Automated Wort and Beer Quality Control Analysis

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Introduction

We describe a system capable of producing fast and reliable results from several analytes by combining automated colorimetric detection and solid phase extraction techniques. The analyzer, Thermo Scientific™ Gallery™ Plus Beermaster, can determine bitterness and simultaneously do other colorimetric determinations (e.g. SO_2, FAN, pH, color, polyphenol and beta-glucan) from beer or wort samples. In addition many water quality parameters can be measured using the same analyzer.

In this study we present a comparison of bitterness measurement from beer and wort samples between a new automated method and the iso-octane extraction method. We also present method comparison studies from beer and wort samples for pH, color, FAN and SO_2.

The bitterness method uses a solid-phase extraction column integrated into an automated photometric analyzer. In the automated bitterness method, samples are first acidified then passed through the extraction column which binds bittering substances. The sample matrix is washed out and bittering substances are eluted and measured at 275 nm. Bitterness units are automatically calculated from absorbance results.

Materials and Methods

Instruments

Thermo Scientific Gallery Plus Beermaster, an automated discrete photometric analyzer, Thermo Fisher Scientific Oy, Vantaa, Finland

Methods

Methods are fully automated using bar-coded traceable system reagents. Bitterness calibration was performed using samples with known bitterness values. Colorimetric methods were calibrated with either a water based standard solution or samples with known values. Reference methods were European Brewery Convention (EBC) 9.8 for bitterness, EBC 8.10 and 9.10 for FAN, EBC 9.6 for Color, EBC 9.25.1 for SO_2 and EBC 9.35 and 8.17 for pH.

Samples

To establish robustness over a range of alcohol and color values, ten small pack beer samples and ten worts were analyzed in duplicate using the Beermaster and reference methods for, pH, Color, Bitterness, Free Amino Nitrogen (FAN), Sulphur Dioxide (SO_2) (Note: SO_2 was measured in beer sample only.)
The worts (Table 1) were frozen prior to analysis to ensure product stability. They were gently defrosted overnight at room temperature and then centrifuged at 3,600 rpm for 5 minutes to remove any cold trub that had formed upon freezing. Ten small pack beers with alcohol content ranging from 0.5 to 9% (Table 2), and covering a range of color values were analyzed in duplicate. All the beers were degassed by leaving them overnight on the bench in a conical flask. In the case of SO_2 analysis a fresh can of sample was opened immediately before analysis.

Table 1. Worts used in this study

Code	Type
WA	1038 Ale
WB	1040 Ale
WC	1040 Ale
WD	Adjunct
WE	1050 Best Bitter
WF	16 Plato Lager
WG	11 Plato Lager
WH	11 Plato Lager
WI	1050 Best Bitter
WJ	16 Plato Lager

Table 2. Beers used in this study

Code	Type	Declared ABV (%)
BA	Lager	0.00
BB	Lager	2.30
BC	Stout	2.80
BD	Ale	3.50
BE	Lager	3.80
BF	Stout	4.20
BG	Lager	4.80
BH	Ale	5.20
BI	Ale	6.60
BJ	Lager	9.00

Results and Discussion

Tables 3-11 summarize the mean and precision data for analyses of wort and beer samples using the Beermaster as compared to the reference methods.

