



European Brewery Convention

EBC PRESS REPORT

Determination of the Accuracy, Repeatability and Reproducibility of a Method for the Determination of Alcohol in Beer by Near Infra Red Spectroscopy

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on behalf of the Analysis Committee of the European Brewery Convention

A method for the determination of alcohol in beer by Near Infra Red Spectroscopy was collaboratively tested by the Analysis Committee of the European Brewery Convention according to ISO Standard 5725 in order to determine its suitability for publication in *Analytica-EBC*. Accuracy, repeatability $r(95)$ and reproducibility $R(95)$ values are presented.

The NIR method was found to have better within and between laboratory precision than the reference distillation method for the determination of alcohol.

Repeatability $r(95)$ was found to be independent of the mean value and was 0,032% V/V over the range 2,18 to 8,77% V/V alcohol.

Reproducibility $R(95)$ was found to be dependent on the mean and is $0,017m + 0,006\%$ V/V over the range of alcohol tested.

The NIR method has acceptable accuracy when compared to the distillation method.

The method is recommended for inclusion in *Analytica-EBC*.

INTRODUCTION

The Analysis Committee of the European Brewery Convention decided to carry out an inter laboratory collaborative trial to determine the accuracy and precision of a method for the determination of alcohol in beer by Near Infra Red Spectroscopy (NIR).

EXPERIMENTAL

The organisation of the trial and the statistical treatment of the data was carried out according to the procedure given in the International Standard ISO 5725-2.

Duplicate samples of five commercially produced and packaged beers, each from a single homogeneous batch,

covering the approximate alcohol range 2,0–9,0% v/v were sent to 24 participating laboratories.

Participants were asked to determine the alcohol content of each sample by NIR using the draft EBC method (appended), using their own choice of NIR instrument. Participants were asked to complete a short questionnaire that requested details of the type of instrument used (make and model) and their calibration procedure.

Four sets of the same samples were sent to a further 4 “reference” laboratories for analysis of alcohol by the distillation procedure so that the accuracy of the NIR method could be determined.

RESULTS AND DISCUSSION

The basic data received from the participating laboratories are shown in Table I.

Analysis of data

The statistical evaluation included the following steps:

1. Analysis of the homogeneity of the within laboratory variance
2. Analysis of outliers among the within laboratory means.
3. Calculation of repeatability $r(95)$ and reproducibility $R(95)$
4. Determination of the dependence of the precision on the mean

Outliers and stragglers – see Table II.

Grubb’s test detected an outlier for sample A – this laboratory’s result was rejected from the calculation of the precision data for sample A.

Cochran's test detected two outliers for sample B and both these were rejected from the overall calculation of precision.

One laboratory was detected as an outlier for Sample E by Cochran's test and two further outliers were detected for this sample by Grubb's test – all these 3 laboratories were rejected as outliers for sample E.

Grubbs test detected a straggler for sample D, but the results from this laboratory were retained.

Precision

The results for the calculation of precision data are shown in Table III.

