Use of an integrating cavity spectrometer to easily determine beer SRM color without filtration, centrifugation or numerical correction

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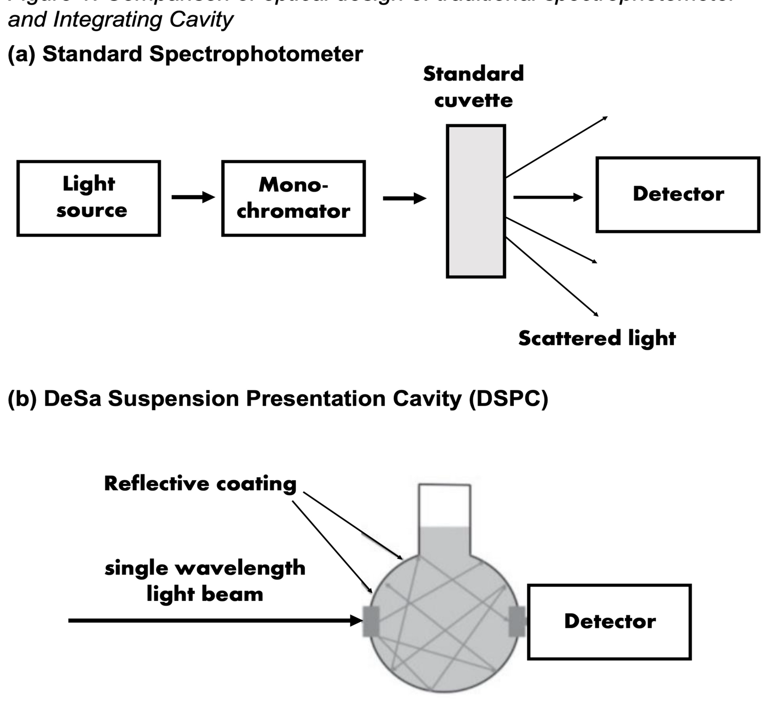
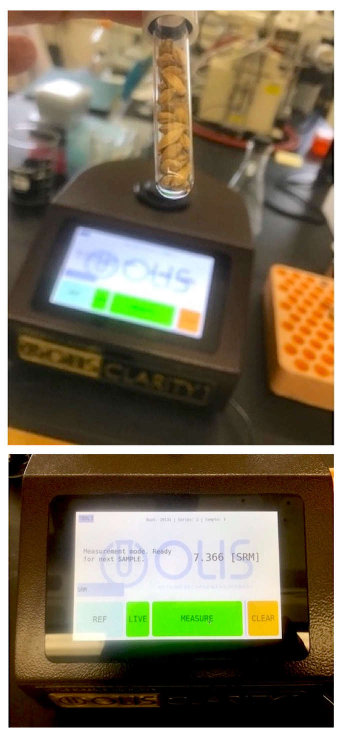
Introduction

Quantification of beer color has presented an issue for brewers in recent years due to the difficulty in accurately measuring the transmission or absorbance in popular craft unfiltered, dry-hopped, hazy, seltzer and fruited beer styles. In this study we employed a novel **integrating cavity spectrometer (ICS),** the OLIS CLARiTY, designed to eliminate the effect of light scatter by the sample, to determine if it was able to more accurately quantify beer color compared to a **conventional scanning spectrophotometer (CSS)**, particularly with hazy and fruited styles of beer. The ICS recaptures scattered light in a reflective cavity and so measurement difference between the blank and sample reflects only light that is truly absorbed--even with, *e.g.,* whole malt kernels showing showing an SRM = 7.366 (**Figure 1**).

