University of Udine
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WORT AND BEER ANALYSIS

Correlation between CDR BeerLab® and official methods

Evaluation of correlation between the results obtained with EBC (European Brewery Convention) official methods and using CDR BeerLab®. The following parameters have been considered:

- ABV (Alcohol By Volume)
- pH
- Color
- FAN (Free Amino Nitrogen)
- Fermentable sugars
- Bitterness
- Lactic acid

PREPARATION OF WORT SAMPLES

28 beers have been analyzed (Table 1). Different brands and beer styles have been considered in order to cover a wide range of values for the tested parameters. Moreover, twelve worts have been produced with different mashing programs and different recipes (Table 2).For all worts the water:grist ratio was 3:1. Four different formulations have been used: 1) 100% barley malt (Pils); 2) 60% barley malt and 40% wheat malt (*Weizen*); 3) 90% barley malt and 10% caramel malt (Caramel); 4) 95% barley malt and 5% dark barley malt (*Chocolate*). A three-step mashing was carried out (58 °C, 65 °C and 72 °C), followed by mash out at 78 °C for 60 minutes. Mashing lasted until negative iodine test. Wort was then separated from husks through filtration and boiled for 60 minutes. Resulted wort was stored in 100 mL polyethylene flasks at 2°C before being analyzed.

To analyze Free Amino Nitrogen (FAN), six additional worts were produced (Table 3), using two different formulations: 1) 100% barley malt (Pils); 2) 50% barley malt and 50% wheat malt (*Weizen)*. Worts were produced using different concentrations of these formulation in order to obtain 6, 12 and 18 °Plato, therefore with different FAN content. A single step mashing was carried out (65 °C), followed by a 60 minutes boil. Collected wort was stored in 100 mL polyethylene flasks at 2°C before being analyzed.

Table 1 Analyzed beers

Beer	Sample Code
Craft 1	1
Craft 2	2
Craft 3	3
Craft 4	4
Craft 5	5
Craft 6	6
Craft 7	7
Craft 8	8
Craft 9	9
Craft 10	10
Craft 11	11
Commercial 1	12
Commercial 2	13
Commercial 3	14
Commercial 4	15
Commercial 5	16
Commercial 6	17
Commercial 7	18
Commercial 8	19
Commercial 9	20
Commercial 10	21
Commercial 11	22
Commercial 12	23
Commercial 13	24
Commercial 14	25
Commercial 15	26
Commercial 16	27
Commercial 17	28

Table 2 Worts produced to analyze fermentable sugars

Malt	Code	Mashing (°C)	Iodine test after 120 min	Iodine test after 135 min	Wort gravity (°Plato)
Pils	M1	58	positive	negative	12,0
Pils	M2	65	negative	-	12,0
Pils	M3	72	negative	-	11,5
Weizen	W1	58	negative	-	12,5
Weizen	W2	65	negative	-	11,0
Weizen	W3	72	negative	-	12,1
Caramel	C1	58	positive	negative	11,9
Caramel	C2	65	negative	-	12,2
Caramel	C3	72	negative	-	11,8
Chocolate	CH1	58	negative	-	12,5
Chocolate	CH2	65	negative	-	11,4
Chocolate	CH3	72	negative	-	12,0

Table 3 Worts produced for FAN analysis.

Malt	Code	Iodine test after 120 min	Wort gravity (°Plato)
Pils	P1	negative	6,3
Pils	P2	negative	12,2
Pils	P3	negative	17,8
Weizen	F1	negative	6,5
Weizen	F2	negative	12,1
Weizen	F3	negative	17,6

STATISTICAL ANALYSIS

To verify correlation among measurements, Pearson correlation coefficient (r) and p-value were used (program CoStat 6.204, CoHort Software, Monterey Ca, Usa). The correlation was considered statistically significant with a p-value < 0,05.

ABV (Alcohol By Volume)

ABV carried out with CDR BeerLab® were compared with ones from Alcolyzer Beer Analyzing System (Anton Paar) to investigate their correlation. Zanker and Benes (2004) previously highlighted that there was no statistically significant difference between results obtained with the EBC official method (EBC 9.2.1) and the Alcolyzer Beer Analyzing System.

Table 4 ABV values obtained with CDR BeerLab® and Alcolyzer Beer Analyzing System on 12 beer samples (n=3).

	CDR BeerLab®					NIR (Alcolyzer Beer Analyzing System)					
Code	ABV	ABV	ABV	Mean	Standard deviation	ABV	ABV	ABV	Mean	Standard deviation	p-value
1	6,29	6,23	6,20	6,24	0,05	6,47	6,42	6,49	6,46	0,04	< 0,05
2	5,48	5,57	5,49	5,51	0,05	5,63	5,67	5,56	5,62	0,06	
3	5,69	5,60	5,66	5,65	0,05	5,94	5,86	5,84	5,88	0,05	
4	4,59	4,51	4,45	4,52	0,07	4,58	4,48	4,51	4,52	0,05	
5	6,13	5,95	6,18	6,09	0,12	6,14	5,99	6,15	6,09	0,09	
6	6,00	5,99	5,90	5,96	0,06	6,02	5,94	5,92	5,96	0,05	
7	5,93	5,98	5,95	5,95	0,03	5,90	6,00	5,94	5,95	0,05	
8	5,12	5,29	5,26	5,22	0,09	5,10	5,20	5,16	5,15	0,05	
9	6,64	6,52	6,54	6,57	0,06	6,70	6,60	6,64	6,65	0,05	
12	4,61	4,55	4,54	4,57	0,04	4,40	4,44	4,52	4,45	0,06	
13	4,14	4,27	4,23	4,21	0,07	4,00	4,14	4,17	4,10	0,09	
14	2,22	2,15	2,37	2,25	0,11	2,09	2,10	2,25	2,15	0,09	

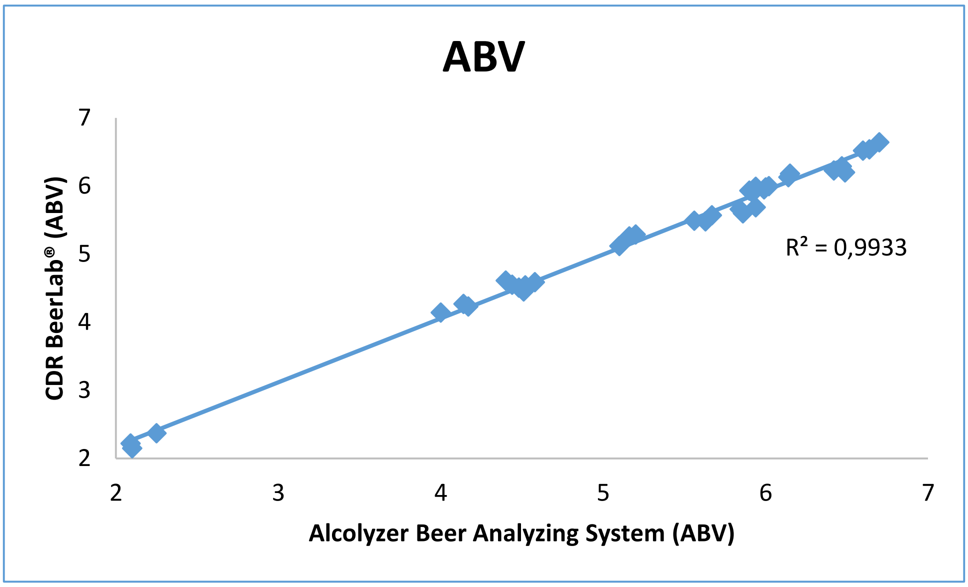

Figure 1 Correlation between ABV values measured with CDR BeerLab® and Alcolyzer Beer Analyzing System.

