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Application News

Spectrophotometric Analysis

Maple Syrup Color Analysis using the Shimadzu UV-2600 UV-Vis Spectrophotometer

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■ Introduction

UV-Visible spectrophotometry is a valuable tool in the laboratory for measuring the properties of various liquids and solids. One of the most common applications for QA/QC environments is Color Analysis and being able to assign a color value to finished products. The color value of a material can be obtained by collecting a % transmittance or reflectance spectrum of the sample under consideration. The Shimadzu UV-2600 spectrophotometer is ideal for making accurate color measurements due to the large photometric range of 5 abs. units. Therefore, dilution is not required for highly absorbing samples such as maple syrup. Samples can be analyzed neat without further dilution. The application illustrates the use of Shimadzu Color Analysis Software and the UV-2600 spectrophotometer for quick and easy spectral acquisition and interpretation into a meaningful color value.

■ Background

Maple syrup is one of the most commonly used sweeteners produced in the USA and Canada. Different grades of maple syrup are assigned primarily by color. The color of maple syrup is a result of the time of season that the maple sap is collected from maple trees. In general, the later in the season the sap is collected, the darker the color of the resulting maple syrup.

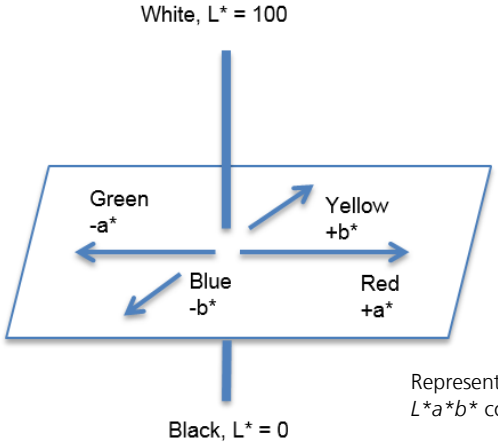
Currently, the United States has three categories of Grade A syrup referred to as Light, Medium, and Dark Amber. Light amber is the lightest of the three followed by Medium and then Dark. However, Vermont has a grade referred to as "Fancy", which has been reported to be lighter in color than the three U.S. Grade A classifications. An additional classification is Grade B, which is darker than Grade A Dark Amber and considered unsuitable for consumer labelling by some vendors. However, consumers are seeking ways to purchase the Grade B syrup because of its sweeter taste, leading to some manufacturers labelling it for sale and allowable for consumption purposes.

The United States Department of Agriculture is providing a path for a universal classification grading system, which is scheduled to be released and made active for consumers beginning in 2015. The new system will remove the Grade B classification and classify maple syrup as Golden Color, Amber Color, Dark Color, and Very Dark Color. Currently, U.S. grading classifications are made by comparing the maple syrup to color glass standards. In addition to the U.S. grade standards, some states use a spectroscopic method to determine the color of maple syrup. This spectroscopic method differentiates maple syrup grades by the % transmittance at a wavelength of 560 nm. Table 1 outlines the classifications of maple syrup both at a state and federal level, along with the proposed new rating program slated for implementation January 1st 2015[1].

Table 1: Federal and State Classifications of Maple Syrup[1]

Current U.S. Standard	Vermont and Ohio	New Hampshire	New York	Maine	Canada all Provinces	Proposed Option, Jan. 1st 2015
U.S. Grade A Light Amber	Vermont Fancy ≥ 75.0% T, Ohio Light	Grade A Light Amber	Grade A Light Amber	Grade A Light Amber ≥75.0%T	Canada No. 1 Extra Light ≥75.0%T	**Grade A Golden Delicate Taste ≥75.0%T**
U.S. Grade A Medium Amber	Grade A Medium Amber 60.5-74.9% T	Grade A Medium Amber	Grade A Medium Amber	Grade A Medium Amber 60.5-74.9%T	Canada No. 1 Light 60.5-74.9%T	**Grade A Amber Rich Taste 50-74.9%T**
U.S. Grade A Dark Amber	Grade A Dark Amber 44.0-60.4%	Grade A Dark Amber	Grade A Dark Amber	Grade A Dark Amber 44.0-60.4%T	Canada No. 1 Medium 44.0-60.4%T	**Grade A Dark Robust Taste 25-49.9%T**
U.S Grade B for Reprocessing	Grade B 27.0-43.9%T	Grade B	Extra Dark for Cooking or Grade B for Reprocessing	Grade A Extra Dark Amber 27.0-43.9%T	Canada No. 2 Amber 27.0-43.9%T	**Grade A Very Dark Strong Taste <25.0%T**
U.S. Grade B for Reprocessing	Commercial Grade <27.0%T	Grade B	Extra Dark for Cooking or Grade B for Reprocessing	Commercial Grade <27.0%T	Canada No. 3 Dark <27.0%T	**Processing Grade any Color Class, any off-flavored syrup.**

