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The influence of alcohol content variation in UK packaged beers on the uncertainty of calculations using the Widmark equation

Peter D. Maskell[a,*], Calum Holmes[b], Margaux Huismann[b], Struan Reid[b], Martin Carr[c], Benjamin J. Jones[a], Dawn L. Maskell[b]

[a] School of Science, Engineering and Technology, Abertay University, Dundee, UK
[b] International Centre for Brewing and Distilling, School of Engineering and Physical Sciences, Heriot-Watt University, Riccarton, Edinburgh, UK
[c] School of Applied Sciences, University of Huddersfield, Huddersfield, UK

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ABSTRACT

It is common for forensic practitioners to calculate an individual's likely blood alcohol concentration following the consumption of alcoholic beverage(s) for legal purposes, such as in driving under the influence (DUI) cases. It is important in these cases to be able to give the uncertainty of measurement on any calculated result, for this reason uncertainty data for the variables used for any calculation are required. In order to determine the uncertainty associated with the alcohol concentration of beer in the UK the alcohol concentration (%v/v) of 218 packaged beers (112 with an alcohol concentration of ≤5.5%v/v and 106 with an alcohol concentration of > 5.5%v/v) were tested using an industry standard near infra-red (NIR) analyser. The range of labelled beer alcohol by volume (ABV's) tested was 3.4%v/v – 14%v/v. The beers were obtained from a range of outlets throughout the UK over a period of 12 months. The root mean square error (RMSE) was found to be ± 0.43%v/v (beers with declared %ABV of ≤5.5%v/v) and ± 0.53%v/v (beers with declared %ABV of > 5.5%v/v) the RMSE for all beers was ± 0.48%v/v. The standard deviation from the declared %ABV is larger than those previously utilised for uncertainty calculations and illustrates the importance of appropriate experimental data for use in the determination of uncertainty in forensic calculations.

1. Introduction

As the pharmacokinetics of alcohol are well understood, it is permissible in law to utilise the Widmark equation (Eq. (1)) to determine the blood alcohol concentration at a specific time if a blood (or alternative) sample is not available for that time point.

$$C_t = \frac{vzd}{rM} - \beta t \quad (1)$$

C_t = blood alcohol (ethanol) concentration at time t (mg/100 ml); v = volume of alcoholic beverage consumed (ml); z = strength of alcohol beverage (%v/v); d = density of ethanol (g/ml); r = the volume of distribution (V_d) of ethanol in an individual (unitless); M = mass of the subject (kg); β = alcohol elimination rate (mg/100 ml/h); t = time the drinking began (h).

Recent guidance by both the UK Forensic Science Regulator [1] and the National Academy of Sciences (NAS) report [2] on strengthening forensic science in the USA have reiterated the importance of including the uncertainty that may be associated with any forensic methods that are utilised. For this reason it is therefore important to determine the associated uncertainties for each of the parameters in the Widmark equation to give the best possible uncertainty of any Widmark based calculations.

Beer is one of the most popular drinks in the UK [3] and is also the most likely to be drunk in "binge drinking" sessions [3]. Due to the lower alcohol concentration of beer compared to wine or sprits (such as whisk(e)y) differences in the actual alcohol content of beer compared to the labelled alcohol content could exhibit greater levels of uncertainty. Previous experimental data from the USA demonstrated that the standard deviation (SD) of the actual alcohol content of packaged beer compared to the labelled alcohol content was ± 0.40%v/v (n = 85) [4]. Maskell and colleagues have previously suggested that, in the UK, based on legal statute and %ABV measurement accuracy data, that a SD of ± 0.14%v/v (for beers ≤5.5%v/v) and ± 0.34%v/v (for beers > 5.5%v/v) should be used for uncertainty calculations [5]. However, there have been no published experimental studies comparing the actual alcohol content of beer to labelled alcohol content in the UK. A study in the UK that determined experimental rather than theoretical

* Corresponding author.
E-mail address: p.maskell@abertay.ac.uk (P.D. Maskell).