Comparison was carried out on 12 beer samples with an alcohol content between 2% and 7% ABV. Results from the two analytical instruments were highly correlated ($p < 0,05$ and $r= 0,9933$) and with low standard deviations (0,03÷0,12 with CDR BeerLab® and 0,04÷0,09 for Alcolyzer Beer Analyzing System) (Table 4, Figure 1).

pH

Selected beer samples were analyzed with CDR BeerLab® and official EBC method (EBC 9.35). Results are reported in Table 5. Correlation were considered statistically significant ($p < 0,05$ and $r = 0,8602$), and both methods showed low standard deviations (Table 5, Figure 2).

Table 5 pH values measured at 20 °C with CDR BeerLab® and EBC method 9.35 on 12 beer samples (n=2).

	CDR BeerLab®				EBC 9.35				
Code	pH	pH	Mean	Standard deviation	pH	pH	Mean	Standard deviation	p-value
12	4,5	4,6	4,6	0,1	4,4	4,5	4,5	0,1	
13	3,4	3,4	3,4	0,0	3,2	3,4	3,3	0,1	
14	4,5	4,6	4,6	0,1	4,6	4,6	4,6	0,0	
15	4,4	4,3	4,4	0,1	4,3	4,3	4,3	0,0	
16	4,3	4,2	4,3	0,1	4,2	4,1	4,2	0,1	
17	4,6	4,7	4,7	0,1	4,6	4,7	4,7	0,1	
18	4,5	4,5	4,5	0,0	4,4	4,3	4,4	0,1	< 0,05
19	4,6	4,7	4,7	0,1	4,5	4,6	4,6	0,1	
20	3,5	3,4	3,5	0,1	3,6	3,4	3,5	0,1	
21	4,4	4,4	4,4	0,0	4,3	4,3	4,3	0,0	
22	4,2	4,2	4,2	0,0	4,2	4,2	4,2	0,0	
23	4,6	4,6	4,6	0,0	4,5	4,7	4,1	0,1	

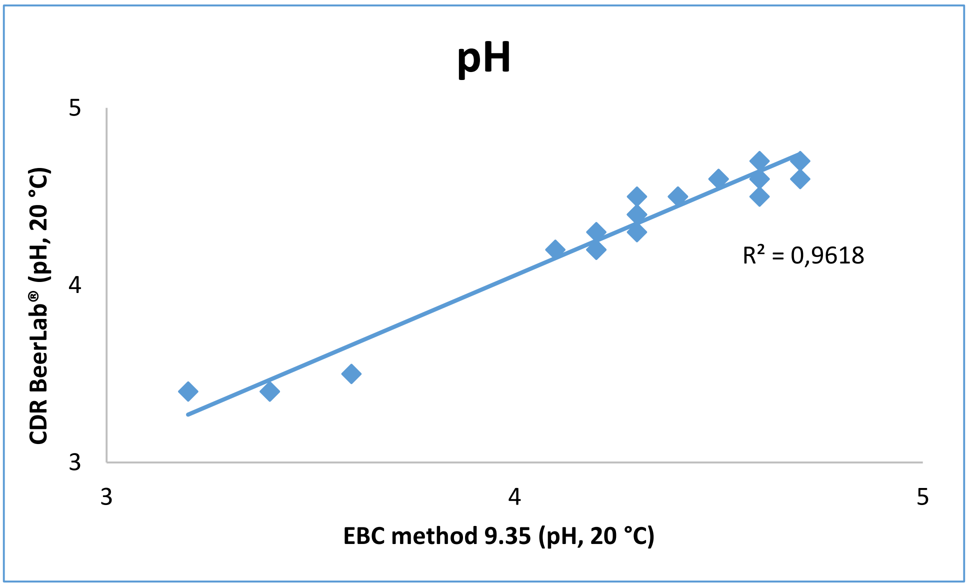

Figure 2 Correlation between pH values measured at 20 °C with CDR BeerLab® and EBC method 9.35.

COLOR

Selected beer samples were analyzed with CDR BeerLab® and official EBC method 9.6. Samples were selected in order to cover a wide spectrum of color (from 7 to 160 EBC). Results obtained from two methods showed strong correlation ($p < 0,05$ and $r = 0,9873$), and both methods provided mostly low standard deviations (Table 6, Figure 3). Darker beers measured with CDR BeerLab® showed lower standard deviations than with official method, probably due to a better linearity of the instrument in a wider absorbance range.

Table 6 EBC values obtained with CDR BeerLab® and EBC method 9.6 on 16 beer samples (n=2).

	CDR BeerLab®				EBC 9.6				
Code	EBC units	EBC units	Mean	Standard deviation	EBC units	EBC units	Mean	Standard deviation	p-value
1	12	12	12	0	13	13	13	0	
2	31	30	29	1	35	37	36	1	
3	25	27	26	1	28	35	32	5	
4	11	12	12	1	14	13	13	1	
5	110	110	110	0	127	145	135	13	
6	15	16	16	1	15	16	16	1	
7	7	8	8	1	9	8	9	1	
8	110	130	120	14	131	186	158	39	< 0,05
9	20	21	21	1	21	22	22	1	
10	10	9	10	1	10	10	10	0	
11	40	43	42	2	49	49	49	0	
12	8	9	9	1	10	10	10	0	
13	10	11	11	1	12	13	13	1	
14	3	4	4	1	6	7	7	1	
15	10	11	11	1	11	11	11	0	
16	42	45	44	2	50	52	51	1	

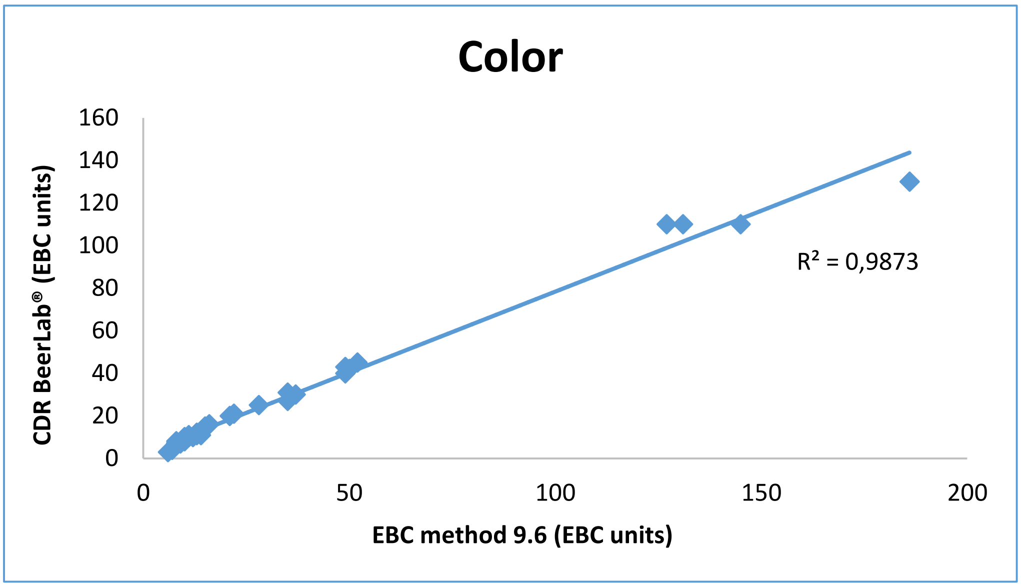

Figure 3 Correlation between color units measured with CDR BeerLab® and EBC method 9.6.