Table 3. Summary of pH analysis results for ten different wort samples

		Measured[1]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
pH	WA		5.13	5.08	**5.11**	0.035	0.025	4.86	4.86	**4.86**	0.000	0.000	***0.065***
	WB	5.22	5.22	5.21	**5.22**	0.007	0.005	5.12	5.12	**5.12**	0.000	0.000	***0.033***
	WC	5.15	5.21	5.21	**5.21**	0.000	0.000	5.14	5.12	**5.13**	0.014	0.010	***0.079***
	WD	5.07	5.08	5.06	**5.07**	0.014	0.010	4.96	4.96	**4.96**	0.000	0.000	***0.058***
	WE	4.87	5.11	5.12	**5.12**	0.007	0.005	4.95	4.95	**4.95**	0.000	0.000	***0.019***
	WF	5.26	5.25	5.25	**5.25**	0.000	0.000	5.22	5.23	**5.23**	0.007	0.005	***0.126***
	WG	5.30	5.28	5.28	**5.28**	0.000	0.000	5.23	5.24	**5.24**	0.007	0.005	***0.070***
	WH	5.31	5.26	5.25	**5.26**	0.007	0.005	5.22	5.22	**5.22**	0.000	0.000	***0.090***
	WI		5.09	5.09	**5.09**	0.000	0.000	4.90	4.88	**4.89**	0.014	0.010	***0.032***
	WJ	5.22	5.23	5.23	**5.23**	0.000	0.000	5.21	5.18	**5.20**	0.021	0.015	***0.258***

[1]These are the reference method mean readings for the fresh pre-frozen worts.

Table 4. Summary of pH analysis results for ten different beer samples

		Measured[2]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
	CB44	4.08	4.16	4.16	**4.16**	0.000	0.000	4.16	4.03	**4.10**	0.092	0.065	***0.500***
pH	BA		4.12	4.12	**4.12**	0.000	0.000	3.98	3.92	**3.95**	0.042	0.030	***0.111***
	BB		4.37	4.34	**4.36**	0.021	0.015	4.28	4.21	**4.25**	0.049	0.035	***0.212***
	BC		5.03	5.02	**5.03**	0.007	0.005	3.93	3.96	**3.95**	0.021	0.015	***0.009***
	BD		4.21	4.32	**4.27**	0.078	0.055	4.00	4.12	**4.06**	0.085	0.060	***0.241***
	BE		4.39	4.30	**4.35**	0.064	0.045	4.26	4.29	**4.28**	0.021	0.015	***0.379***
	BF		4.62	4.63	**4.63**	0.007	0.005	3.98	4.03	**4.01**	0.035	0.025	***0.026***
	BG		4.12	4.11	**4.12**	0.007	0.005	4.00	4.05	**4.03**	0.035	0.025	***0.176***
	BH		4.20	4.20	**4.20**	0.000	0.000	3.81	3.80	**3.81**	0.007	0.005	***0.008***
	BI		4.27	4.33	**4.30**	0.042	0.030	4.25	4.28	**4.27**	0.021	0.015	***0.486***
	BJ		4.10	4.09	**4.10**	0.007	0.005	4.06	4.09	**4.08**	0.021	0.002	***0.426***

[2]This is the QC sample from a commercially available lager. The value is the mean of readings developed as a reference method between February 2013 and July 2013.

The standard deviations of the duplicate samples showed that the precision of the Beermaster relative to the reference pH method was similar for both beers and worts. Overall the precision of the Beermaster in measuring pH proved better than that of the reference method and was within acceptable levels for such an instrument. Statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that in the majority of cases and based on current data there is no statistically significant difference (p-value >0.05) in pH measurements for beer and wort when using the Beermaster versus the reference pH method.

Table 5. Summary of color analysis results for ten different wort samples

		Measured[1]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
Colour	WA		25.78	26.05	**25.91**	0.190	0.140	27.48	27.50	**27.49**	0.014	0.010	***0.055***
(EBC)	WB	38.00	31.09	31.12	**31.10**	0.021	0.015	33.50	33.55	**33.53**	0.035	0.025	***0.008***
	WC	35.00	31.15	30.95	**31.05**	0.141	0.100	33.63	33.65	**33.64**	0.014	0.010	***0.025***
	WD	12.00	11.90	11.88	**11.89**	0.014	0.010	12.85	12.88	**12.87**	0.021	0.015	***0.012***
	WE	37.00	36.77	36.74	**36.76**	0.021	0.015	38.65	38.70	**38.68**	0.035	0.025	***0.010***
	WF	20.00	19.40	19.44	**19.42**	0.028	0.020	20.15	20.18	**20.17**	0.021	0.015	***0.021***
	WG	11.00	11.48	11.48	**11.48**	0.000	0.000	11.55	11.60	**11.58**	0.035	0.025	***0.164***
	WH	13.00	13.10	13.12	**13.11**	0.014	0.010	13.33	13.33	**13.33**	0.000	0.000	***0.029***
	WI		39.59	39.55	**39.57**	0.028	0.020	40.98	41.05	**41.02**	0.049	0.035	***0.018***
	WJ	21.00	19.28	19.32	**19.30**	0.028	0.020	20.48	20.50	**20.49**	0.014	0.010	***0.012***