Table I. Basic data results abv % v/v

Participant ID No.	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2	Instrument used
Ref 1	2,17	2,17	4,88	4,87	3,73	3,73	7,46	7,48	8,74	8,72	Distillation
Ref 2	2,14		4,902		3,728		7,392		8,582		Distillation
Ref 3	2,166		4,906		3,767		7,494		8,735		Distillation
Ref 4	2,144	2,165	4,801	4,801	3,672	3,736	7,288	7,276	8,538	8,562	Distillation
1	2,15	2,16	4,9	4,89	3,74	3,74	7,5	7,48	8,63	8,78	Not provided
2	2,21	2,2	4,9	4,9	3,73	3,74	7,48	7,47	8,83	8,84	Foss Infratec 1256
3	2,18	2,18	4,89	4,89	3,71	3,72	7,48	7,47	8,85	8,86	Foss Infratec 1256
4	2,2	2,18	4,9	4,9	3,72	3,72	7,46	7,45	8,82	8,83	Foss Infratec 1256
5	2,22	2,21	4,92	4,91	3,72	3,73	7,47	7,46	8,82	8,83	Foss Infratec 1256
6	2,22	2,19	4,9	4,89	3,76	3,76	7,44	7,47	8,76	8,79	Paar Alcoolyzer
7	2,21	2,2	4,91	4,92	3,77	3,77	7,48	7,48	8,78	8,78	Paar Alcoolyzer
8	2,16	2,17	4,9	4,89	3,73	3,74	7,46	7,46	8,75	8,74	Paar Alcoolyzer
9	2,16	2,13	4,89	4,89	3,74	3,73	7,47	7,47	8,77	8,76	Paar Alcoolyzer
10	2,19	2,21	4,91	4,91	3,74	3,74	7,49	7,48	8,8	8,79	Paar Alcoolyzer
11	2,14	2,15	4,85	4,86	3,71	3,71	7,42	7,43	8,7	8,73	Paar Alcoolyzer
12	2,18	2,2	4,91	4,91	3,76	3,75	7,43	7,45	8,74	8,72	Paar Alcoolyzer
13	2,18	2,17	4,82	4,89	3,77	3,78	7,5	7,53	9	9	Paar Alcoolyser
14	2,17	2,17	4,87	4,86	3,72	3,72	7,41	7,41	8,71	8,67	Paar Alcoolyser
15	2,219	2,174	4,959	4,935	3,752	3,742	7,627	7,572	9,06	8,989	Paar Alcoolyser
16	2,17	2,16	4,88	4,88	3,73	3,73	7,46	7,46	8,76	8,77	Paar Alcoolyzer
17	2,3	2,28	4,92	4,96	3,79	3,79	7,41	7,45	8,91	8,85	Foss Rapitec
18	2,19	2,18	4,87	4,89	3,73	3,74	7,47	7,46	8,77	8,75	Paar Alcoolyzer
19	2,19	2,16	4,88	4,88	3,74	3,74	7,43	7,44	8,68	8,72	Paar Alcoolyser
20	2,14	2,14	4,86	4,87	3,72	3,72	7,42	7,45	8,72	8,75	Paar Alcoolyzer
21	2,17	2,18	4,91	4,91	3,78	3,78	7,39	7,41	8,67	8,62	Paar Alcoolyzer
22	2,18	2,19	4,9	4,9	3,75	3,75	7,47	7,47	8,77	8,76	Paar Alcoolyzer plus
23	2,18	2,18	4,9	4,9	3,75	3,74	7,48	7,48	8,78	8,79	Paar Alcoolyzer
24	2,18	2,22	4,88	4,88	3,73	3,75	7,34	7,34	8,76	8,75	Foss Infratec 1256

Table II. Results of statistical evaluation of outliers and stragglers.

Lab	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
1	2,15	2,16	4,90	4,89	3,74	3,74	7,50	7,48	8,63**	8,78**
2	2,21	2,20	4,90	4,90	3,73	3,74	7,48	7,47	8,83	8,84
3	2,18	2,18	4,89	4,89	3,71	3,72	7,48	7,47	8,85	8,86
4	2,20	2,18	4,90	4,90	3,72	3,72	7,46	7,45	8,82	8,83
5	2,22	2,21	4,92	4,91	3,72	3,73	7,47	7,46	8,82	8,83
6	2,22	2,19	4,90	4,89	3,76	3,76	7,44	7,47	8,76	8,79
7	2,21	2,20	4,91	4,92	3,77	3,77	7,48	7,48	8,78	8,78
8	2,16	2,17	4,90	4,89	3,73	3,74	7,46	7,46	8,75	8,74
9	2,16	2,13	4,89	4,89	3,74	3,73	7,47	7,47	8,77	8,76
10	2,19	2,21	4,91	4,91	3,74	3,74	7,49	7,48	8,80	8,79
11	2,14	2,15	4,85	4,86	3,71	3,71	7,42	7,43	8,70	8,73
12	2,18	2,20	4,91	4,91	3,76	3,75	7,43	7,45	8,74	8,72
13	2,18	2,17	4,82**	4,89**	3,77	3,78	7,50	7,53	9,00°	9,00°
14	2,17	2,17	4,87	4,86	3,72	3,72	7,41	7,41	8,71	8,67
15	2,22	2,17	4,96	4,94	3,75	3,74	7,63°	7,57°	9,06°	8,99°
16	2,17	2,16	4,88	4,88	3,73	3,73	7,46	7,46	8,76	8,77
17	2,30°	2,28°	4,92**	4,96**	3,79	3,79	7,41	7,45	8,91	8,85
18	2,19	2,18	4,87	4,89	3,73	3,74	7,47	7,46	8,77	8,75
19	2,19	2,16	4,88	4,88	3,74	3,74	7,43	7,44	8,68	8,72
20	2,14	2,14	4,86	4,87	3,72	3,72	7,42	7,45	8,72	8,75
21	2,17	2,18	4,91	4,91	3,78	3,78	7,39	7,41	8,67	8,62
22	2,18	2,19	4,90	4,90	3,75	3,75	7,47	7,47	8,77	8,76
23	2,18	2,18	4,90	4,90	3,75	3,74	7,48	7,48	8,78	8,79
24	2,18	2,22	4,88	4,88	3,73	3,75	7,34°	7,34°	8,76	8,75

* detected as straggler by Cochran's test; retained

** detected as outlier by Cochran's test; rejected

° detected as straggler by Grubbs' test; retained

°° detected as outlier by Grubbs' test; rejected

Table III. Precision data – all participants.