FAN (Free Amino Nitrogen)

The correlation between FAN analysis with CDR BeerLab® and official EBC methods 8.10 and 9.10 was also evaluated. Six beer samples and six wort samples were analyzed. Results were significantly correlated ($p < 0,05$; r = 0,9915 regarding wort and r = 0,9624 regarding beers) (Table 7, 8 and Figure 4, 5).

Table 7 FAN content (mg/L) measured with CDR BeerLab® and EBC method 8.10 on six wort samples (n=2).

	CDR BeerLab®				EBC 8.10				
Code	FAN mg/L	FAN mg/L	Mean	Standard deviation	FAN mg/L	FAN mg/L	Mean	Standard deviation	p-value
P1	99	93	96	4	104	91	98	10	< 0,05
P2	189	187	188	1	168	173	171	4	
P3	270	275	273	4	245	252	249	5	
F1	40	41	41	1	34	38	36	3	
F2	88	89	89	1	74	74	74	0	
F3	118	128	123	7	118	111	115	5	

Table 8 FAN content (mg/L) measured with CDR BeerLab® and EBC method 9.10 on six beers (n=2).

	CDR BeerLab®				EBC 9.10				
Code	FAN mg/L	FAN mg/L	Mean	Standard deviation	FAN mg/L	FAN mg/L	Mean	Standard deviation	p-value
1	63	69	66	4	58	53	56	4	< 0,05
2	52	59	56	5	44	41	43	2	
3	36	29	33	5	25	29	27	3	
12	173	155	164	13	115	116	115	1	
13	43	40	42	2	34	32	33	1	
14	80	79	80	1	72	65	69	5	

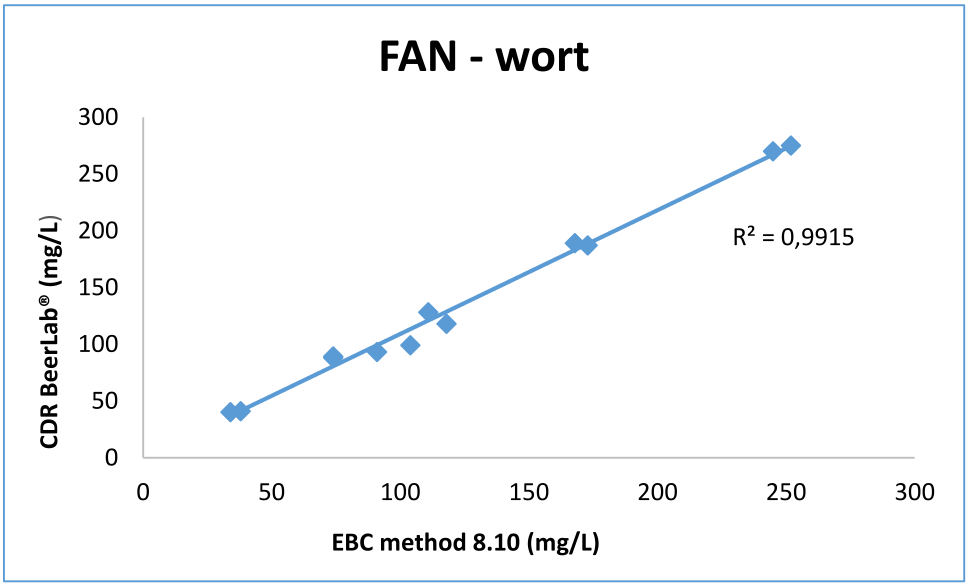

Figure 4 Correlation between FAN content in worts measured with CDR BeerLab® and EBC method 8.10.

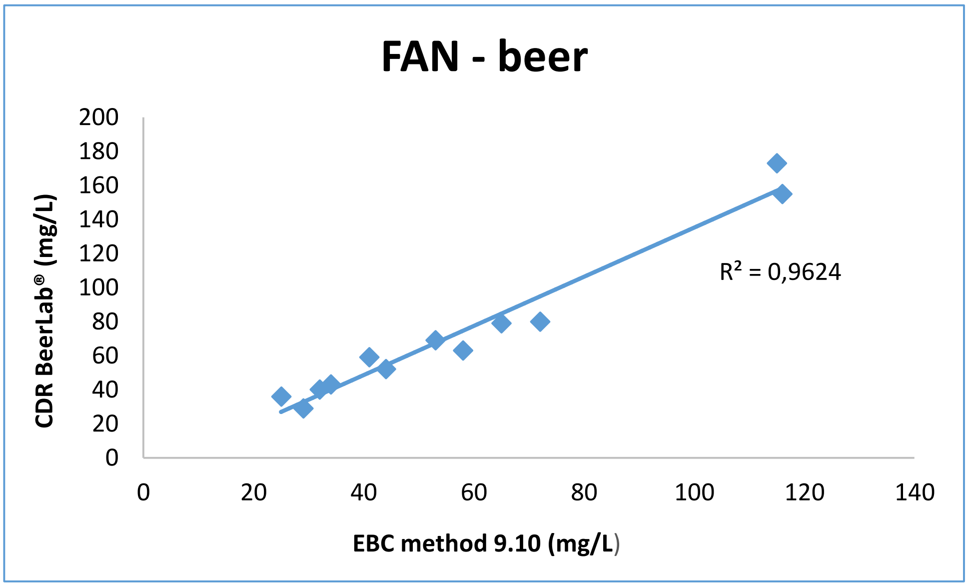

Figure 5 Correlation between FAN content in worts measured with CDR BeerLab® and EBC method 9.10.

FERMENTABLE SUGARS

CDR BeerLab® was compared to EBC method 8.7. Glucose, fructose and maltose in 12 worts were analysed, and results expressed as sum of their concentrations (Table 9).

Table 9 Fermentable sugars (glucose, fructose and maltose) content in 12 different worts, measured with CDR BeerLab® and EBC method 8.7 (n=2).