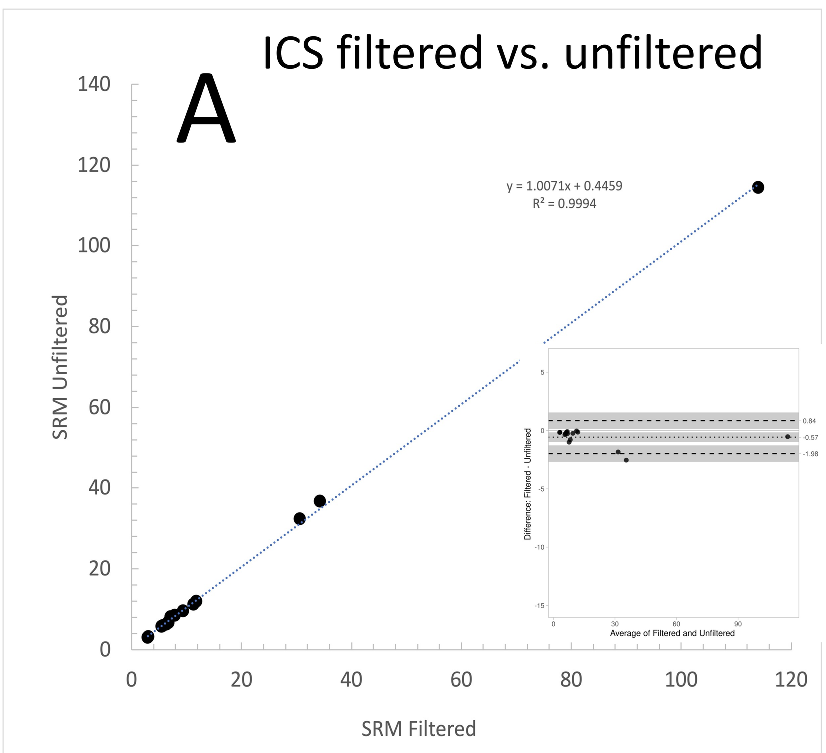
Figure 1. Comparison of optical design of traditional spectrophotometer and Integrating Cavity

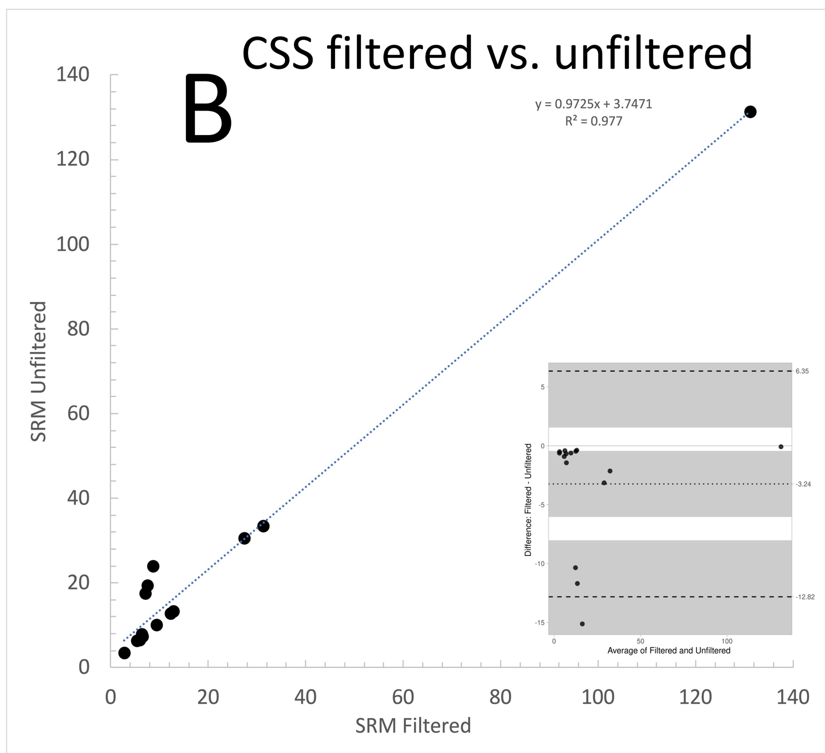




Methodology

We employed a Cary 50 scanning spectrophotometer (CSS) and CLARiTY 1 ICS to measure the absorbance and transmission of 15 highly diverse filtered and unfiltered craft brewery beer samples from Modicum Brewing. This allowed us to determine the SRM color value (ASBC Standard Reference Method, Beer-10). The ICS measures absorbance with 430 nm LED to determine the single-point SRM value for each beer. The CIE L*a*b tristimulus color values were also determined using the CSS. The SRM values of unfiltered or 0.2 μM filtered beer samples determined by these two methods were compared using direct and Bland-Altman analysis and regression fits (**Figure 2**).