[1]These are the reference method mean readings for the fresh pre-frozen worts.

Table 6. Summary of color analysis results for ten different beer samples

		Measured[2]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
	CB44	8.88	8.50	8.52	**8.51**	0.014	0.010	8.93	8.93	**8.93**	0.000	0.000	***0.015***
Colour	BA		7.76	7.77	**7.77**	0.001	0.005	8.13	8.10	**8.12**	0.021	0.015	***0.029***
(EBC)	BB		5.08	5.09	**5.09**	0.007	0.005	5.38	5.38	**5.38**	0.000	0.000	***0.011***
	BC		165.77	165.66	**165.71**	0.080	0.055	181.30	184.50	**182.90**	2.263	1.600	***0.059***
	BD		14.46	14.46	**14.46**	0.001	0.001	15.15	15.20	**15.18**	0.035	0.025	***0.022***
	BE		8.12	8.11	**8.12**	0.007	0.005	8.68	8.70	**8.69**	0.014	0.010	***0.012***
	BF		91.77	91.99	**91.88**	0.156	0.110	102.30	103.00	**102.65**	0.495	0.350	***0.022***
	BG		7.36	7.32	**7.34**	0.028	0.020	7.58	7.58	**7.58**	0.000	0.000	***0.053***
	BH		52.69	52.94	**52.82**	0.177	0.130	58.80	59.30	**59.05**	0.354	0.250	***0.029***
	BI		13.39	13.40	**13.39**	0.007	0.005	14.08	14.15	**14.12**	0.049	0.035	***0.031***
	BJ		13.12	13.11	**13.11**	0.007	0.005	13.68	13.73	**13.71**	0.035	0.025	***0.027***

[2]This is the QC sample from a commercially available lager. The value is the mean of readings developed as a reference method between February 2013 and July 2013.

The standard deviation of the duplicate samples showed that the precision of the Beermaster relative to the reference color method was similar for both beers and worts. Interestingly in all cases the color readings from the Beermaster were slightly lower than that of the reference method. As a result, statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that based on the current data there was a statistically significant difference (p-value >0.05) in color measurements for beer and wort when using the Beermaster versus the reference color method.

To assess whether inclusion of a factor would compensate for these differences, the statistical tests were re-run using the original Beermaster values multiplied by a factor of 1.05. By applying a factor of 1.05 to the Beermaster data, statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that in the majority of cases and based on current data there is no statistically significant difference (p-value >0.05) in color measurements for beer and wort when using the Beermaster versus the reference color method.