CDR BeerLab®					EBC 8.7				
Code	**g/L**	**g/L**	**Mean**	**Standard deviation**	**g/L**	**g/L**	**Mean**	**Standard deviation**	**p-value**
M1	79,8	77,4	78,6	1,7	86,1	82,9	84,5	2,3	< 0,05
M2	72,9	71,1	72,0	1,3	86,3	90,5	88,4	3,0	
M3	75,8	76,8	76,3	0,7	58,2	61,5	59,9	2,3	
C1	93,4	94,4	93,9	0,7	96,3	97,5	96,9	0,8	
C2	72,5	65,1	68,8	5,2	76,9	80,2	78,6	2,3	
C3	68,2	67,8	68,0	0,3	70,7	72,8	71,8	1,5	
W1	72,3	72,3	72,3	0,0	76,1	72,3	74,2	2,7	
W2	80,8	77,1	79,0	2,6	86,8	85,6	86,2	0,8	
W3	67,0	65,8	66,4	0,8	62,8	60,3	61,6	1,8	
CH1	71,4	70,6	71,0	0,6	84,9	82,4	83,7	1,8	
CH2	69,8	71,4	70,6	1,1	81,1	79,5	80,3	1,1	
CH3	174,2	169,3	171,8	3,5	128,9	127,1	128,0	1,3	

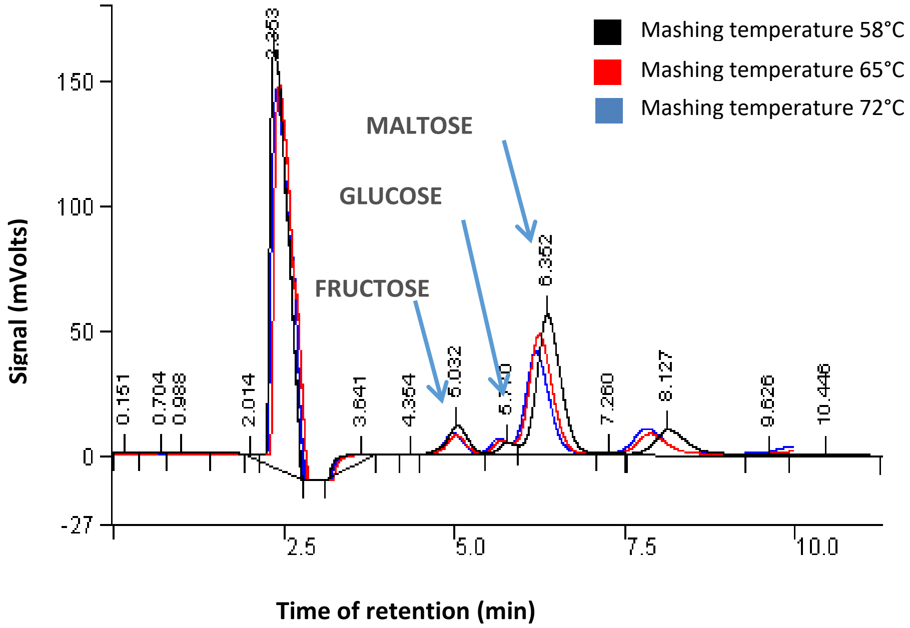

Figure 6 HPLC analysis (EBD method 8.7) of fermentable sugars in worts produced with 90% of barley malt and 10% of Caramel malt, at three different mashing temperatures.

Figure 6 highlights maltose is the predominant sugar in wort, regardless of mashing temperature. Generally lower mashing temperatures (near 60 °C) promote the beta-amylase activity, which hydrolyze the starch chain at the not-reducing ends, producing more maltose-rich wort. Higher mashing temperature promotes alfa-amylase, which produces more dextrinic wort (Briggs et al., 2004).

Tested wort showed fermentable sugar content between 59,9 and 128,0 g/L. Results of CDR BeerLab® and EBC method 8.7 analysis were statistically correlated ($p < 0,05$) (Table 9). Furthermore, the HPLC analysis does not include maltotriose determination, which is instead carried out by CDR BeerLab®.

BITTERNESS

For this parameter the CDR BeerLab® results were compared to EBC method 9.8.

Table 10 Bitterness values (IBU) resulting from CDR BeerLab® analysis and EBC method 9.8 on 12 different beers (n=2).

CDR BeerLab®					EBC 9.8				
Code	IBU	IBU	Mean	Standard deviation	IBU	IBU	Mean	Standard deviation	p-value
1	40	41	41	1	39	38	39	1	< 0,05
2	61	63	62	1	58	58	58	0	
3	14	13	14	0	12	13	13	1	
4	11	12	12	0	10	12	11	1	
9	18	16	17	1	17	16	17	1	
13	36	36	36	0	34	36	35	1	
15	22	24	24	1	22	21	22	1	
24	17	18	18	1	13	15	14	1	
25	19	19	19	0	16	16	16	0	
26	33	34	34	1	34	34	34	0	
27	52	53	53	1	50	50	50	0	
28	28	30	29	1	25	26	26	1	

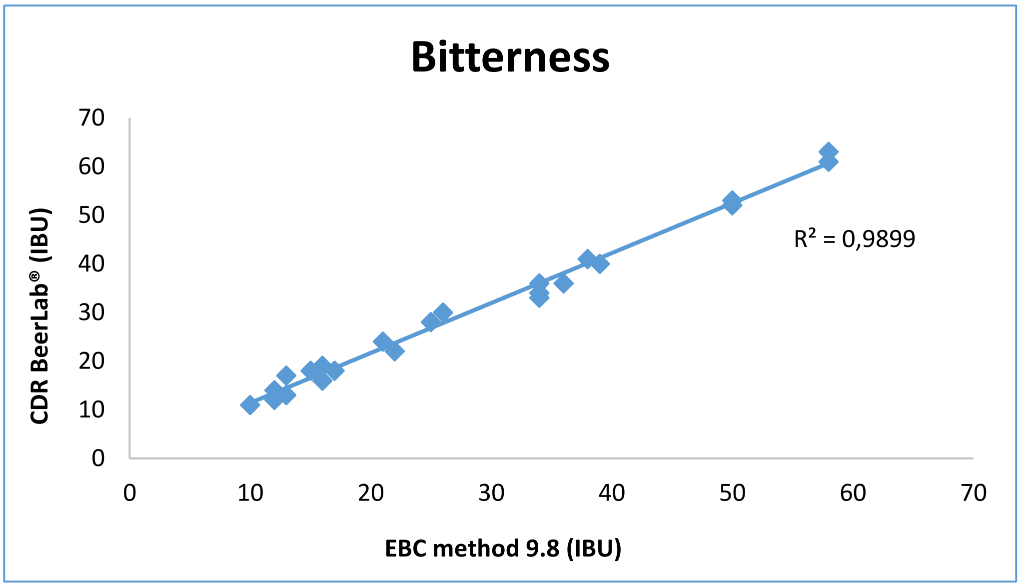

Figure 8 Correlation between bitterness evaluated with CDR BeerLab® and EBC method 9.8.

Commercial beers present bitterness values between 10 and 50 IBU (Briggs et al., 2004). Data from CDR BeerLab® and EBC method 9.8 showed a good correlation ($p < 0,05$ and $r = 0,9899$) and good precision.

LACTIC ACID

Total lactic acid content (sum of D-lactic acid and L-lactic acid, expressed as mg/L) was measured with CDR BeerLab® and enzymatic kit from Megazyme (EBC method 9.34) (Table 11).

Table 11 Total lactic acid content (mg/L) of 12 beers, measured with CDR BeerLab® and Megazyme kit (EBC method 9.34) (n=2).

