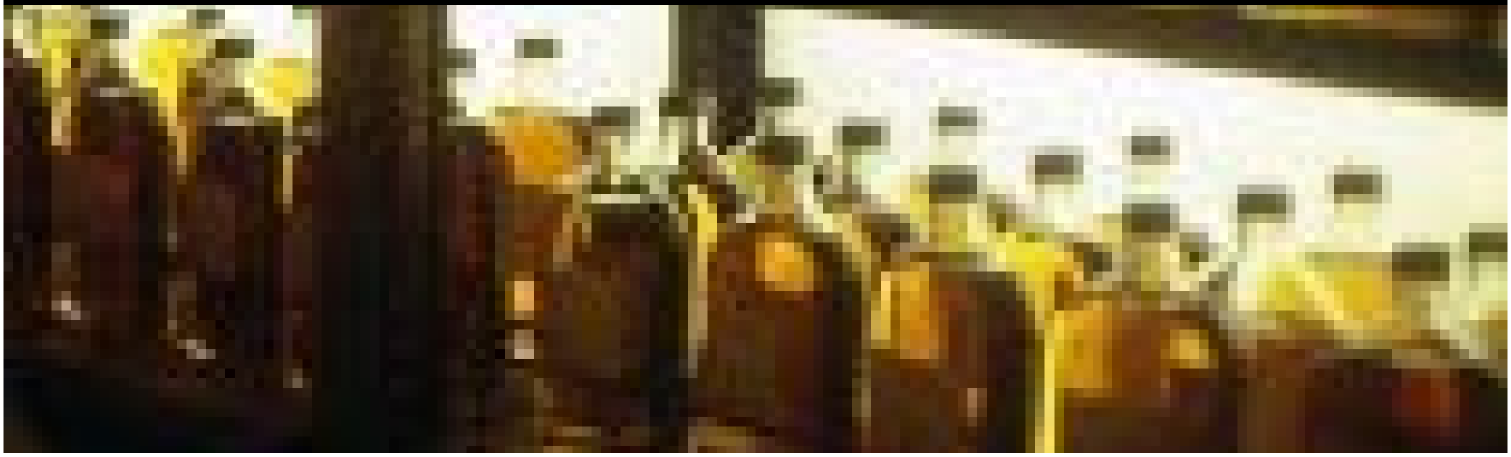
Measuring Proof and Color in Whiskey

Applied Analytics Application Note No. AN-012



Application Summary

Analytes: ethanol concentration, product color

Detector: OMA-300 Process Analyzer

Process Stream: whiskey

Zeroing Fluid: air

Calibration Fluid: standard (known proof) whiskey samples

Path Length: 1 cm

Response Time: every 1-5 seconds

Introduction

For the purposes of quality control, whiskey manufacturers desire a method to monitor alcohol content (proof) and color across the bottled yield. The absorbance spectrum of a whiskey sample is an excellent, non-invasive tool for determining these specifications in real time.

Ethanol and water both have unique structural features in their absorbance spectra which will have stronger or weaker prominence depending on their concentrations in the measured whiskey sample. Similarly, the absorbance spectrum of a whiskey sample can easily be correlated to a host of color scales (both standard and arbitrary), such that product color can be verified using absorbance spectroscopy.

The OMA is a single analyzer providing extremely fast response on both ethanol concentration and product color. Measuring a full, high-resolution absorbance spectrum in the continuously drawn whiskey sample, the instrument is able to “lock in” the background absorbance (i.e. the total absorbance structure of all the non-ethanol compounds in whiskey) and isolate the absorbance of ethanol, which correlates directly to its real-time concentration.

Test Results of Ethanol and Water Concentration Analysis

The case study system was calibrated using eight standard samples of fine, high-proof Bourbon whiskey furnished by Brown-Forman of Louisville, Kentucky.

Below, the characteristic absorbance peaks of both ethanol and water are displayed. The height of the ethanol peak correlates directly to its concentration in the sample. The eight samples display a variety of proofs based on absorbances at this peak wavelength. The OMA measures the real-time concentration of both ethanol and water in order to calculate proof.

