TECHNICAL NOTE

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Alcohol Content of Beer and Malt Beverages: Forensic Considerations

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ABSTRACT: Beer consumption is commonly an issue in a medico-legal setting, requiring estimates either of a likely blood alcohol concentration (BAC) for a given pattern of consumption or vice versa. Four hundred and four beers and malt beverages available for sale in the State of Washington were tested by gas chromatography for their alcohol content. Considerable variability in the alcoholic strength was found, even within the same class. Overall the range of concentrations was 2.92%v/v to 15.66%v/v. The mean alcohol concentration for ales was 5.51%v/v (SD 1.23%v/v), and for lagers, 5.32% (SD 1.43%v/v). Some specialty brews had characteristically higher or lower mean concentrations; ice beers 6.07%v/v, malt liquor 7.23%v/v, light beer 4.13%v/v, seasonal ales 6.30%v/v. Six brands of lager and four light beers account for the majority of all beer sales in the United States, and the mean alcohol concentration for these products was measured as 4.73%v/v and 4.10%v/v respectively. Few of the beers (17%) were labeled with respect to alcohol content, and in some cases, there was a significant disparity between the concentration listed on the label, and the measured alcohol concentration. Toxicologists need to exercise caution when performing Widmark type calculations, using all available information to select the most appropriate estimate for alcoholic strength of a beer or malt beverage.

KEYWORDS: forensic science, beer, alcohol, driving under influence, forensic toxicology

Beer is the alcoholic beverage whose recent use is cited most often by driving under the influence (DUI) offenders in the United States (1). In a sample of 100 cases reviewed in the State of Washington in 1995, beer consumption was cited by 81% of those drivers who admitted to drinking (unpublished data). A similar report from the Bureau of Justice Statistics (2) indicated that 52% of DUI arrestees had consumed beer only, while another 21% had consumed beer and hard liquor. Demographic studies have shown that the choice of alcoholic beverage is influenced somewhat by gender, age and socioeconomic status (3,4), with beer being preferred by males in the 21–35 year age range-the group known to be at the highest risk for DUI arrest (5,6).

Industry estimates (7) indicate that in 1996 there were about 1,500 breweries in North America, producing more than 3,300 different brands of beer. Between them, the ten largest breweries alone in the United States (US) produced over 190 million, 31-gallon barrels of beer. The United States has one of the highest rates of abstention from alcohol in the West, with over 30% of American adults classified as non-drinkers (8,9). Nevertheless, per capita beer consumption in the United States in 1995 amounted to 243, 12 oz beers per head of population per year.

The forensic toxicologist is frequently required to testify in DUI cases with respect to issues involving alcohol consumption and its effects. This often includes the use of calculations based on the work of Eric Widmark (10), which relates the volume and concentration of alcohol consumed, and the subjects weight, gender, and time over which drinking took place, to a likely range of blood alcohol concentration. Conversely the calculation can be used to estimate the volume of alcoholic beverage consumed if the subject's blood or breath alcohol concentration is known. These calculations have been shown, within limits, to be accurate (11–13), however the accuracy depends on a number of factors, including an assumption that the subject has a normal ("Widmark") pattern of absorption, distribution and elimination, and that information regarding the alcoholic strength of the beverage consumed is accurate. It has been our personal experience however, that even when a DUI defendant makes statements about their alcohol consumption, they will frequently not recall the brand of beer consumed. This often leads to an assumption for the purposes of the calculation that the beer was a domestic US beer with a nominal alcoholic strength of 5% by volume (%v/v)[2]. Other workers have reported alcohol concentrations of beer in the past, but have not critically evaluated the forensic implications of their findings (14–17). Given the recent proliferation of specialty brews from the major breweries, microbreweries, independent small breweries and brewpubs however, we were concerned about the validity of this assumption, and conducted the following analysis of commercially available domestic and imported canned and bottled beers for their alcohol concentration. We then discuss the implications of these findings for future use of Widmark's formula in cases involving beer consumption. Since brewers and brands come and go,

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[2] Alcoholic beverage strength is most often given as percent by volume (%v/v). When it is given as percent by weight (%w/v), the strength in percent by volume can be calculated by multiplying by the specific gravity (typically 1.005 − 1.010), and dividing by 0.789, the density of ethanol. Liquor alcoholic strength is often given in degrees proof, with 80° proof being equivalent to 40%v/v in the United States. Some beers are now also listed as "proof of spirits," which again is twice percent by volume.

this should not be considered the definitive list of alcohol strengths of available beers, but it does represent most of those products available for sale in Washington State during 1997.

Methods

Bottles and cans of over 400 brands of beer and malt beverages were provided by the Washington State Liquor Control Board, or purchased from local stores. Manufacturers were contacted by phone, fax or e-mail, for information about alcohol concentrations they believed their beers to have. Some of this information is also available on the Internet. Bottle labels and packaging were inspected to see if the alcohol strength was listed.