	CDR BeerLab®				EBC 9.34				
Code	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	Mean	Standard deviation	p-value
1	136	138	137	1	136	135	136	1	
2	138	129	134	6	131	134	132	2	
12	137	128	133	6	131	133	132	1	
14	152	148	150	3	158	160	159	1	
15	75	69	72	4	80	86	83	4	
16	62	68	65	4	59	68	63	6	> 0,05
18	150	149	150	1	140	146	145	3	
19	179	168	174	8	170	163	166	5	
20	72	78	75	4	71	74	73	2	
21	57	65	61	6	52	67	60	11	
22	83	94	89	8	92	101	97	7	
23	24	25	25	1	39	39	39	0	

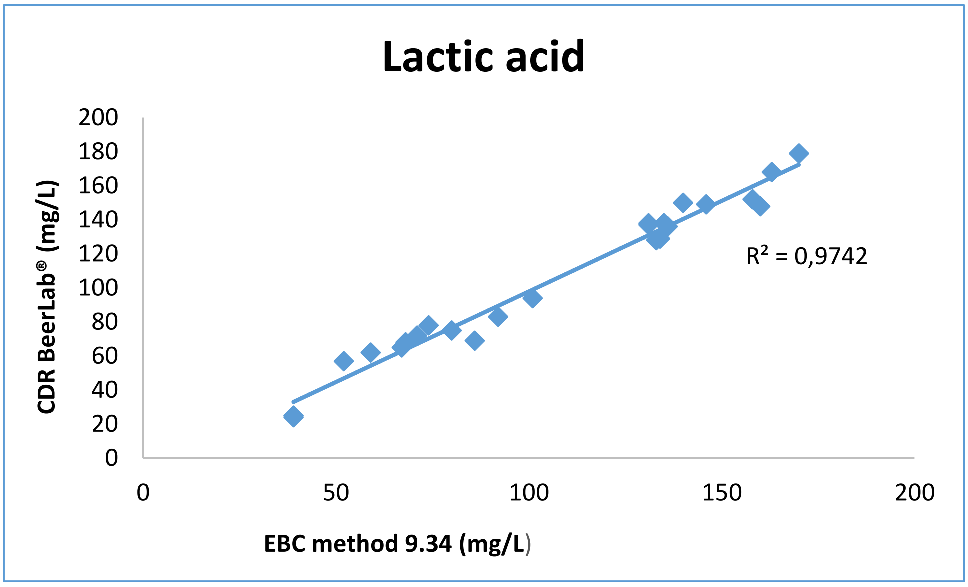

Figure 9 Correlation between total lactic acid content with CDR BeerLab® and EBC method 9.34.

Lactic acid content of the 12 analyzed beers was within the CDR BeerLab® recommended range. The correlation was statistically significant ($p < 0,05$ and $r = 0,9742$) and both methods showed low standard deviations (Table 11 and Figure 9).

WATER ANALYSIS

Correlation between CDR BeerLab® and official methods

The following compounds were analyzed with CDR BeerLab® and official methods to evaluate the correlation between two procedures :

- Calcium
- Magnesium
- Potassium
- Chlorides
- Sulphates
- Bicarbonates

WATER SAMPLES

Drinking water is normally classified by its level of total dissolved solids expressed as ppm (mg/L), which can normally vary between 50 to 1500 mg/L. Nineteen different waters (commercial and tap water) were analyzed in order to cover a wide range of water parameters (Table 12).

Table 12 Analyzed waters.

Water	Sample code
Donat	1
Lauretana	2
Goccia di Carnia	3
Fonte Essenziale	4
Ferrarelle	5
San Pellegrino	6
Acqua Panna	7
San Benedetto	8
Lete	9
Sangemini	10
Sant’Anna	11
Radenska	12
Vera Nestlè	13
Norda	14
Eva	15
Pordenone (tap water)	16
Maniago (tap water)	17
Majano (tap water)	18
DI4A department (tap water)	19

STATISTICAL ANALYSIS

To evaluate the correlation between CDR BeerLab® and official methods, Pearson correlation coefficient (r) and p-value were used (program CoStat 6.204, CoHort Software, Monterey Ca, Usa). Correlation was considered statistically significant with a p-value < 0,05.

CALCIUM

For this parameter CDR BeerLab® results were compared to ones obtained with official spectrophotometric method using Merck kit reagents (Spectroquant® Calcium Test).

Table 13 Calcium content (mg/L) of 6 different water samples, measured with CDR BeerLab® and spectrophotometric analysis (n=3).

	CDR BeerLab®					Spectrophotometric method					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
1	318,4	329,3	346,6	331,4	14,2	370,2	383,4	386,1	379,9	8,5	< 0,05
3	23,8	24,3	23,6	23,9	0,4	17,3	26,4	20,9	21,5	4,6	
8	55,8	54,8	52,4	54,3	1,7	41,1	48,0	61,9	50,3	10,6	
9	316,2	308,6	322,5	315,8	7,0	320,4	324,2	325,3	323,3	2,6	
17	59,9	58,3	59,1	59,1	0,8	61,8	76,4	69,9	69,4	7,3	
19	55,4	55,2	58,5	56,4	1,9	48,4	58,2	68,5	58,4	10,1	

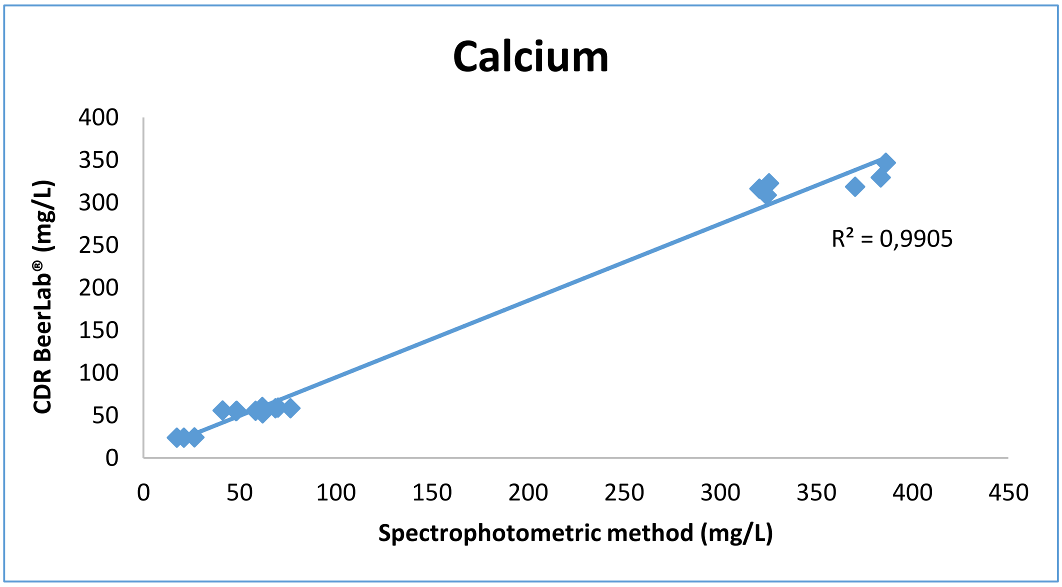

Figure 10 Correlation between calcium content in waters with CDR BeerLab® and spectrophotometric method.