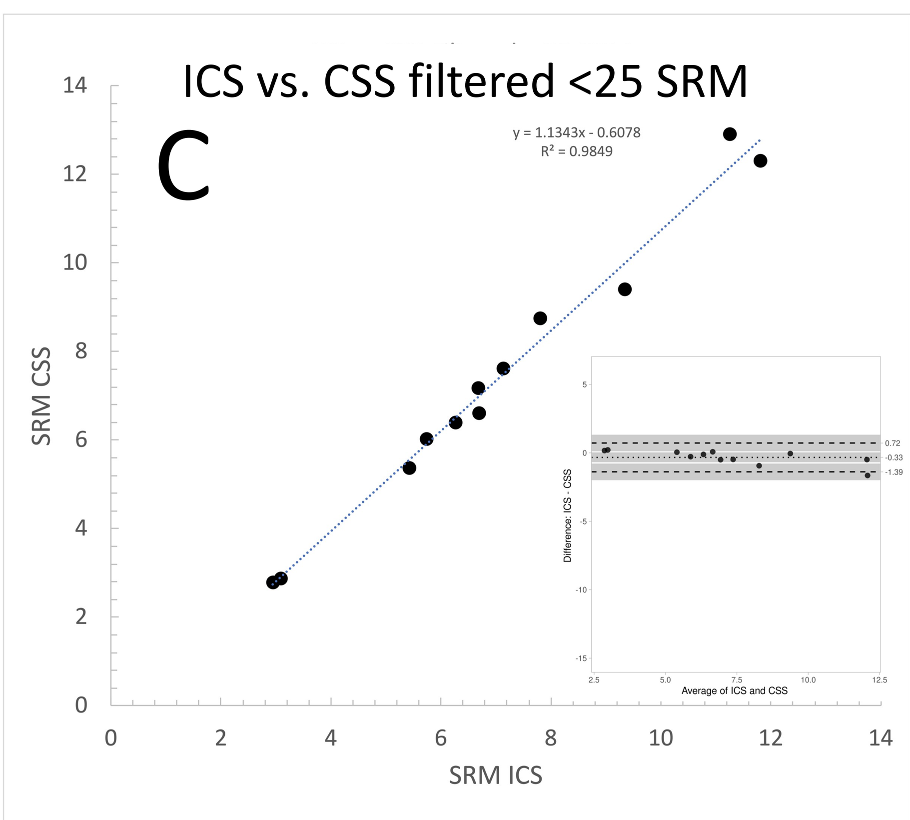


Figure 2. SRM vs. Instrumental and filtration status. **A**. Dilution-corrected SRM determined by the OLIS CLARiTY 1 ICS for filtered vs. unfiltered draft beer samples. The nearly ideal slope of the fit indicates high correlation and the very narrow confidence intervals in the Bland-Altman plot show the equivalence of values obtained by the two treatments. Note that even higher SRM beers are well fitted. **B.** SRM determined by the Agilent Cary 50 CSS for filtered vs. unfiltered draft beer samples. The poorer fit and broader confidence limits in the right panel demonstrate the effect on SRM by turbidity in conventional systems, though the non-turbid samples are highly correlated. **C.** Direct comparison of SRM by Agilent Cary 50 CSS vs. the OLIS CLARiTY 1 for clear filtered draft beer samples with SRM <25. The fit shows high correlation and the Bland-Altman analysis in the right panel emphasizes the very tight confidence intervals between the methods when higher SRM beers are not included.

Conclusions

We show that SRM determination by ICS is **equivalent** to standard spectrophotometer single-point methods for clear beers and **superior** in accurately determining the SRM color of hazy beers without filtration or centrifugation, even very dense fruited sours. For that alone, an ICS would be worth adding to any brewer's QC/QA lab—especially since the haze itself may add to the perceived color. Ideally an ICS system employing validated and selected multiple LEDs or a fixed-grating monochromator and a diode array detector would be a faster, more rugged way to measure the data needed for the CIELAB color, allowing a more accurate and thorough depiction of beer or other beverage color regardless of ingredients or turbidity.