	A	B	C	D	E
n	23	22	24	24	21
s_r^2	0,000188	0,000040	0,000029	0,000194	0,000331
S_L^2	0,0003	0,0004	0,0004	0,0021	0,0030
s_r	0,0137	0,0064	0,0054	0,0139	0,0182
s_R	0,0213	0,0208	0,0213	0,0476	0,0581
m	2,180	4,894	3,742	7,459	8,768
r₉₅	0,038	0,018	0,015	0,039	0,051
R₉₅	0,065	0,058	0,060	0,133	0,163
CVS_r	0,63	0,13	0,14	0,19	0,21
CVS_R	1,06	0,42	0,57	0,64	0,66

The repeatability limit (r_{95}) does not depend on the mean.
 The reproducibility limit (R_{95}) depends on the mean: $R_{95} = 0,025 + 0,014m$.

Repeatability $r(95)$ was found to be independent of the mean value and equal to 0,032% V/V.

Reproducibility $R(95)$ was found to be dependent on the mean and is given by $0,017m + 0,006\%$ V/V.

There were insufficient laboratories using the Foss equipment to enable a robust statistical evaluation of the comparative precision between the Foss Infratec and Paar Alcolyzer instruments. Tables IV and V give the raw data and precision calculations for the laboratories using the Paar Alcolyzer and the Foss instruments, respectively. The precision data from the two instrument types indicates that there is no significant difference in their accuracy or precision. However, the one laboratory using the Foss

Table IV a. Paar Alcolyser – Raw data.

Lab	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
6	2,22	2,19	4,90	4,89	3,76	3,76	7,44	7,47	8,76	8,79
7	2,21	2,20	4,91	4,92	3,77	3,77	7,48	7,48	8,78	8,78
8	2,16	2,17	4,90	4,89	3,73	3,74	7,46	7,46	8,75	8,74
9	2,16	2,13	4,89	4,89	3,74	3,73	7,47	7,47	8,77	8,76
10	2,19	2,21	4,91	4,91	3,74	3,74	7,49	7,48	8,80	8,79
11	2,14	2,15	4,85	4,86	3,71	3,71	7,42	7,43	8,70	8,73
12	2,18	2,20	4,91	4,91	3,76	3,75	7,43	7,45	8,74	8,72
13	2,18	2,17	4,82**	4,89**	3,77	3,78	7,50	7,53	9,00 ^{oo}	9,00 ^{oo}
14	2,17	2,17	4,87	4,86	3,72	3,72	7,41	7,41	8,71	8,67
15	2,22	2,17	4,96	4,94	3,75	3,74	7,63 ^{oo}	7,57 ^{oo}	9,06 ^{oo}	8,99 ^{oo}
16	2,17	2,16	4,88	4,88	3,73	3,73	7,46	7,46	8,76	8,77
18	2,19	2,18	4,87	4,89	3,73	3,74	7,47	7,46	8,77	8,75
19	2,19	2,16	4,88	4,88	3,74	3,74	7,43	7,44	8,68	8,72
20	2,14	2,14	4,86	4,87	3,72	3,72	7,42	7,45	8,72	8,75
21	2,17	2,18	4,91	4,91	3,78	3,78	7,39	7,41	8,67	8,62
22	2,18	2,19	4,90	4,90	3,75	3,75	7,47	7,47	8,77	8,76
23	2,18	2,18	4,90	4,90	3,75	3,74	7,48	7,48	8,78	8,79

* detected as straggler by Cochran's test; retained
 ** detected as outlier by Cochran's test; rejected
 ° detected as straggler by Grubbs' test; retained
 °° detected as outlier by Grubbs' test; rejected

Table IV b. Precision data – Paar Alcolyzer.

	A	B	C	D	E
n	17	16	17	16	15
s_r^2	0,000186	0,000049	0,000021	0,000122	0,000327
S_L^2	0,0003	0,0005	0,0004	0,0008	0,0015
s_r	0,0136	0,0070	0,0045	0,0110	0,0181
s_R	0,0224	0,0235	0,0198	0,0308	0,0432
m	2,177	4,894	3,744	7,455	8,743
r₉₅	0,038	0,020	0,013	0,031	0,051
R₉₅	0,063	0,066	0,056	0,086	0,121
CVS_r	0,63	0,14	0,12	0,15	0,21
CVS_R	1,03	0,48	0,53	0,41	0,49

Table V b. Precision data – Foss Infratec and Rapitec.