Table 7. Summary of bitterness analysis results for ten different wort samples

		Measured[1]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
Bitterness	WA		41.83	42.03	**41.93**	0.141	0.100	33.65	33.70	**33.68**	0.035	0.025	***0.008***
(BU)	WB	34.00	24.73	22.82	**23.78**	1.351	0.950	29.30	28.75	**29.03**	0.389	0.027	***0.119***
	WC	36.00	25.19	24.44	**24.82**	0.530	0.370	29.65	29.60	**29.63**	0.035	0.025	***0.050***
	WD	26.00	32.84	31.81	**32.33**	0.728	0.520	23.40	23.35	**23.38**	0.035	0.025	***0.037***
	WE	51.00	56.56	63.33	**59.95**	4.787	3.400	55.10	56.30	**55.70**	0.849	0.600	***0.433***
	WF	34.00	39.91	38.48	**39.20**	1.011	0.710	32.50	33.45	**32.98**	0.672	0.480	***0.087***
	WG	35.00	41.95	42.14	**42.05**	0.134	0.095	30.90	31.75	**31.33**	0.601	0.430	***0.026***
	WH	32.00	40.06	41.03	**40.55**	0.686	0.480	27.95	30.00	**28.98**	1.450	1.100	***0.062***
	WI		51.99	53.71	**52.85**	1.216	0.860	51.75	53.20	**52.48**	1.025	0.730	***0.795***
	WJ	32.00	37.9	33.84	**35.87**	2.871	2.000	31.30	32.10	**31.70**	0.566	0.400	***0.293***

[1]These are the reference method mean readings for the fresh pre-frozen worts.

Table 8. Summary of bitterness analysis results for ten different beer samples

		Measured[2]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
	CB44	15.90	18.33	17.66	**17.99**	0.474	0.330	15.63	16.03	**15.83**	0.283	0.200	***0.114***
Bitterness	BA		22.11	21.86	**21.98**	0.177	0.130	17.50	17.90	**17.70**	0.283	0.200	***0.035***
(BU)	BB		15.91	15.51	**15.71**	0.283	0.200	13.18	13.58	**13.38**	0.283	0.200	***0.014***
	BC		20.28	18.47	**19.38**	1.280	0.910	23.40	24.20	**23.80**	0.566	0.400	***0.140***
	BD		25.47	24.01	**24.74**	1.032	0.730	20.25	20.28	**20.26**	0.021	0.015	***0.103***
	BE		15.44	14.83	**15.13**	0.431	0.300	12.38	12.45	**12.42**	0.049	0.035	***0.072***
	BF		26.76	24.56	**25.66**	1.556	1.100	24.20	24.45	**24.33**	0.177	0.130	***0.441***
	BG		20.19	22.33	**21.26**	1.512	1.100	19.85	19.62	**19.74**	0.163	0.110	***0.391***
	BH		23.18	23.14	**23.16**	0.028	0.020	26.80	26.70	**26.75**	0.071	0.050	***0.010***
	BI		17.33	16.92	**17.13**	0.289	0.200	17.20	17.30	**17.25**	0.071	0.050	***0.660***
	BJ		26.14	26.01	**26.08**	0.092	0.065	22.25	22.30	**22.28**	0.035	0.025	***0.012***

[2]This is the QC sample from a commercially available lager. The value is the mean of readings developed as a reference method between February 2013 and July 2013.

The standard deviation of the duplicate samples showed that the precision of the Beermaster relative to the reference bitterness method was similar for both beers and worts, and was within acceptable levels for such an instrument. Statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that in the majority of cases and based on current data there is no statistically significant difference (p-value >0.05) in bitterness measurements for beer and wort when using the Beermaster versus the reference bitterness method.