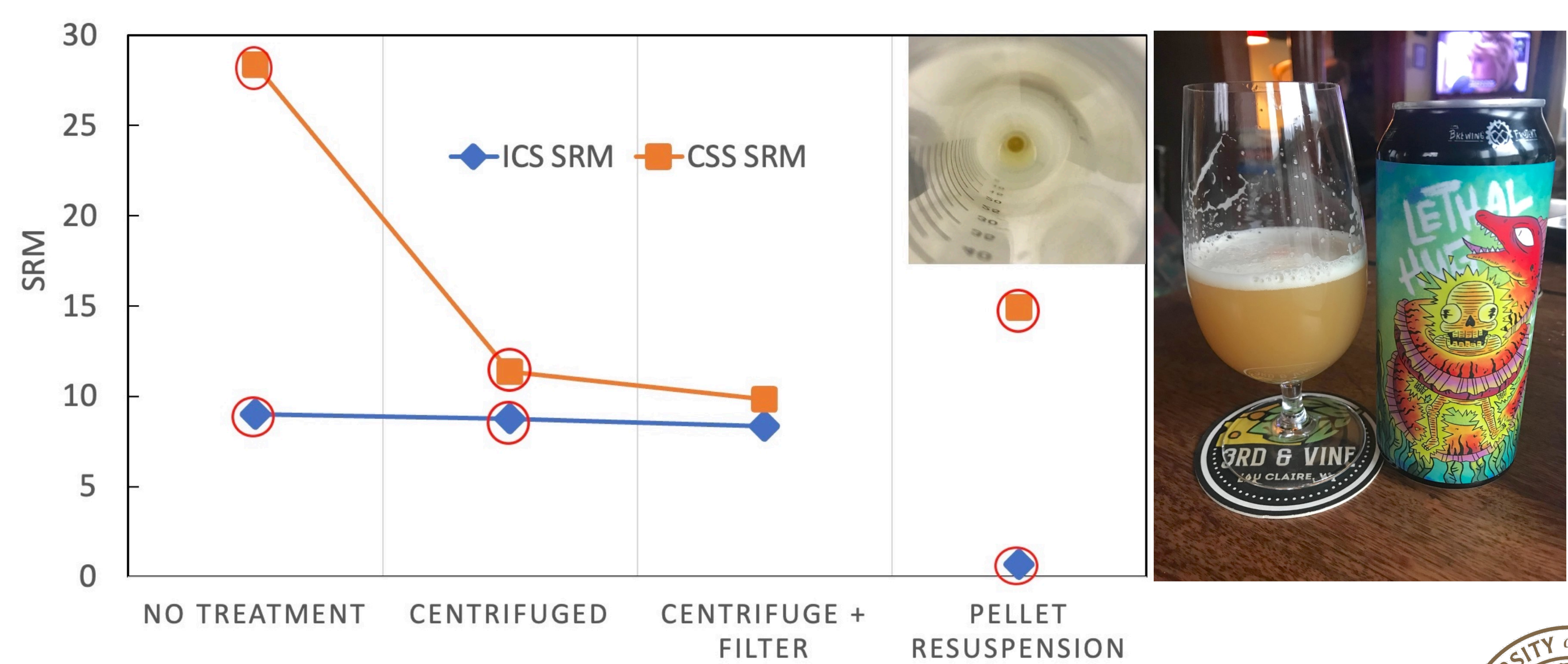
Results

Filtered and very clear beers showed strong agreement between the methods and Bland-Altman analysis confirms their equivalence, particularly for SRM < 25. Using the ICS alone, filtered beer versus unfiltered beer showed highly correlated values and narrow limits of agreement, successfully negating the effects of haze. Conversely, hazy beers showed poorer correlation by CSS with very broad limits of agreement. In filtered samples our results showed that on average SRM values were biased toward slightly higher values when using a CSS versus the ICS (ΔSRM < 1.0), suggesting unfilterable haze particles may be affecting CSS SRM by scattering. A centrifugation and filtration experiment on a particularly hazy IPA confirms that the scattering particles may also contribute color (**Figure 3**). The single-point SRM values commonly employed in QC/QA are an oversimplification of beer color in comparison to tristimulus values which define a point in 3-dimensional color space, drawn from data spanning the visible range. Beers with similar single-point SRM can have radically different perceived colors depending upon ingredients (*cf.* Filtered Beer 1 vs. 7). **Table 1** clearly shows that particle and colloidal scattering has a major impact on the tristimulus values measured using the CSS.