The analysis was carried out on six different waters, chosen to cover a range of calcium content between 20 and 300 mg/L (considering that calcium in beer should not exceed 90 mg/L, according to Eumann and Schildbach, 2012). The two methods showed correlated results ($p < 0,05$ and $r = 0,9905$) and low standard deviations (Table 13 and Figure 10).

MAGNESIUM

For this cation CDR BeerLab® results were compared to ones obtained with official spectrophotometric method using Merck kit reagents (Spectroquant® Magnesium Test).

Table 14 Magnesium content (mg/L) of 6 different water samples, measured with CDR BeerLab® and spectrophotometric analysis (n=3).

	CDR BeerLab®					Spectrophotometric method					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
3	4,4	4,2	4,3	4,3	0,1	3,9	4,6	4,0	4,2	0,4	< 0,05
5	24,0	28,2	26,7	26,3	2,1	22,6	25,1	24,2	24,0	1,3	
10	16,9	17,9	17,2	17,3	0,5	14,4	15,8	15,9	15,4	0,8	
13	13,9	12,9	14,1	13,6	0,6	12,2	12,5	13,2	12,6	0,5	
15	4,5	4,1	3,3	4,0	0,6	4,1	5,1	4,1	4,4	0,6	
16	22,7	22,2	22,0	22,2	0,4	19,8	20,2	20,5	20,2	0,4	

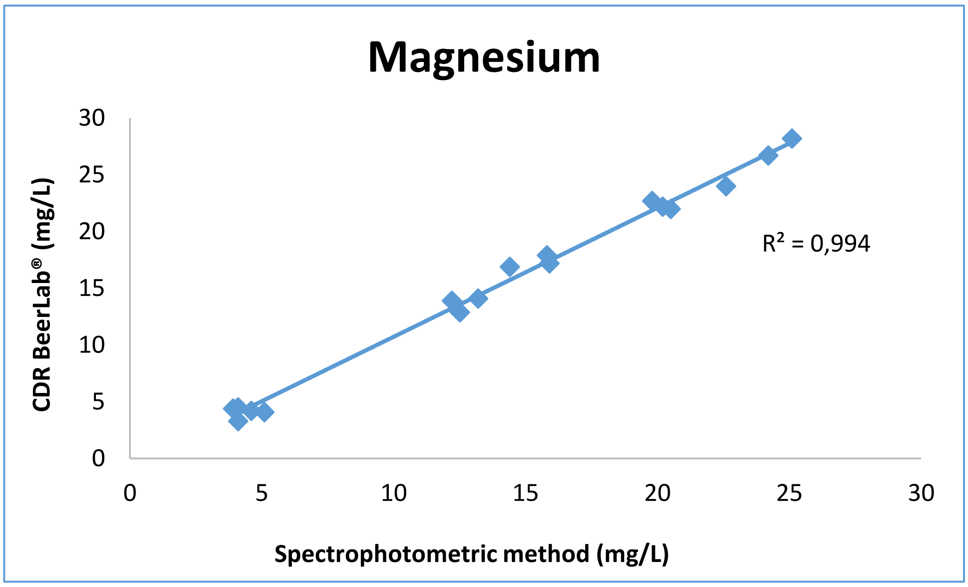

Figure 11 Correlation between magnesium content in water with CDR BeerLab® and spectrophotometric method.

The analysis was carried out on 6 different waters, chosen to cover a range of magnesium content between 4 and 30 mg/L. The two methods showed correlated results ($p < 0,05$ and $r = 0,994$) and low standard deviations (Table 14 and Figure 11).

POTASSIUM

For this cation CDR BeerLab® results were compared to ones obtained with official spectrophotometric method using Merck kit reagents (Spectroquant® Potassium Test).

Table 15 Potassium content (mg/L) of six different water samples, measured with CDR BeerLab® and spectrophotometric analysis (n=3).

CDR BeerLab®						Spectrophotometric method					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
1	<50	<50	<50	/	/	<50	<50	<50	/	/	
2	<50	<50	<50	/	/	<50	<50	<50	/	/	
3	<50	<50	<50	/	/	<50	<50	<50	/	/	
5	58,0	53,0	57,0	56,0	2,6	44,3	47,4	45,3	45,7	1,6	/
17	<50	<50	<50	/	/	<50	<50	<50	/	/	
18	<50	<50	<50	/	/	<50	<50	<50	/	/	

Analysis was carried out on six different waters. Only potassium content of sample 5 was above the detection limit (DL) for both methods (Table 15). Therefore, five different standard solutions were prepared: 10, 20, 30, 60 and 80 mg of potassium chloride (dried for 1 h at 110 °C) were weighted and dissolved in five different flasks with 100 mL of distilled water. The five different solutions final concentration of potassium chloride were: 100 mg/L (Sol. 1), 200 mg/L (Sol. 2), 300 mg/L (Sol. 3), 600 mg/L (Sol. 4) and 800 mg/L (Sol. 5). These samples and again the sample 5 (Ferrarelle water) were analyzed with CDR BeerLab® and official spectrophotometric method. Data are reported in Table 16. Depending on specific needs, it is possible to customize CDR BeerLab® and optimize its detection range.

Table 16 Potassium content (mg/L) of 6 different water samples (5 potassium chloride solutions and one commercial water), measured with CDR BeerLab® and spectrophotometric analysis (n=3).

CDR BeerLab®						Spectrophotometric method					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
Sol. 1	56,4	58,9	53,2	56,2	2,9	53,1	48,4	55,8	52,4	3,7	< 0,05
Sol. 2	98,7	94,2	91,0	94,6	3,9	104,8	102,9	106,9	104,9	2,0	
Sol. 3	141,4	145,8	149,4	145,5	4,0	151,4	160,8	159,6	157,3	5,1	
Sol. 4	318,4	311,1	317,3	315,6	3,9	312,7	319,6	311,4	314,6	4,4	
Sol. 5	421,1	425,7	419,3	422,0	3,3	422,7	416,8	418,9	419,5	3,0	
5	58,0	53,0	57,0	56,0	2,6	44,3	47,4	45,3	45,7	1,6	

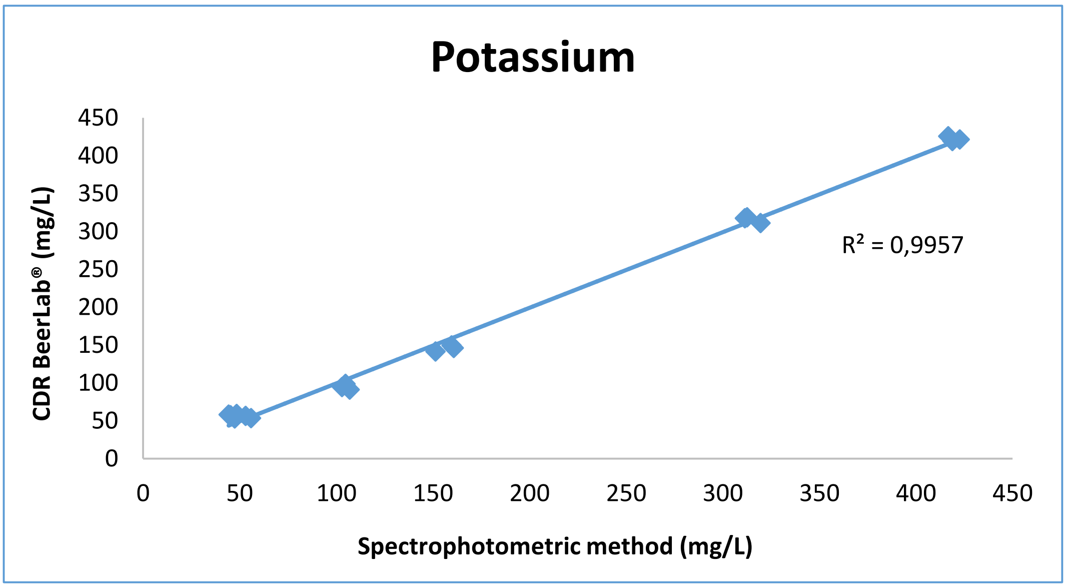

Figure 12 Correlation between potassium content in water with CDR BeerLab® and spectrophotometric method.

