AH, THE MANY WONDERFUL COLORS OF BEER! The pale straw of Belgian wit, the rich gold of Pilsner, the burnished copper of London ale and the pre-dawn darkness of stout . . . when you see a freshly-poured beer sparkling in the glass, it's the color that first whets your thirst.

Beer color comes from malted barley. Different types of malt have different characteristic colors, depending on how long and at what temperature they were kilned. During the mash, color-carrying molecules are dissolved into the wort. Malt extracts are just concentrated worts, so the color of the extract will depend on the malts that were mashed in order to make it. Other factors in the brewing process can also influence beer color, such as caramelization or darkening during the boil.

When beers are judged in a competition, beer color is often the first check a judge makes as he determines how well a beer has been brewed to style. The judge will pour about an inch of beer into a clear plastic judging cup and swirl the cup to dislodge any bubbles on the sides. Then the beer will be held up to the light to gauge its color against a color guide. Dark beers are often examined with a flashlight held behind the beer to determine clarity and its effect on the color.

We can reasonably predict the final color of our beer by calculating the color contribution of each malt, malt extract and adjunct that we use in our recipe. All malts are analyzed for color during production and, in the case of specialty malts, are produced to a specific color range. We can use the color ratings provided by the manufacturers to determine whether our recipe will meet the range for the intended style. Typical color ratings for several common malts, malt extracts and adjuncts are given in tables below.

raise the colors!

How to **MEASURE**, **CALCULATE** and **CONTROL** the **COLOR OF YOUR BEER.**

SPECIFIED COLORS FOR UNHOPPED MALT EXTRACTS*

Extract Type	Coopers	Muntons**
Wheat LME	4.5°L	<5 °L
Extra-Light LME	—	2–3.5 °L
Light DME	3 °L	3.5–6 °L
Light LME	3.5 °L	4–6 °L
Amber DME	—	12–22 °L
Amber LME	16 °L	8–10 °L
Dark DME	—	22–35 °L
Dark LME	66 °L	25–30 °L

** Information taken from the manufacturer's Website.*
*** Converted from EBC.*

Typical Color Ratings of Common Malts and Adjuncts

Malt or Adjunct	°SRM Rating
2-Row Lager Malt	1.5 °L
Wheat Malt	2 °L
Pale Ale Malt	3 °L
Vienna Malt	4 °L
Munich Malt	10 °L
Biscuit Malt	25 °L
Crystal 40	40 °L
Crystal 60	60 °L
Crystal 120	120 °L
Chocolate Malt	350 °L
Black Patent Malt	500 °L
Flaked Barley	1.5 °L
Flaked Corn	1 °L
Flaked Rice	1 °L
Flaked Rye	2 °L
Flaked Wheat	2 °L
Torrified Wheat	1.5 °L
Malto-Dextrin Powder	0 °L
Dextrose, glucose, sucrose, fructose	0 °L

When you see a beer sparkling in the glass, it's the color that first whets your thirst.

Story and Graphics by **John Palmer**

How BEER and MALT COLOR is MEASURED

Historically, the color of beer and brewing malts has been rated in degrees Lovibond (°L). This system was created in 1883 by J.W. Lovibond and consisted of glass slides of various shades that could be combined to produce a range of colors. A standard sample of beer or wort would be compared to combinations of these slides to determine the rating.

The color rating of a malt is determined by conducting a Congress Mash (a standardized mashing method) and measuring the wort color. The original glass slide system was later modified to the Series 52 Lovibond Scale, which consisted of individual slides or solutions for specific Lovibond ratings. However, the system still suffered from inconsistency due to fading, mislabeling and human error.

Standard Reference Method

In 1950, the American Society of Brewing Chemists (ASBC) adopted the use of optical spectrophotometers to measure beer color. Spectrophotometers are machines that shine light through liquid samples. A detector on the other side of the sample measures how much of the light shone on the sample actually makes it through. In the case of beer, a specific wavelength of light (430 nanometers) is shined through a standard-sized sample. A darker wort or beer absorbs more light and therefore yields a higher measurement. This method allowed for consistent measurement of samples and the Standard Reference Method (SRM) for determining color was born.