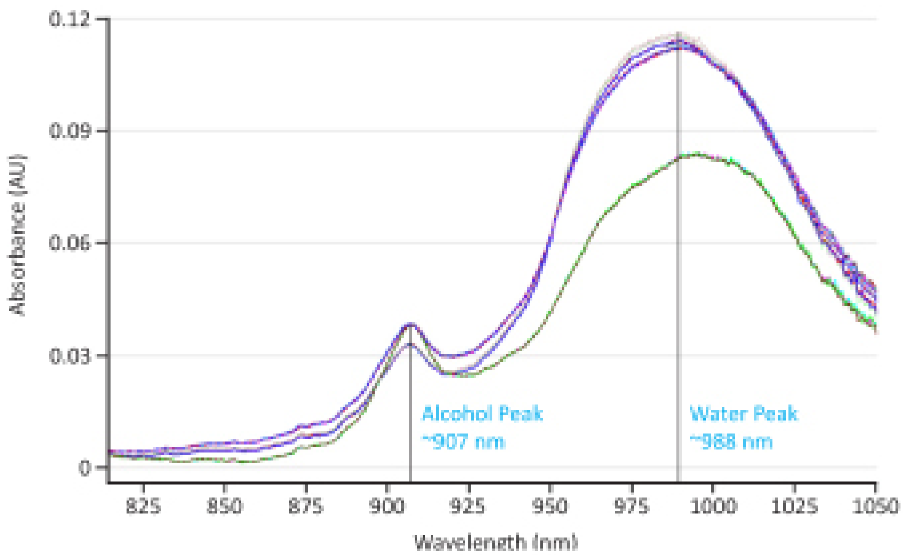


Figure 01: Absorbance curves of ethanol and water in a whiskey background matrix.

When tested against lab readings on a whiskey stream with unknown proof, the OMA demonstrated exceptional accuracy and background correction:

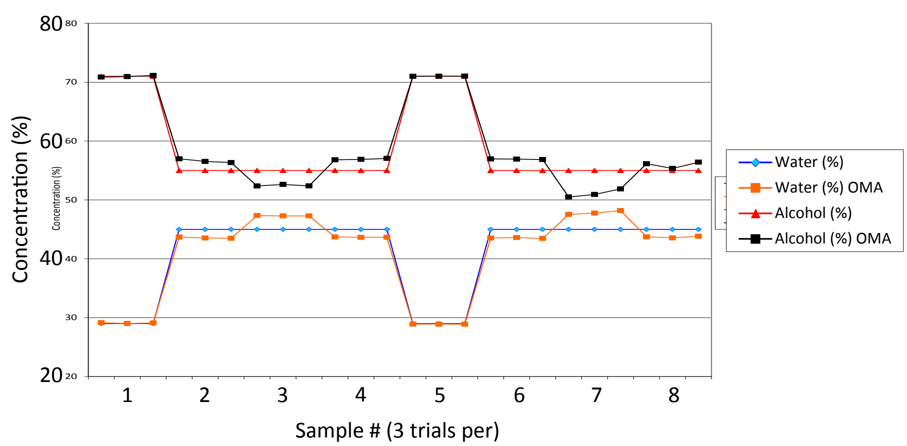


Figure 02: Trend graph comparing OMA accuracy with lab results across 8 samples.

The OMA software can simultaneously produce a 1st derivative visualization for the absorbance spectrograph:

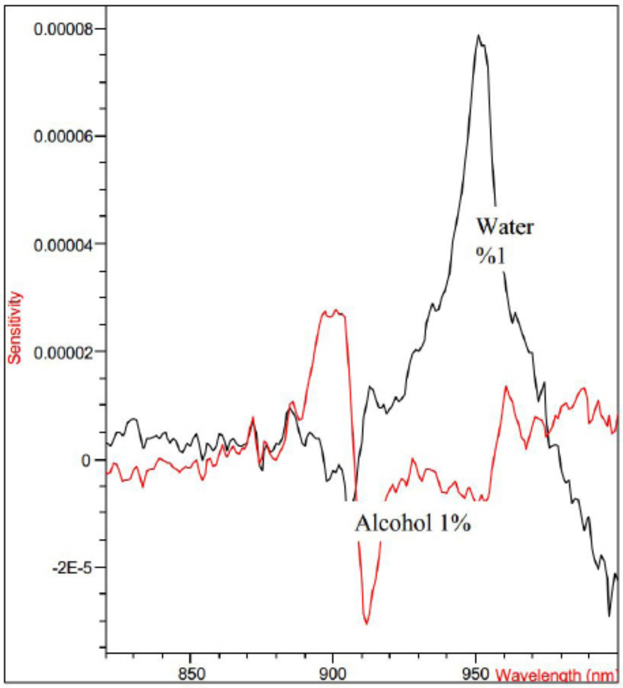


Figure 03: 1st derivative of water and alcohol absorbance curves.

Running the OMA on our whiskey samples and comparing the continuous measurement log against the labels on the samples produced the results in the table below. Any error in the sample prepration would have to be considered as a factor for any discrepancy between the bottle label and the OMA reading.