The measurements of two methods were statistically correlated ($p < 0,05$ and $r = 0,9957$) and showed low standard deviations (Table 16 and Figure 12).

CHLORIDES

As for the potassium analysis, the chlorides content of tested waters was below detection limits (100 mg/L) of CDR BeerLab® (only sample 1 resulted above the DL). Data are not reported. Therefore, five solutions of potassium chloride were prepared as above mentioned (page 24), and then analyzed with CDR BeerLab® and official method (argentometric titration, Belli et al., 2003). Data are reported in Table 17.

Table 17 Chlorides content (mg/L) of 6 different water samples (5 potassium chloride solutions and one commercial water), measured with CDR BeerLab® and argentometric titration (n=3).

	CDR BeerLab®					Argentometric titration					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
Sol. 1	61,3	57,5	56,1	58,3	2,7	45,8	44,3	52,6	47,6	4,4	< 0,05
Sol. 2	101,3	111,4	99,7	104,1	6,3	92,4	98,5	94,3	95,1	3,1	
Sol. 3	119,4	127,2	129,5	125,4	5,3	137,8	148,5	141,7	142,7	5,4	
Sol. 4	251,2	250,4	253,2	251,6	1,4	282,2	289,2	284,4	285,3	3,6	
Sol. 5	325,2	312,3	308,7	315,4	8,7	375,3	384,2	381,6	380,4	4,6	
1	76,5	69,7	82,1	76,1	6,2	71,4	75,3	78,2	75,0	3,4	

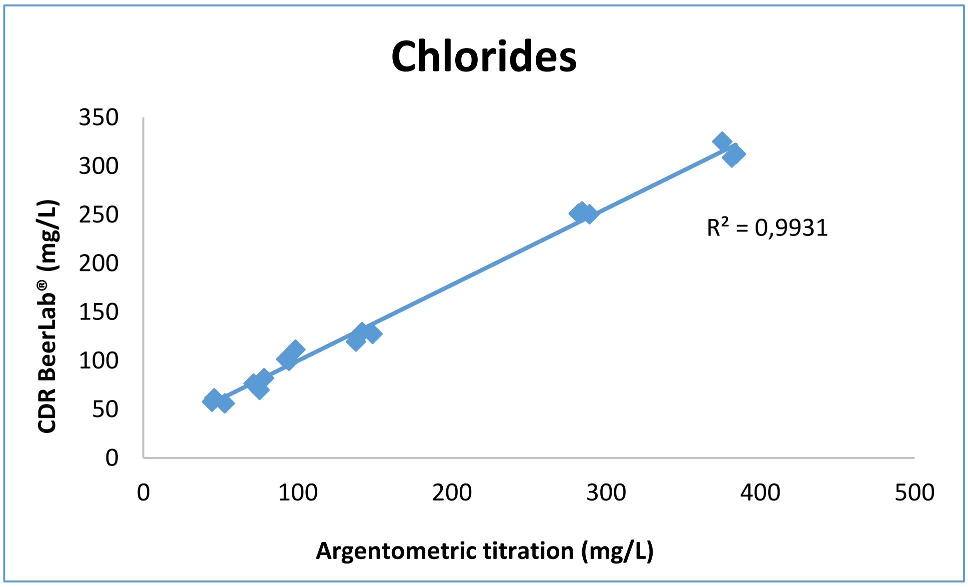

Figure 13 Correlation between chlorides content in water with CDR BeerLab®r and argentometric titration.

The measurements of two methods were statistically correlated ($p < 0,05$ and $r = 0,9931$) and showed low standard deviations (Table 17 and Figure 13).

SULPHATES

Sulphates content was measured with CDR BeerLab®, and results compared with official method (turbidimetry, Belli et al., 2003). To determine the sulphates content with the turbidimetry, first a calibration curve (Figure 14) was obtained following the official method (Belli et al., 2003).

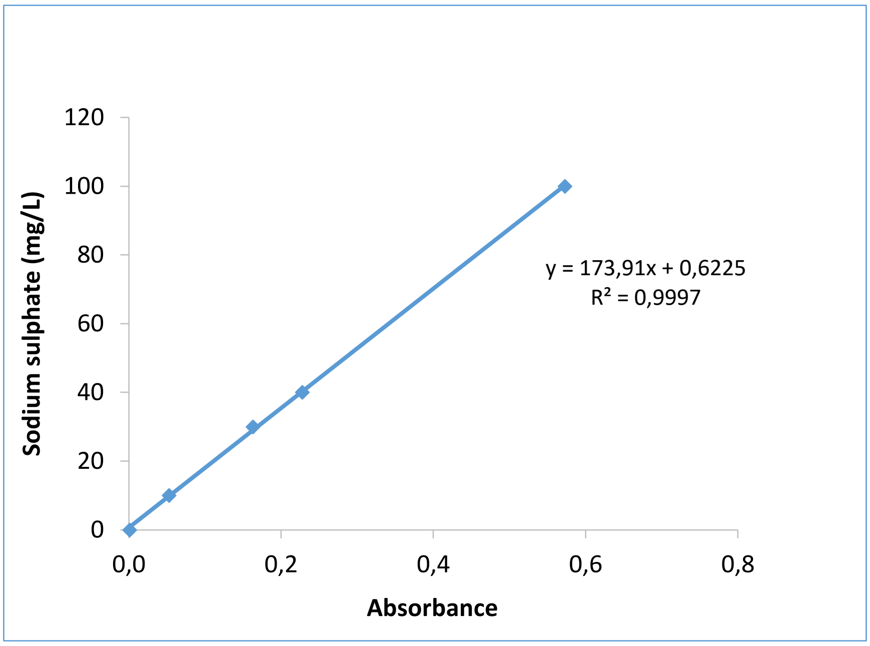

Figure 14 Calibration curve for the turbidimetric analysis of sulphates.

Table 18 Sulphates content (mg/L) of 6 different water samples, measured with CDR BeerLab® and turbidimetry (n=3).