Color is a complex quality and may be more accurately interpreted by the concept of color scales rather than the %T value at a single wavelength. Multiple color scales are used in various lab settings depending on the user's protocol. One commonly used color scale is CIE *L*a*b**. In this color scale, color values are calculated from a mathematical combination of %T. *L** out of the CIE *L*a*b** color scale measures the lightness of a sample. An *L** value of 100 represents the maximum brightness of a color, whereas an *L** value of 0 represents the minimum brightness of a color. *a** measures the red or green components of a given sample. Positive values of *a** represent a more red color component, whereas negative values lean more towards a dominant green component. Similarly, the *b** value measures the yellow or blue components of a sample. Positive values of *b** represent a stronger yellow, whereas negative values represent more blue in the sample[2].



Representation of the CIE *L*a*b** color space.

■ Experimental

Four separate samples labelled as "Vermont Fancy", "Grade A Medium Amber", "Grade A Dark Amber", and "Grade B", were received as is from a maple syrup sampling kit. Transmittance spectra were collected using standard 10 mm quartz cuvettes with an empty cuvette as a reference with no additional sample preparation. Along with the four samples obtained from the kit, ten commercial samples from different parts of the U.S. were analyzed.

Experimental parameters for the color calculation are given in Figure 1.

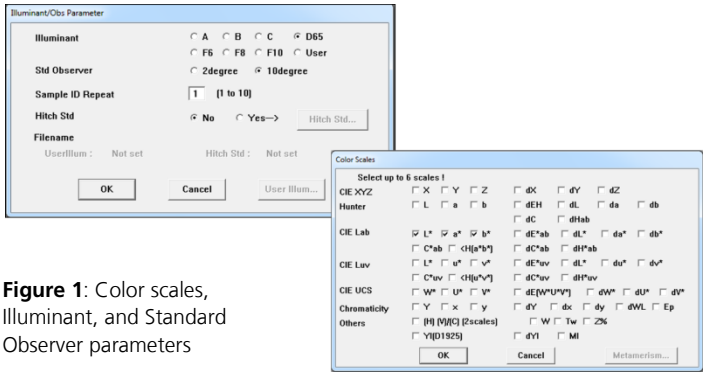


Figure 1: Color scales, Illuminant, and Standard Observer parameters

■ Results and Discussion

Spectra of the four different pure maple syrup samples are shown in Figure 2, with corresponding CIE *L*a*b** values and the %T at 560 nm presented in Table 2. The transmittance spectra are similar in profile and demonstrate a decrease in magnitude going from the lighter Vermont Fancy to darker Grade B.

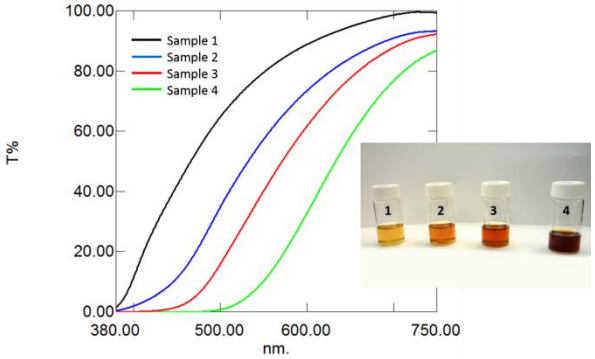


Figure 2: Transmittance spectra of maple syrup samples from sampling kit

As shown in Table 2, the %T at 560 nm decreases as the samples become darker. This trend is in good agreement as supported by the decreasing *L** values obtained, which indicate lightness. However, this alone does not offer any insight into the color of the sample.

Under the new classification system scheduled to go into effect in 2015, terms such as "Golden", "Amber", and "Dark" will be used to name the maple syrup. By visually inspecting the samples, the colors range from light yellow to a reddish brown between Vermont Fancy and Grade B. As previously discussed, positive *a** values indicate a more red component in the overall color determination, along with a positive *b** value, which corresponds with a more yellow sample. The color "Amber" is a yellowish-orange color and is halfway between yellow and orange on the color wheel. Thus, the values for *a** and *b** increase going from Vermont Fancy to Medium Amber and Dark Amber, as expected.

As shown in Table 2, the value of *b** for Grade B drops slightly as compared to Dark Amber, but rises significantly for *a** from 19.13 to 41.60. This is to be expected after visual inspection of Grade B since it is a dark color with a very intense red component, and less of a yellow component. This additional insight into the colors present in the maple syrup is gained through the use of the Shimadzu Color Analysis Software.