The SRM method was originally set up to approximate the Series 52 Lovibond scale and the two scales can be considered to be nearly identical for most of their range. However, the resolution of a spectrophotometer diminishes greatly for dark brown or black worts, when little light can penetrate the sample to reach the detector. To accommodate dark worts, the sample is diluted and the measurement is scaled to assign an undiluted value. Unfortunately, dilutions have been shown to be non-linear for beers made from highly colored malts (see sources 3 and 7 on page 33).

When provided with consistent, precise references, the human eye can distinguish very narrow differences in color. This is because of the variety of wavelengths of visible light coming from a sample that can be compared, as opposed to the information conveyed by a single wavelength. There is less variation in a single wavelength measurement, but there is also a corresponding loss in range. For this reason, the Series 52 Lovibond scale is still in use today in the form of precision visual comparators. It is most often used to determine the rating of dark and roasted malts. The use of comparators is most prevalent in the malting industry, and therefore the color of malts is typically discussed as °L, while beer color is discussed as °SRM, though the basis (absorbance at 430 nm) is the same.

European Brewing Congress

Prior to 1990, the European Brewing Congress (EBC) used a different wavelength for measuring absorbance, and conversion between the two methods was an approximation. Today, the EBC scale uses the same wavelength for measurement, but uses a smaller sample glass. The °EBC rating for a malt or beer is not equivalent to the °L rating. If you are converting from EBC units, it is probably a good idea to check with the manufacturer to see which EBC method they are using. Some malt manufacturers have reportedly not upgraded to the new standard. The current EBC scale for rating beer color is about twice the SRM rating. The actual conversion factor between the two methods is 1.97, but to argue whether an Irish stout with an EBC rating of 90 is 45 °SRM or 45.6 °SRM is pointless.

Color swatches to illustrate seven levels of beer color are shown in the figure at the bottom of the page. These color swatches for °SRM colors are taken from Promash Brewing Software (version 1.8). They represent beer that has been poured to a depth of about 1.5” in a typical 6-ounce clear plastic judging cup, swirled to de-gas, and held up to good lighting against a white background.

The main constituents of color in malts are the melanoidins produced by Maillard or browning reactions. Browning reactions between sugars and amino acids occur whenever food is heated — like toast. Different heating methods with different sugars and amino acids will produce different colors — from amber to red, brown and black. So the wide spectrum of beer color is primarily due to the variety of germination and kilning procedures used in the production of malts.

ESTIMATING BEER COLOR with MALT COLOR Units (MCUs)

The final color of a beer can be estimated from a recipe by adding up the melanoidin contributions in the form of malt color units (MCU). An MCU is like an alpha acid unit (AAU) for hop bitterness (IBU) calculations. The color rating of the malt (°L) is multiplied by the weight (lbs.) used in the recipe, just like the weight of a hop

A representation of beer color from 5 to 35 °SRM. Pour 1.5 inches (3.8 cm) of beer in a 6 oz. cup and compare to color swatches. Although comparing colored liquid to a printed color guide isn’t perfect, you can at least get a rough guide to beer color in this manner. Some judges at beer competitions have color transparencies that are somewhat more accurate.

addition is multiplied by its alpha acid rating. To estimate the °SRM color of a beer, the MCUs are divided by the recipe volume and multiplied by a constant, similar to the percent utilization in the IBU calculation. For light beers (yellow, gold or light amber) the relationship between °SRM and MCU is about one to one.