Table 9. Summary of FAN analysis results for ten different wort samples

		Measured[1]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
FAN	WA		131.21	132.23	**131.72**	0.721	0.51	146.80	142.10	**144.45**	3.323	2.400	***0.119***
(mg/L)	WB	212.00	201.52	207.94	**204.73**	4.540	3.20	229.90	207.90	**218.90**	15.556	11.000	***0.433***
	WC	208.00	199.52	198.11	**198.82**	0.997	0.70	208.00	207.90	**207.95**	0.071	0.050	***0.049***
	WD	315.00	303.78	300.61	**302.20**	2.242	1.60	279.30	290.30	**284.80**	7.778	5.500	***0.202***
	WE	172.00	186.37	185.02	**185.70**	0.955	0.67	169.70	179.50	**174.60**	6.930	4.900	***0.267***
	WF	269.00	250.41	253.47	**251.94**	2.164	1.50	231.90	240.00	**235.95**	5.728	4.100	***0.168***
	WG	175.00	176.09	175.33	**175.71**	0.537	0.38	177.80	171.20	**174.50**	4.667	3.300	***0.778***
	WH	179.00	188.07	187.43	**187.75**	0.453	0.32	171.20	177.40	**174.30**	4.384	3.100	***0.145***
	WI		168.90	169.30	**169.10**	0.283	0.20	156.20	161.20	**158.70**	3.536	2.500	***0.151***
	WJ	263.00	258.55	259.64	**259.10**	0.771	0.54	231.80	243.40	**237.60**	8.202	5.800	***0.168***

[1]These are the reference method mean readings for the fresh pre-frozen worts.

Table 10. Summary of FAN analysis results for ten different beer samples

		Measured[2]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
	CB44	76.68	69.82	69.46	**69.64**	0.255	0.180	81.33	79.72	**80.53**	1.138	0.81	***0.048***
FAN	BA		60.83	60.96	**60.89**	0.092	0.065	57.10	58.40	**57.75**	0.919	0.650	***0.130***
(mg/L)	BB		28.96	30.30	**29.63**	0.949	0.670	31.80	31.30	**31.55**	0.354	0.250	***0.227***
	BC		12.26	11.76	**12.01**	0.354	0.250	19.60	19.80	**19.70**	0.141	0.100	***0.022***
	BD		34.49	35.61	**35.05**	0.792	0.560	36.20	35.60	**35.90**	0.424	0.300	***0.409***
	BE		96.01	95.09	**95.55**	0.651	0.460	92.10	90.30	**91.20**	1.273	0.900	***0.145***
	BF		71.23	71.71	**71.47**	0.339	0.240	75.10	73.70	**74.40**	0.990	0.700	***0.157***
	BG		58.04	59.06	**58.55**	0.721	0.510	58.00	57.40	**57.70**	0.424	0.300	***0.387***
	BH		26.50	26.61	**26.55**	0.077	0.055	41.10	40.60	**40.85**	0.354	0.250	***0.011***
	BI		112.56	109.59	**111.07**	2.101	1.500	110.70	108.30	**109.50**	1.697	1.200	***0.561***
	BJ		107.97	108.92	**108.45**	0.674	0.480	105.10	102.50	**103.80**	1.838	1.300	***0.184***

[2]This is the QC sample from a commercially available lager. The value is the mean of readings developed as a reference method between February 2013 and July 2013.

The standard deviation of the duplicate samples showed that the precision of the Beermaster in measuring FAN proved better than that of the reference method (especially in the case of worts) and was within acceptable levels for such an instrument. Statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that in the majority of cases and based on current data there is no statistically significant difference (p-value >0.05) in FAN measurements for beer and wort when using the Beermaster versus the reference FAN method.

Table 11. Summary of SO_2 analysis results for ten different beer samples

		Measured[2]	Thermo Scientific Method					Reference Method					
Analysis	Sample				Mean	Std Dev	SE Mean			Mean	Std Dev	SE Mean	*P-Value*
	230	5.60	4.81	4.94	**4.88**	0.092	0.065	5.60	5.12	**5.36**	0.339	0.240	***0.302***
SO2	BA		3.10	3.00	**3.05**	0.071	0.050	4.80	4.96	**4.88**	0.113	0.080	***0.033***
(mg/L)	BB		5.10	5.10	**5.10**	0.000	0.000	5.76	5.44	**5.60**	0.226	0.160	***0.197***
	BC		0.10	0.10	**0.10**	0.000	0.000	1.12	1.44	**1.28**	0.226	0.160	***0.086***
	BD		1.30	1.30	**1.30**	0.000	0.000	1.60	1.76	**1.68**	0.113	0.080	***0.132***
	BE		11.90	12.10	**12.00**	0.141	0.100	12.32	12.80	**12.56**	0.339	0.240	***0.227***
	BF		0.80	0.90	**0.85**	0.071	0.050	2.40	2.08	**2.24**	0.226	0.160	***0.076***
	BG		4.00	4.10	**4.05**	0.071	0.050	2.91	3.01	**2.96**	0.071	0.015	***0.004***
	BH		2.40	2.40	**2.40**	0.000	0.000	2.24	1.92	**2.08**	0.226	0.160	***0.295***
	BI		1.80	1.80	**1.80**	0.000	0.000	1.60	1.28	**1.44**	0.226	0.160	***0.266***
	BJ		15.10	19.70	**17.40**	3.253	2.300	16.32	16.80	**16.56**	0.339	0.240	***0.778***