	A	B	C	D	E
n	6	5	6	6	6
s_r^2	0,000217	0,000000	0,000058	0,000167	0,000342
S_L^2	0,0014	0,0001	0,0007	0,0026	0,0016
s_r	0,0147	0,0000	0,0076	0,0129	0,0185
s_R	0,0408	0,0084	0,0279	0,0526	0,0440
m	2,213	4,892	3,738	7,440	8,829
r₉₅	0,041	0,000	0,021	0,036	0,052
R₉₅	0,114	0,023	0,078	0,147	0,123
CVS_r	0,67	0,00	0,20	0,17	0,21
CVS_R	1,84	0,17	0,75	0,71	0,50

Table V a. Foss Infratec and Rapitec – Raw data.

Lab	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2
2	2,21	2,20	4,90	4,90	3,73	3,74	7,48	7,47	8,83	8,84
3	2,18	2,18	4,89	4,89	3,71	3,72	7,48	7,47	8,85	8,86
4	2,20	2,18	4,90	4,90	3,72	3,72	7,46	7,45	8,82	8,83
5	2,22	2,21	4,92	4,91	3,72	3,73	7,47	7,46	8,82	8,83
17	2,30°	2,28°	4,92**	4,96**	3,79°	3,79°	7,41*	7,45*	8,91*	8,85*
24	2,18	2,22	4,88	4,88	3,73	3,75	7,34	7,34	8,76	8,75

* detected as straggler by Cochran's test; retained
 ** detected as outlier by Cochran's test; rejected
 ° detected as straggler by Grubbs' test; retained

Table VI. Questionnaire results

Partici- pant	Instrument used	Water check	Calibration	Beer check
1	Paar Alcolyzer			
2	Foss Infracore 1256		0–11%	
3	Foss Infracore 1256		0–11%	
4	Foss Infracore 1256		0–11%	
5	Foss Infracore 1256		0–11%	
6	Paar Alcolyzer	daily	daily 10% v/v	daily 5,4% v/v
7	Paar Alcolyzer	daily	weekly 9,6% v/v	no
8	Paar Alcolyzer			
9	Paar Alcolyzer	yes	daily 5% v/v	yes 5,2% vol
10	Paar Alcolyzer	daily	daily 11% v/v	daily 4,98% v/v
11	Paar Alcolyzer	yes	yes 10% v/v	yes 4,97% v/v
12	Paar Alcolyzer	daily	daily 0–10% v/v	
13	Paar Alcolyzer	yes	yes 8,61% v/v	yes 4,46% v/v
14	Paar Alcolyzer	yes	yes 9,61% v/v	yes 5,37% v/v
15	Paar Alcolyzer	daily	daily 4,93% v/v	no
16	Paar Alcolyzer	daily	weekly 10–12% v/v	no
17	Foss Rapitec	no	no	yes, 1 in every 10 samples
18	Paar Alcolyzer	daily	daily 10,05% v/v	no
19	Paar Alcolyzer	daily	daily 10% v/v	no
20	Paar Alcolyzer DMA 4500	daily	daily 8,7% v/v	
21	Paar Alcolyzer 560771	daily	monthly 10% v/v	monthly
22	Paar Alcolyzer plus	yes	yes 9,64% v/v	yes 4,5% v/v
23	Paar Alcolyzer	daily	alcohol 0,45% vol alcohol 12% vol	yes, daily
24	Foss Infracore 1256	yes	yes	yes 5%

Rapitec was identified as an outlier for 2 out of the 5 samples.

A comparison of the NIR results to the results from the distillation method show that the difference between the distillation and the NIR results for each sample are within the range of reproducibility of the distillation method. It is therefore concluded that the NIR method has acceptable accuracy when compared to the distillation method (which is the accepted reference procedure). A comparison of the grand mean value from each level suggests an alcohol recovery by the NIR method of 99,1%.

Questionnaire results

The Paar Alcolyzer was the most popular instrument used in the test.

The procedure for checking and calibrating the instrument varied between participants, most carried out a water zero check on a daily basis and a daily calibration check with a standard ethanol solution, although the concentration of the standard used varied considerably. A majority

of participants also carried out a calibration check using a beer sample on a daily basis (see Table VI).

The method recommends a daily or weekly check with water and an ethanol standard solution and a standard beer sample.

CONCLUSION

The NIR method was found to have better within and between laboratory precision than the reference distillation method for the determination of alcohol.

Repeatability $r(95)$ was found to be independent of the mean value and was 0,032% V/V over the range 2,18 to 8,76% V/V alcohol.

Reproducibility $R(95)$ was found to be dependent on the mean and is $0,017m + 0,006\%$ V/V over the range of alcohol tested.

The NIR method has acceptable accuracy when compared to the distillation method.

The method is recommended for inclusion in Analytica-EBC.