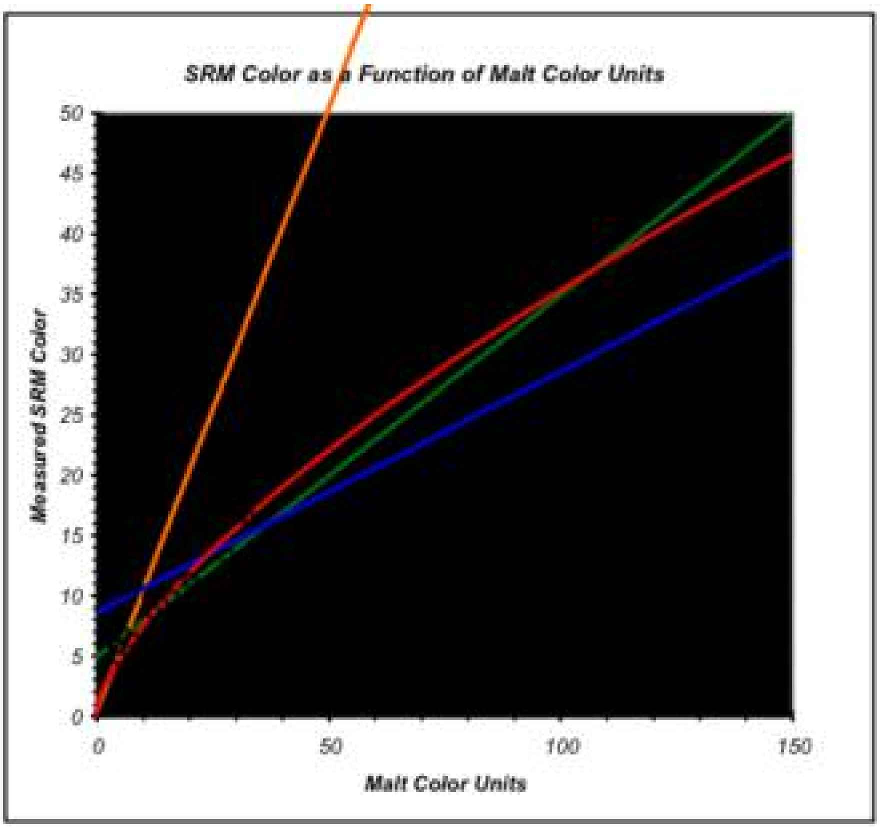
As a brief example, if 8 pounds of 2-row lager malt (2 °L) and 2 pounds of Vienna malt (4 °L) were used for a five-gallon batch, the estimated color would be [(8 x 2) + (2 x 4)] / 5 = 4.8 or about 5 °SRM. Unfortunately this simple model does not work when the MCUs exceed 15. Linear models have been proposed by homebrew authors Randy Mosher and Ray Daniels, but data for the full spectrum of beer color (some of which is illustrated at right) may be better fit by an exponential curve, such as the one described by D. Morey's equation (see table below).

The figure at right shows a comparison of four models for final beer color. The orange line is a reference for the case if °SRM = MCU. The green line traces Mosher's equation, the blue is for Daniels, and the red is for Morey's. Analysis of commercial as well as homebrewed beer has shown that the measured color tapers off, even as the malt color contributions increase dramatically. (The data shown here is from the article "Beer Color Demystified—Part III: Controlling and Predicting Beer Color(5)" by Ray Daniels.)

Proposed Models for Beer Color as a Function of MCU

°SRM = MCU	(traditional)
°SRM = 0.3 x MCU + 4.7	Mosher
°SRM = 0.2 x MCU + 8.4	Daniels
°SRM = 1.49 x MCU$^{0.69}$	Morey

The problem with the linear models proposed by Mosher and Daniels is that there is a lower limit for beer color at 4.7 and 8.4 °SRM, respectively. Obviously, there are beer styles — such as Belgian wit, Pilsner and American light lager — that are lighter than these limits. An exponential equation fits the data better. The function is nearly equal to MCU at low MCU values. However, as the MCUs go to higher values — corresponding to brown ales, porters and stout — the actual color diverges from the MCU = °SRM line and increases at a lower rate than depicted by the linear models of Mosher and Daniels. A beer with an MCU of 200 compared to one with a rating of 100 is still just "very dark," instead of twice as dark, as the °SRM = MCU model would have you believe. Even expert beer judges cannot discern a difference between color values greater than 40 °SRM.



Data points (open circles) show measured beer color (in °SRM) versus their malt color units (MCU). Colored lines represent proposed models for beer color as a function of MCUs. See the box at left for the corresponding equations.

Another aspect of beer color that needs to be mentioned is hue. In this case, hue means the gradation or variety of a color. Different beers with the same °SRM rating can actually be different hues because the measurement is based on the absorbance of a single wavelength of (blue-violet) light. The human eye sees all the visible wavelengths, and will perceive other colors transmitted or reflected from the sample that the spectrophotometer detector will not. Thus, a spectophotometer might see two beers with a 15 °SRM color rating whereas a brewer will see a reddish American amber ale and a British bitter with a hint of brown.