[2]This is the QC sample from a commercially available lager. The value is the mean of readings developed as a reference method between February 2013 and July 2013.

The standard deviation of the duplicate samples showed that the precision of the Beermaster relative to the reference SO_2 method was similar. Overall the precision of the Beermaster in measuring SO_2 proved better than that of the reference method and was within acceptable levels for such an instrument. Statistical analysis using the two-sample *t*-test and the one-way ANOVA test suggested that in the majority of cases and based on current data there is no statistically significant difference (p-value >0.05) in SO_2 measurements for beer and wort when using the Beermaster versus the reference SO_2 method.

Ten replicates of a commercially available canned lager were analyzed for pH, color, bitterness, FAN and SO_2 using the Beermaster and traditional reference methods. Table 12 summarizes the mean and precision data for these analyses.

Table 12. Summary of pH, color, bitterness, FAN and SO_2 analysis results for ten replicates of a single brand of beer

	pH		Color (EBC)		Bitterness (BU)		FAN (mg/L)		SO_2 (mg/L)	
	Beermaster	Reference	Beermaster	Reference	Beermaster	Reference	Beermaster	Reference	Beermaster	Reference
Mean	4.14	4.03	7.32	7.58	22.16	19.74	58.16	57.75	3.97	2.96
SD	0.016	0.024	0.032	0.021	0.831	0.185	0.596	0.706	0.106	0.253
95% Confidence Interval for Mean	4.13, 4.15	4.01, 4.04	7.30, 7.35	7.56, 7.59	21.56, 22.75	19.60, 19.87	57.73, 58.59	57.25, 58.26	3.89, 4.05	2.78, 3.14

The precision of the Beermaster, as expressed in the standard deviation of the ten replicates showed with the current data and this brand of beer, precision was greatest for pH measurement and least for bitterness. The current data also suggested that the Beermaster was more precise in the measurement of pH, FAN and SO_2 compared with the reference methods used.

Conclusion

Based on the data obtained during this study, the Thermo Scientific Gallery Plus Beermaster analyzer has been shown to provide comparable performance to established methods in the measurement of pH, bitterness, FAN and SO_2. In the case of color measurement, the Gallery Plus Beermaster had similar precision to the reference method but consistently gave slightly lower results suggesting that a factor of 1.05 be included to compensate for these differences in the methodology. When this factor was included, the Gallery Plus Beermaster was comparable to the established method. Analysis of ten replicates of the same brand of beer showed that the Gallery Plus Beermaster had greater precision in the measurement of pH, FAN and SO_2 compared to the reference methods used in this study. Precision values for all analyses are within acceptable levels for spectrophotometers in the brewing industry. The Gallery Plus Beermaster has been proven to provide faster results when compared to time consuming traditional methods. The low reagent and water volumes required for analysis not only reduce reagent costs but also reduce the amount of waste produced, thereby providing analysis with low environmental impact. The new bitterness measurement uses environmentally safe reagents without the requirement to use harmful iso-octane in routine analysis. The analyzer is very straightforward to use and requires minimal training or skills to run and maintain.

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