	Standard Name	H2O(%) Sample	H2O(%) Measured	Alco(%) Sample	Alco(%) Measured
25.	s1	29	29.14300	71	70.86500
26.	s1	29	29.01800	71	70.94400
27.	s1	29	29.11200	71	71.13800
28.	s2	45	43.69400	55	56.98400
29.	s2	45	43.53800	55	56.54000
30.	s2	45	43.48200	55	56.34600
31.	s3	45	47.34800	55	52.37300
32.	s3	45	47.29000	55	52.63500
33.	s3	45	47.29400	55	52.38700
34. 0	s4	45	43.71700	55	56.82000
35.	s4	45	43.65000	55	56.88600
36.	s4	45	43.66500	55	57.05300
37.	s5	29	28.90700	71	70.99900
38.	s5	29	28.90500	71	71.01900
39.	s5	29	28.88800	71	71.02700
40.	s6	45	43.53800	55	56.97000
41.	s6	45	43.61100	55	56.93200
42.	s6	45	43.46200	55	56.85700
43.	s7	45	47.54500	55	50.50300
44.	s7	45	47.76700	55	50.93400
45.	s7	45	48.20100	55	51.88100
46.	s8	45	43.73700	55	56.15600
47.	s8	45	43.55600	55	55.35100
48.	s8	45	43.84400	55	56.41300

Figure 04: Table of Results

Test Results of Whiskey Color Analysis

Product color is known to correlate to the steepness of the curve within the 400-600nm wavelength range of the whiskey absorbance spectrum. In the experimental spectra (Figure 3), the colors of the samples can easily be differentiated by the separation in the overlapping curves. In the graph, the samples range from darkest to lightest as follows:

(DARKEST) S1 = S5 > S3 = S7 > S4 = S8 > S2 = S6 (LIGHTEST)

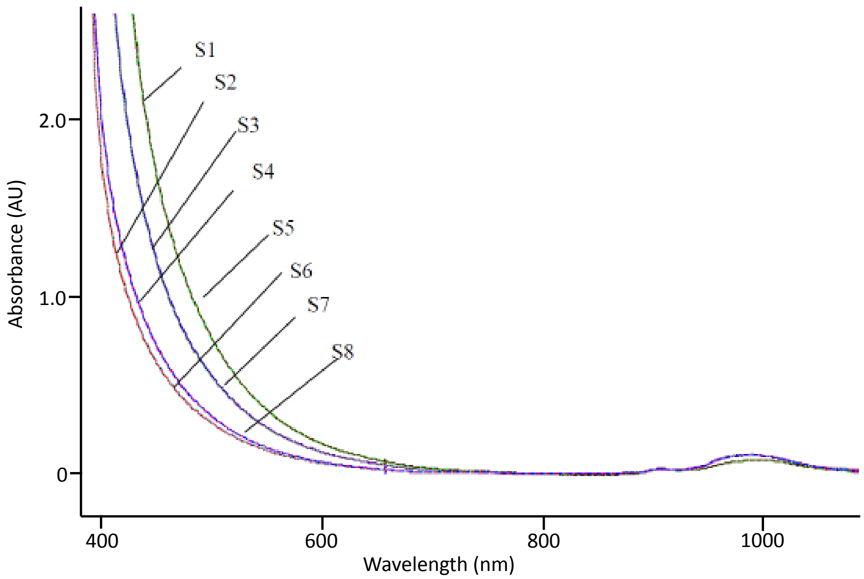


Figure 05: Color curves of the whiskey absorbance spectra. Steepness of curve indicates relative darkness.

These absorbance curves in the spectra above can easily be translated to any sort of arbitrary color scale or standard scales (e.g. Degrees Lovibond, APHA, and more). To demonstrate how we can normalize the color analysis to an arbitrary scale, we subtracted the absorbance at the 590 nm wavelength from the absorbance at the 460 nm wavelength to produce the graph and table below:

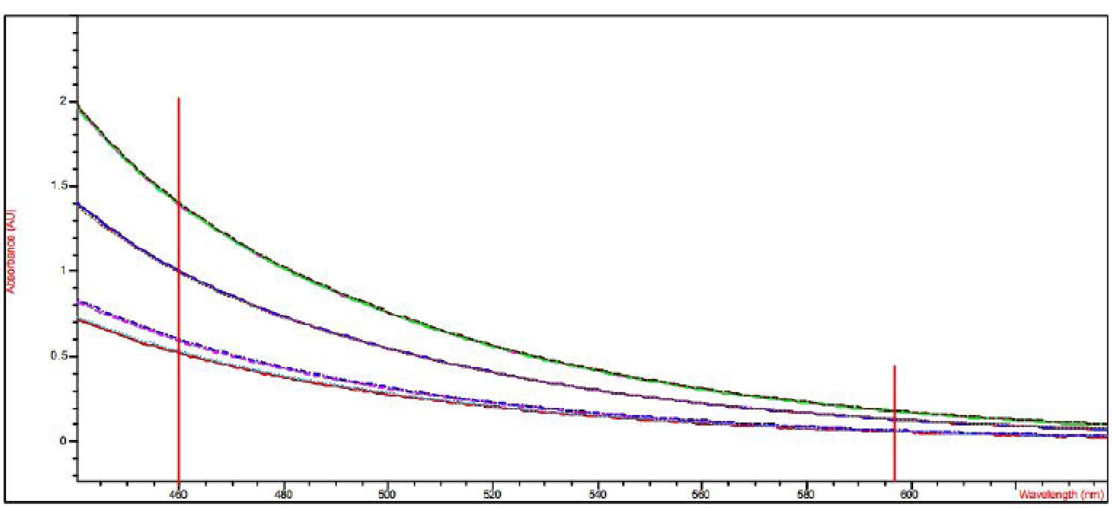


Figure 06: Spectrograph of whiskey color range. The vertical lines indicate measurement and reference wavelengths.

Using the two indicated wavelengths above, we produced the table of values below. We used 3-wavelength ranges for the measurement wavelength and the reference wavelength to allow for some statistical averaging of multiple data points. This signifcantly reduces the effect of signal noise at any single photodiode since the correlated color value from each of the 3 absorbance data points is averaged.

#	Name	Color	Abs<459nm>	Abs<460nm>	Abs<461nm>	Abs<589nm>	Abs<590nm>	Abs<591nm>
1.	s1	1.19470	1.40880	1.39670	1.36890	0.19966	0.19708	0.19337
2.	s1	1.19420	1.41380	1.39000	1.36930	0.19970	0.19718	0.19344
3.	s1	1.19680	1.41210	1.39600	1.37270	0.19975	0.19734	0.19340
4.	s2	0.45320	0.52711	0.51888	0.51034	6.6697E-2	6.5975E-2	6.4063E-2
5.	s2	0.45329	0.52711	0.51834	0.51057	6.6479E-2	6.5767E-2	6.3890E-2
6.	s2	0.45327	0.52700	0.51855	0.51013	6.6445E-2	6.5661E-2	6.3780E-2
7.	s3	0.85890	1.01950	1.00370	0.98647	0.14646	0.14467	0.14178
8.	s3	0.85887	1.01880	1.00300	0.98667	0.14611	0.14431	0.14147
9.	s3	0.85976	1.01950	1.00510	0.98827	0.14667	0.14490	0.14198
10. 0	s4	0.51902	0.60077	0.59178	0.58154	7.3573E-2	7.2798E-2	7.0661E-2
11.	s4	0.51944	0.60116	0.59137	0.58147	7.3142E-2	7.2300E-2	7.0235E-2
12.	s4	0.51946	0.60076	0.59140	0.58159	7.3009E-2	7.2257E-2	7.0094E-2
13.	s5	1.20130	1.42430	1.40560	1.37980	0.20484	0.20235	0.19857
14.	s5	1.20150	1.42340	1.40420	1.38220	0.20470	0.20219	0.19833
15.	s5	1.20190	1.42350	1.40640	1.37980	0.20430	0.20182	0.19798
16.	s6	0.46048	0.53811	0.52951	0.52102	7.0204E-2	6.9484E-2	6.7501E-2
17.	s6	0.46054	0.53778	0.52964	0.52095	7.0042E-2	6.9377E-2	6.7319E-2
18.	s6	0.46055	0.53789	0.52939	0.52096	6.9980E-2	6.9341E-2	6.7288E-2
19.	s7	0.84517	1.00860	0.99221	0.97672	0.14941	0.14782	0.14474
20.	s7	0.84626	1.00960	0.99245	0.97736	0.14895	0.14731	0.14437
21.	s7	0.84632	1.00660	0.99437	0.97763	0.14856	0.14705	0.14401
22.	s8	0.52647	0.61127	0.60170	0.59140	7.6205E-2	7.5482E-2	7.3276E-2
23.	s8	0.52719	0.61167	0.60226	0.59221	7.6056E-2	7.5348E-2	7.3158E-2
24.	s8	0.52723	0.61221	0.60209	0.59228	7.6248E-2	7.5436E-2	7.3217E-2

Figure 07: Color to Absorbance Correlation Results

Conclusion

As demonstrated herein, the OMA is highly suited to monitoring whiskey product quality, defined in this particular application as consistent proof (ethanol level) and color.

The OMA offers an elegant solution as a one-stop device for both parameters. Ethanol concentration and whiskey color are both monitored in real-time in a continuously drawn sample. The accuracy of the system aligns closely with lab measurement of these parameters.

Further Reading

Subject	Location
OMA-300 Process Analyzer	http://www.a-a-inc.com/documents/AA_DS001A_OMA300.pdf
Advantage of Collateral Data	http://www.a-a-inc.com/documents/AA_TN-202_CollateralData.pdf
Multi-Component Analysis	http://www.a-a-inc.com/documents/AA_TN-203_MultiComponentAnalysis.pdf

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