This drawback in the current ASBC method was noted in a recent brewing study at UC Davis. In the study, two lagers (a pale ale and a stout) were diluted to the same color rating (3.5–3.6 °SRM). A group of 31 people were presented with ten pairings of these diluted beers and asked to determine if they were the same or different.

The results clearly showed that the panelists could correctly determine a difference in color between different beers, except in the case of the two lagers, which were perceived as being the same. The original color of the undiluted all-malt lager was 8 °SRM, and the undiluted color of the other lager, containing cereal adjuncts, was 4 °SRM. It is interesting to note that the undiluted color measurements of the three paler beers were nearly the same (<1 °) when measured by both the ASBC method

Beer Style	SRM	Color
German Pilsener	2.5-4	very pale-pale
Belgian White Ale	2-4	very pale, cloudy
American Light Lager (Lite)	2-4	very pale
American Light Lager (Standard)	2-4	very pale
American Light Lager (Dry)	2-4	pale-golden
Cream Ale	2-4	very pale
Berliner Weisse	2-4	very pale-pale
American Light Lager (Premium)	2-6	pale-golden
American Wheat	2-8	pale-amber
Belgian Ale	3.5-12	light-amber
Belgian Brown Ale	3.5-20	pale to dark brown
Kölsch	3.5-5	pale gold
Trippel Ale	3.5-5.5	light-pale
Munich Helles	3-5	very pale-golden
Bohemian Pilsener	3-5	pale-golden
German-style Weizen	3-9	pale-golden
Helles Bock	4.5-6	pale gold
Classic English Pale Ale	4-11	pale-deep amber/copper
American Pale Ale	4-11	pale-deep amber/red/copper
Dortmund Export	4-6	very pale-golden
Fruit Ale or Lager	5-50	varies
Herb Ale or Lager	5-50	varies
Belgian [illegible]	6-12	pale-amber
Oktoberfest/Märzen	7-14	amber/deep amber/copper
German-style Weizenbock	7-30	amber-dark brown
English Bitter (ordinary)	8-12	gold-copper
Vienna	8-12	amber deep amber/copper
English Bitter (special)	8-14	gold-copper
English Extra Special	8-14	gold-copper
India Pale Ale	8-14	pale-deep amber/copper
Scottish Light	8-17	gold-dark amber/copper/brown
California Common Beer	8-14	pale amber-deep amber
Dubbel Ale	10-14	amber-brown
English Old (Strong) Ale	10-16	light-dark amber/copper
Scottish Heavy	10-19	gold-dark amber/copper/brown
Scottish Export	10-19	gold-dark amber/copper/brown
American Dark	10-20	deep copper-dark brown
Bamberg-style Rauchbier	10-20	dark amber-deep brown
Strong Scotch Ale	10-47	copper-black
Düsseldorf-style Altbier	11-19	dark amber-dark brown
Flanders Brown Ale	12-18	copper-brown
Doppelbock	12-30	amber-dark brown
Barley wine	14-22	copper-medium brown
English Brown Ale	15-22	medium-dark brown
American Brown Ale	15-22	medium-dark brown
German-style Dunkelweizen	17-23	dark copper-brown
Munich Dunkel	17-23	deep copper-dark brown
English Mild Ale	17-34	medium-dark brown
Eisbock	18-50	deep copper-black
Imperial Stout	20+	dark copper-black
Traditional German Bock Beer	20-30	copper-dark brown
Brown Porter	20-35	medium-dark brown
Schwarzbier	25-30	dark brown-black
Robust Porter	30+	[illegible]
Classic Dry Irish Stout	40+	black-opaque
Foreign Style Stout	40+	black-opaque
Sweet Stout	40+	black opaque
Belgian Lambic (Faro)	NA	NA
Belgian Lambic (Fruit)	NA	NA

Source: Papazian, C. (1994) The Home Brewer's Companion

BJCP Style Guidelines for California Common Beer

OG	1.044-1.055
FG	1.011-1.014
IBU	35-45
Color	8-14 °SRM (pale amber, deep amber)

No. 4 Shay Steam California Common Beer

Recipe OG = 1.048

Recipe Malts	Color Rating	MCUs	MCU	Mosher	Daniels	Morey
6 lbs. of light LME	5 °L	6	12	8	11	8
0.75 lbs. of crystal 40 °L malt	40 °L	6				
0.25 lbs. of malto-dextrin powder	0 °L	0				

Comment: In this example, the recipe malts yield an °SRM color rating within the BJCP guidelines for all three color models. The brewer can be confident that the entry would not be marked down for color.