	CDR BeerLab®					Turbidimetry					
Code	**mg/L**	**mg/L**	**mg/L**	**Mean**	**Standard deviation**	**mg/L**	**mg/L**	**mg/L**	**Mean**	**Standard deviation**	**p-value**
4	1.600,4	1.602,2	1.601,3	1601,3	0,9	1.620,5	1.623,4	1.625,6	1623,2	2,6	
6	415,5	412,8	409,6	412,6	3,0	449,0	452,2	450,1	450,4	1,6	
7	13,5	14,0	13,5	13,7	0,3	20,6	21,2	20,9	20,9	0,3	< 0,05
10	60,0	54,0	57,1	57,0	3,0	43,3	42,8	42,6	42,9	0,4	
12	115,0	108,1	121,0	114,7	6,5	74,3	74,3	74,3	74,3	0,0	
18	65,1	62,0	63,1	63,4	1,6	62,6	61,7	62,0	62,1	0,4	

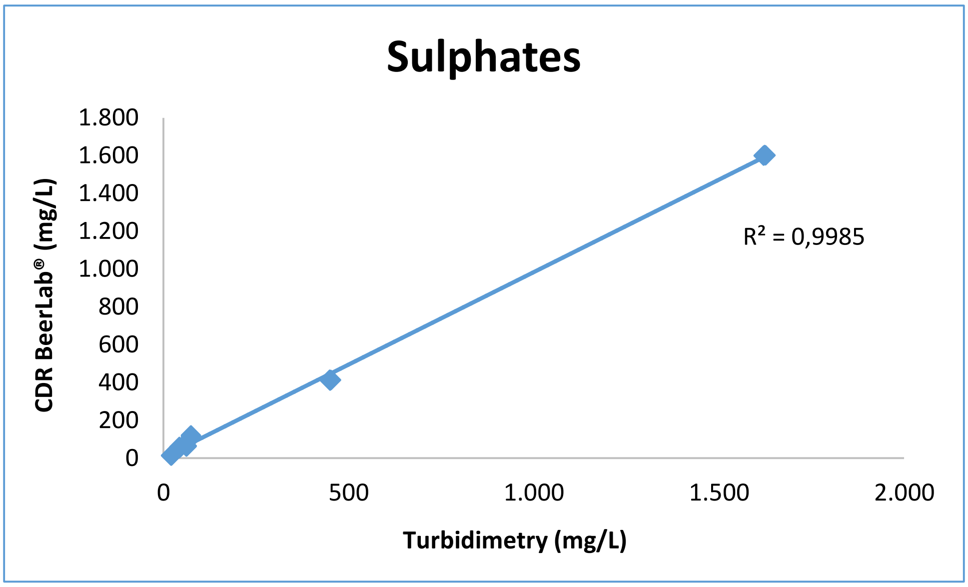

Figure 15 Correlation between sulphates content in water with CDR BeerLab® and turbidimetry.

Samples 4 and 6, with high sulphate content, required a 1:10 dilution with distilled water.

The measurements of two methods were statistically correlated ($p < 0,05$ and $r = 0,9985$) and showed low standard deviations (Table 18 and Figure 15).

BICARBONATES

For this anion CDR BeerLab® results were compared to ones obtained with official complexometric titration method (Belli et al., 2003) on six different water samples.

Table 19 Bicarbonates content (mg/L) of 6 different water samples, measured with CDR BeerLab® and complexometric titration (n=3).

	CDR BeerLab®					Complexometric titration					
Code	mg/L	mg/L	mg/L	Mean	Standard deviation	mg/L	mg/L	mg/L	Mean	Standard deviation	p-value
11	37,0	33,0	43,0	37,7	5,0	32,5	22,0	27,3	27,3	5,3	< 0,05
13	139,0	137,0	136,0	137,3	1,5	135,1	134,1	136,2	135,1	1,1	
14	130,0	144,0	144,0	139,3	8,1	136,1	138,0	136,5	136,9	1,0	
16	206,0	213,0	209,0	209,3	3,5	205,2	218,2	213,1	212,2	6,6	
17	143,0	142,0	144,0	143,0	1,0	135,1	134,7	135,4	135,1	0,4	
18	199,2	210,0	209,0	206,1	6,0	197,2	220,7	218,7	212,2	13,0	

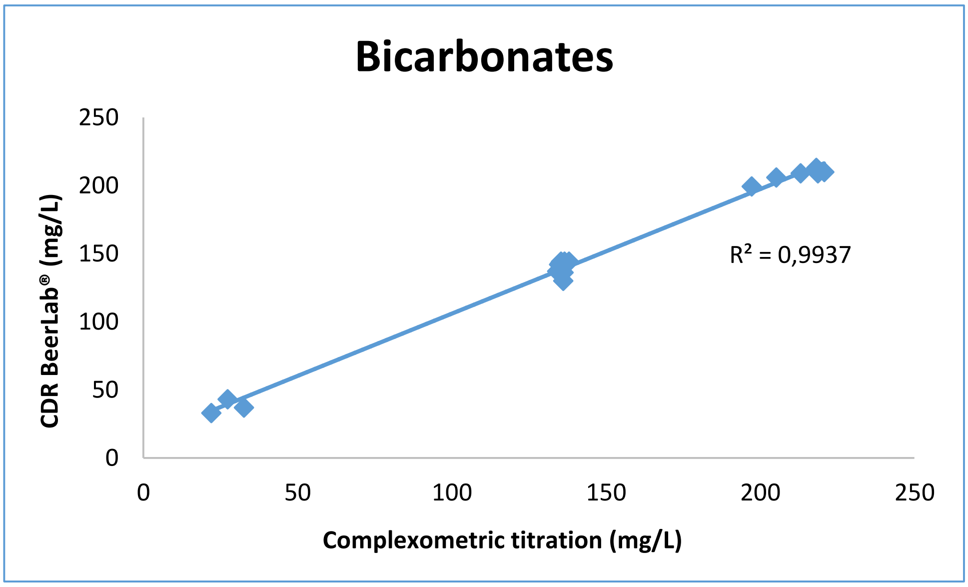

Figure 16 Correlation between bicarbonates content in water with CDR BeerLab® and complexometric titration.

The measurements of two methods were statistically correlated ($p < 0,05$ and $r = 0,9937$) and showed low standard deviations (Table 19 and Figure 16).

FINAL CONSIDERATIONS

All the evaluated analysis (ABV, pH, color, FAN, fermentable sugars, bitterness, lactic acid, calcium, magnesium, potassium, chlorides, sulphates and bicarbonates) carried out with CDR BeerLab® were statistically correlated with official methods.

For all tested compounds, the CDR BeerLab® analysis requires as pretreatment only a degassing of samples (beer or water) and no calibration curve is needed. Moreover, the detailed instructions present on the screen easily guide the operator through the whole analytic process making the CDR BeerLab® a friendly user instrument. Cuvette, vials, reagents, etc. are all provided by manufacturer.

However, the analysis procedure software could be improved with more flexibility. Indeed, in case of error operator during the procedure (for example an incorrect reading of a cuvette), it is not possible to repeat a single step but only to start again the whole test. Furthermore, lowering the detection limits for potassium and chlorides determination would help, since most water samples were below the DL of the instrument.

With CDR BeerLab® equipment the required sample and reagents quantity is highly reduced compared to official methods (especially regarding bitterness or sulphates analysis). Finally CDR BeerLab® instrument can reduces analytical costs, enhance the operational safety reducing health risks for the operator and, being friendly user, suits very well with a craft brewery needs.

In further investigations new analytical parameters as well as additional software functionalities of the instrument CDR BeerLab® will be tested.

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