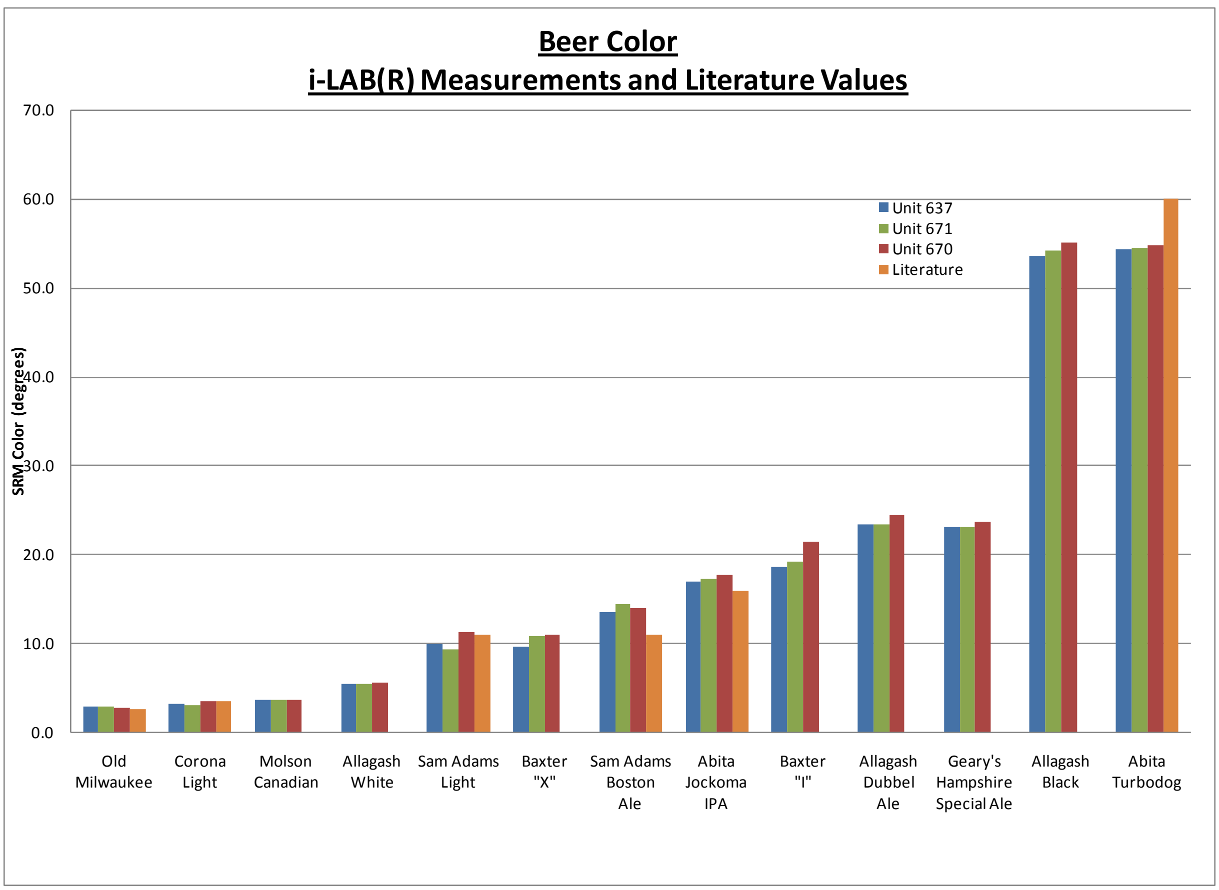

Fig. 5: A Histogram of Beer Color measured by i-LAB® units and Literature Values

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