BJCP Style Guidelines for Brown Porter

OG	1.040-1.050
FG	1.008-1.014
IBU	20-30
Color	20-35 °SRM (medium-dark brown)

BJCP Style Guidelines for Robust Porter

OG =	1.050-1.065
FG =	1.012-1.016
IBU =	25-45
Color =	30+ °SRM (black-opaque)

Port O' Palmer Porter

Recipe OG = 1.048

Recipe Malts	Color Rating	MCUs	MCU	Mosher	Daniels	Morey
6 lbs. of light LME	5 °L	6	72	26	23	28
0.5 lbs. of crystal 60°L malt	60 °L	6				
0.5 lbs. of chocolate malt	350 °L	35				
0.25 lbs. of black patent malt	500 °L	25				

Comment: In this example, the recipe malts yield an °SRM color rating and an OG within the BJCP guidelines for brown porter, although the use of black patent malt adds some roast character that is more appropriate to the robust porter category. The brewer can use color modeling to adjust the recipe to firmly place it in the robust category if they wish. Both the OG and the color would need to be increased. There are lots of options to do this; here are three:

1. Add 1.5 lbs. of dark DME. This will add about 12 points to the OG and the MCU total. The drawback is that the OG increases significantly (to 1.060) without changing the color much.

2. Increase the 0.5 lbs. of chocolate malt to 1 pound. This will change the MCU total to 107 without changing the OG much.

3. Increase the light LME to 7 pounds, and increase the chocolate malt to 1 pound. This increases the gravity but the MCUs only change by 1 point.

and a Series 52 Lovibond Comparator (Tintometer Ltd., Salisbury, UK). The stout was the exception with the comparator measuring 115 °L, and the spectrophotometer measuring 86 °SRM. This difference illustrates the drawback mentioned earlier of the ASBC method for determining the color of very dark malts and beers.

Other COLOR FACTORS

The color of the malts is not the only factor that determines a beer's final color. Other variables — such as boil time, heating method, hopping rate, yeast flocculation, clarity, age or oxidation — effect the absorbance of light and the perceived color.

Long boils over high heat promote the caramelization of sugars and darken the wort. The oxidation of polyphenols (tannins) from grain husks or hop cones also contributes to wort darkening. Wort that has been oversparged or heavily hopped has a greater propensity for darkening as it ages.

During the boil and subsequently during chilling, proteins combine with polyphenols to form the hot and cold break and this decreases wort color. Other color-carrying compounds will settle out during fermentation as the yeast flocculates. And of course, the overall clarity of a beer will effect the degree to which light is absorbed and the perceived color.

These other factors that effect beer color are diverse and significant enough that the actual color could be plus or minus twenty percent of the estimated value. And, that being the case, a simplified exponential equation of $°SRM = 1.5 \times MCU^{0.7}$ is just as valid as the derived values of Morey's equation. My purpose in stating this isn't to propose a new model, but instead to point out the inherent limits of any model for beer color. None of the three models is necessarily any more correct than another, although Morey's may be more forgiving for very light beer styles. Hopefully this caveat will prevent overly-technical readers from trying to calculate color to the fourth decimal place as other factors not in the equation have an effect on beer color.

ESTIMATING BEER COLOR from a HOMEBREW RECIPE

To plan the color of your recipe, calculate the MCU values for each of your malts and grains. To do this, multiply the malt's Lovibond rating by the number of pounds that you are going to use, and divide by the recipe volume. Then sum all the numbers. (See examples on page 32.)

SUMMARY

Although beer color is primarily determined by malt color — and malt color units are based solely on malt color — it is also important to remember that final beer color is driven by many factors from all parts of the brewing process, and that these are not factored into the color models. You will need to examine your equipment, your processes, and your beers to determine which model works best for you — just as in the case of hops and IBU calculations. These tools are not the end, they are the means to an end, and the proof is in the beer.■

John Palmer is the author of "How to Brew: Ingredients, Methods, Recipes and Equipment for Brewing Beer at Home" (Defenestrative Publishing Company, 2001).

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