In addition to the samples analyzed from the sampling kit, ten separate commercial samples labelled as "Pure Maple Syrup" with various classification grades were analyzed for this Application News. Table 3 summarizes the results obtained for analyzing these products.

Table 2: *CIE L*a*b** values and %Transmittance (560 nm) for samples from sampling kit measured on the Shimadzu UV-2600

Sample ID	Sample Classification	*L**	*a**	*b**	%T at 560 nm
1	Vermont Fancy	90.49	0.40	33.31	81.61
2	Grade A Medium Amber	79.17	7.80	61.61	60.83
3	Grade A Dark Amber	69.33	19.13	83.67	44.64
4	Grade B	45.87	41.60	77.78	13.69

Table 3: CIE *L*a*b** values and %Transmittance (560 nm) for samples from sampling kit, along with commercial samples measured on the Shimadzu UV-2600

Sample ID	Sample Classification	*L**	*a**	*b**	%T at 560 nm
Sampling Kit					
1	Vermont Fancy	90.49	0.40	33.31	81.61
2	Grade A Medium Amber	79.17	7.80	61.61	60.83
3	Grade A Dark Amber	69.33	19.13	83.67	44.64
4	Grade B	45.87	41.60	77.78	13.69
Commercial Samples	**Classification Label**				
5	U.S. Grade A Light Amber	84.46	4.51	59.49	71.31
6	***Grade A Medium Amber***	***70.96***	***16.72***	***79.39***	***47.05***
7	U.S. Grade A Dark Amber	69.71	20.72	91.23	45.81
8	U.S. Grade A Dark Amber	67.26	16.97	83.47	41.73
9	U.S. Grade A Dark Amber	67.96	23.32	94.77	42.93
10	Grade A Dark Amber	70.38	19.77	88.68	46.78
11	U.S. Grade A Dark Amber	67.98	19.16	84.89	42.64
12	U.S. Grade A Dark Amber	66.32	18.05	82.72	40.07
13	U.S. Grade A Dark Amber	73.31	13.76	75.29	51.08
14	U.S. Grade B	52.62	22.69	79.41	22.75

Although the %T values are reported in Table 3, it is important to keep in mind that the majority of these samples were classified under the U.S. grading system. The U.S. system does not rely on %T for classifying maple syrup. Rather, the U.S. system relies on the color of the sample as compared to colored glass standards, which further supports the importance of color analysis[1].

The color results obtained for the commercial samples demonstrate that as the syrup becomes darker, the lightness value decreases. In addition to the lightness value, L*, it is observed that as the amber color darkens, the red component increases, and the yellow component decreases. Thus, a more complete picture of the color of the sample is established for each material.

Interestingly, sample #6, which is classified as "Grade A Medium Amber" on the packaged bottle, demonstrated transmittance and color values close to that of a dark amber maple syrup. More specifically, the color values and %T are similar to samples 3 and 7-13. Visually comparing the samples, #6 has the appearance of an Amber color more close to that of dark amber, rather than medium. The transmittance spectrum of sample 6 is shown in Figure 3, overlaid with the spectra from the sampling kit in Figure 2.

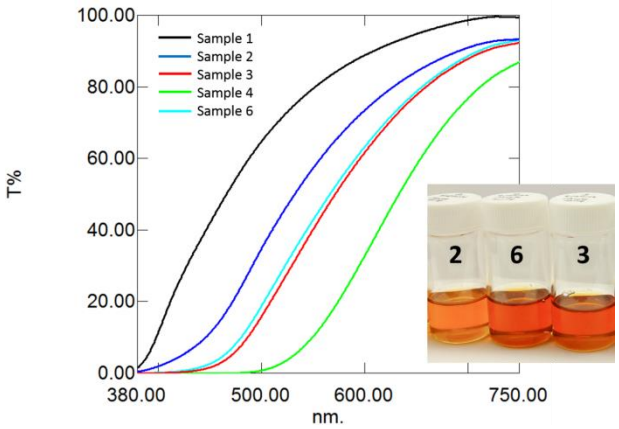


Figure 3: Transmittance spectra of maple syrup samples

■ Conclusion

The Shimadzu UV-2600 with Color Analysis software offers an accurate and effective means for obtaining a meaningful color value for maple syrup. The software and spectrophotometer together offer the ideal solution for any QA/QC laboratory requiring the analysis of finished products.

■ References

1. Federal Register/Vol. 79, No. 88/ Wednesday, May 7, 2014. "United States Standards of Maple Sirup".
2. Hunter, R.S., Harold, R.W. "The Measurement of Appearance". Second Edition. John Wiley & Sons.

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