Table 1. Master Data Table with CIE L*a*b* tristimulus color rendering. The darker beers that were diluted are entered as their corrected SRM values and are indicated by their "X" values. The CIE L*a*b* color for the diluted beers were rendered from the diluted samples. For unfiltered hazies (1,13,15), the CIE L*a*b* colors are clearly not accurate.

Sample/X dilution		SRM ICS	SRM CSS	L*	a*	b*	CIE L*a*b Color	Turbidity (x=fail)	ΔSRM ICS Unfiltered minus filtered	ΔSRM CSS Unfiltered minus filtered	ΔE* ab Unfiltered minus filtered
1.Boom Boom Raspberry Fruit Sour Ale	Unfiltered	8.13	19.30	45.77	26.11	37.23		x	1.00	11.69	31.09
	Filtered	7.13	7.61	75.10	27.26	26.96					
2. Brockmann's Bitter English Special Bitter	Unfiltered	11.95	12.77	82.61	3.14	55.30		x	0.14	0.462	1.42
	Filtered	11.81	12.30	83.62	2.39	54.66		x			
3. Dagnabbit Scottish Ale/5X	Unfiltered	32.45	33.42	90.69	-1.49	35.33		x	1.84	2.14	1.75
	Filtered	30.61	31.28	91.41	-1.71	33.74					
4. Divine Dramedy Abbey Dubbel/5X	Unfiltered	36.77	30.52	90.89	-0.96	32.83			2.54	3.145	2.96
	Filtered	34.23	27.37	90.54	-0.71	35.76					
5. Greedslayer IPA	Unfiltered	5.78	6.29	89.61	-1.46	31.53		x	0.36	0.911	3.30
	Filtered	5.42	5.38	92.02	-1.81	29.30					
6. Heavens Helles Lager	Unfiltered	3.11	3.41	93.13	-1.45	17.71		x	0.17	0.625	2.92
	Filtered	2.95	2.78	95.55	-1.74	16.09					
7.High Fantasy BA Wild Ale	Unfiltered	6.96	7.30	86.34	1.23	34.56		x	0.27	0.682	2.38
	Filtered	6.69	6.62	88.31	0.72	33.33		x			
8. Idiom Amber Lager	Unfiltered	9.59	10.01	86.60	0.98	48.34			0.24	0.614	1.91
	Filtered	9.35	9.40	87.88	0.51	47.00					
9. Need for Tweed English Mild	Unfiltered	6.43	7.83	83.41	-1.25	33.77		x	0.15	1.44	6.84
	Filtered	6.27	6.39	90.22	-0.74	34.21					
10. Pils German Pilsner	Unfiltered	3.24	3.37	93.70	-1.84	17.86		x	0.15	0.5	2.24
	Filtered	3.09	2.87	95.59	-1.97	16.65					
11. Question Imperial Stout /10X	Unfiltered	114.45	131.31	77.21	6.72	54.96		x	0.53	0.08	1.04
	Filtered	113.92	131.23	78.21	6.65	55.23		x			
12.Terra Wet Hopped Pale Ale	Unfiltered	5.99	6.44	89.69	-1.53	32.54		x	0.25	0.416	1.41
	Filtered	5.74	6.02	90.70	-1.66	31.57		x			
13. DMT NEIPA	Unfiltered	8.60	23.87	47.61	10.28	47.12		x	0.79	15.12	43.40
	Filtered	7.81	8.75	89.51	-1.05	46.94					
14. Moniker Biere de Garde	Unfiltered	11.29	13.28	78.80	5.32	53.55		x	0.04	0.379	1.84
	Filtered	11.25	12.91	80.53	5.27	54.19		x			
15. Gibberish Rye Farmhouse	Unfiltered	6.77	17.53	45.69	2.39	27.07		x	0.09	10.35	45.43
	Filtered	6.68	7.18	89.74	-0.38	37.82					
								AVERAGE	0.57	3.24	10.00

Figure 3. Hazy head to head comparison. The effect of filtration and centrifugation on SRM of a juicy NEIPA. The orange squares represent values obtained by CSS and the blue diamonds by ICS. The ICS gave slightly reduced SRM from the initial state to the final state, approximately equal to the SRM amount lost to the pellet. Symbols with circles around them failed the turbidity criterion in the ASBC method. Inset: image of the pellet produced after 3000xg centrifugation of 30. mL of beer for 60 minutes.



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