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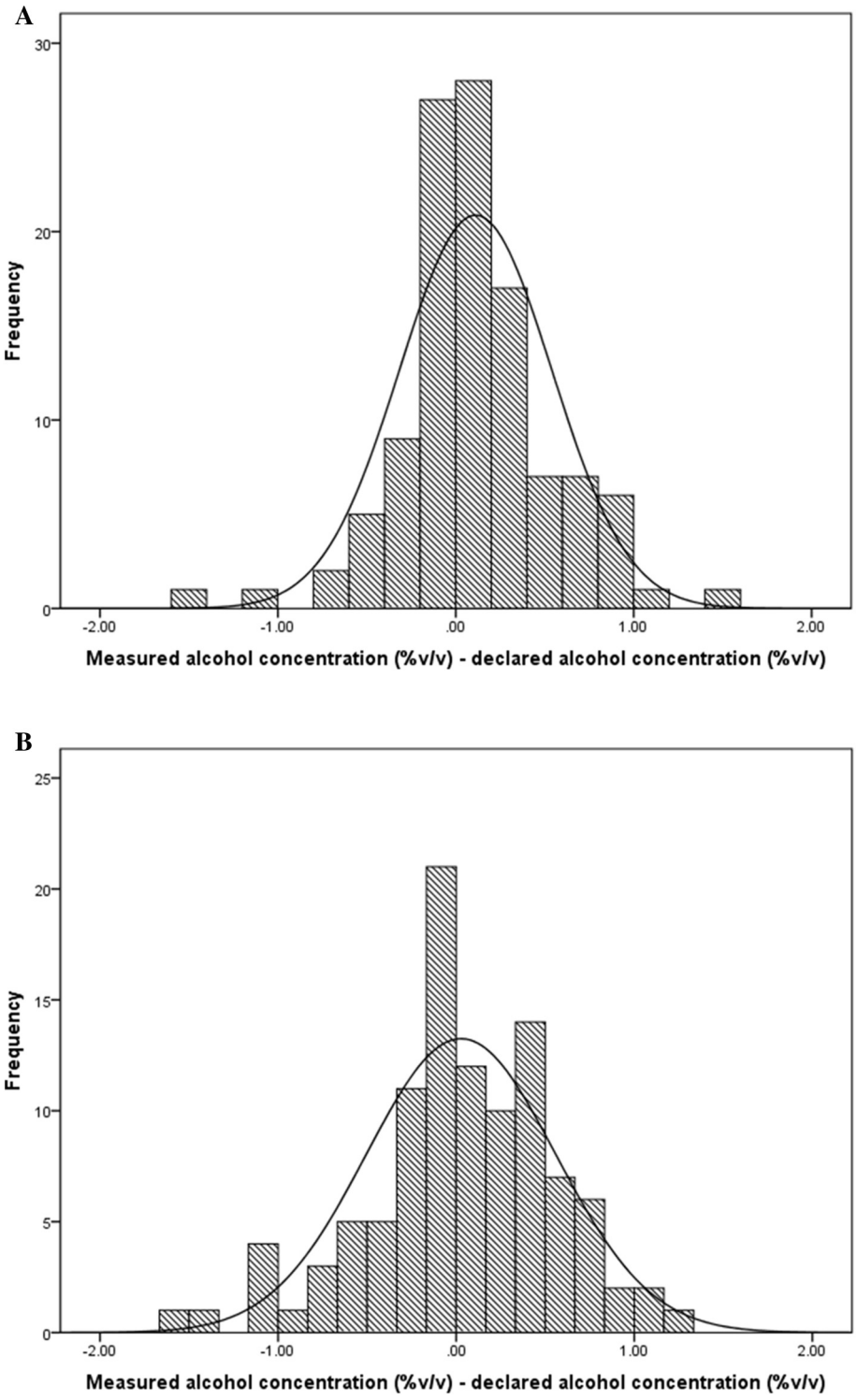

Fig. 1. A) Histogram of the residuals of the 112 UK beers with a declared %ABV of ≤5.5% showing normal distribution. B) Histogram of the residuals of the 106 UK beers with a declared %ABV of > 5.5% showing normal distribution.

alcohol concentration accuracy data for uncertainty of measurement calculations would be useful to give more reliable data for determining the overall uncertainty for alcohol calculations using the Widmark equation.

The aim of this study was to determine the SD (and percent coefficient of variation (%CV)) of the labelled %ABV on packaged, UK brewed beer to provide experimentally derived %ABV data for uncertainty calculations when using the Widmark equation. The influence of the experimentally derived uncertainty of alcohol concentration on the uncertainty Widmark calculations of the maximum blood alcohol concentration is also shown.

2. Methodology

2.1. Sample selection

In order to determine the uncertainty (standard deviation (SD) and percent coefficient of variance (%CV)) of the labelled %ABV of

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