Beverage containers were opened and an aliquot of the contents (10 mL) was degassed by filtration through medium speed 0.210 mm filter paper (Schleicher and Schuell, Keene, NH). The filtrate was diluted 1:50 with 8 MΩ water (Millipore, Milford, MA) using volumetric glassware. Aliquots (200 μL) of these solutions were pipetted and mixed with an aqueous solution of n-propanol (1 g/L) (1500 μL) as internal standard and placed in sealed 10 mL headspace vials (Hewlett Packard, Palo Alto, CA) for analysis by gas chromatography (GC). Packed column GC analysis was performed on model 6890 gas chromatographs (Hewlett Packard, Palo Alto, CA) coupled to HP7694 headspace autosamplers (Hewlett Packard, Palo Alto, CA). Two aliquots of each beverage were prepared, and each was tested in duplicate on both Carbowax 20 M and THEED phases, both on Carbopak 80/100 support in 6 ft. glass columns with an internal diameter of ⅛ in. The specificity of this approach has been discussed elsewhere (18). The results of the two determinations were averaged, and mathematically rounded to two decimal places.

Four hundred and four beers and malt beverages were tested for alcohol content. 73.7% were domestic US brands, followed in frequency by England (6.4%), Belgium (5.0%), and Canada (4.2%). Note, however, that many foreign brands are brewed by contract brewers under license in the United States.

Results and Discussion

The analytical method was demonstrated to have between day precision (CV) of 1.6%, and an accuracy of 0.08% based on replicate ($n = 12$) analysis of a 5%v/v control. The distribution of alcohol strength for all the products tested is shown in Fig. 1. A table showing the actual analytical data is published elsewhere (19).

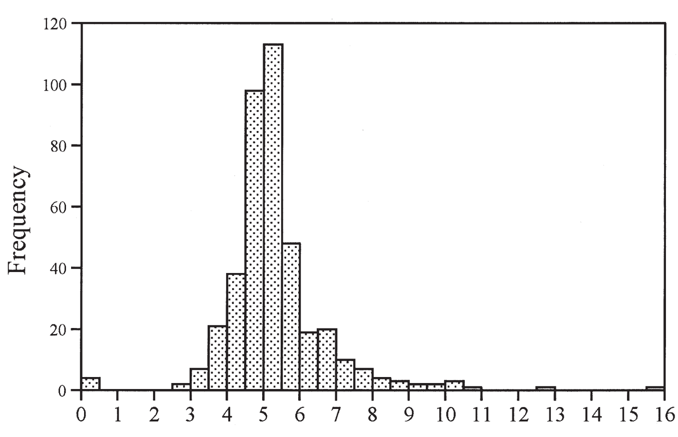

FIG. 1—*Distribution of alcoholic strength of all beers and malt beverages tested (*$n = 404$*).*

Beer is traditionally defined as an alcoholic beverage derived from fermented grains. The flavor, color, and alcoholic strength of the beverage is determined by the choice and blend of grains, how they are roasted, the fermentation process, the microorganism used, and the use of additives. Beers can be divided generally into two categories, ales or lagers, depending on the brewing process (20).

Ales are made using top fermenting yeasts at temperatures of between 16 and 21°C, and when brewed traditionally are made from malted barley, hops, water, and yeast. Sugar, barley, corn, rice, or potato starch and other grains are, however, commonly added. Ales are typically slightly carbonated. There are several styles of ales including amber ale, bitter, mild, pale ale, brown ale, hefeweizen, stout, porter, and barley wine. Fruit beers are typically ales to which fruit juices or extracts are added during the brewing process. Lambics are also top fermented beers, brewed from a wort containing fruit, but using bacteria (lactobaccilus) as opposed to yeast, to ferment the sugars to alcohol. Barleywines are brewed from a wort with a very high sugar content, usually using a wine yeast which can survive greater concentrations of alcohol.

Table 1 summarizes the data for some of these classifications of beer. Ales as a class ($n = 256$) had a mean alcohol concentration of 5.51%v/v, (SD 1.23, median 5.25%v/v). The range was very broad however from 2.29% − 12.69%v/v. Barleywines clearly had a greater alcohol content than other ales. Seasonal ales, typically winter beers brewed with spices, had an average alcohol content of 6.30%v/v, higher than typical ales, by 0.8%v/v. There were relatively few of these two latter types of ale however. The largest category, "other ales," included amber ales, pale ales, and brown ales, ($n = 135$) and had an average alcohol content of 5.54%v/v, very close to the average of all ales of 5.51%v/v, suggesting that in the absence of more specific information about the type of ale ingested, an assumption of 5.5%v/v would be the most reasonable, although clearly some significant variability occurs.

Lagers are brewed with bottom fermenting yeasts, initially at temperatures of between 4 and 16°C, and then undergo a secondary fermentation at temperatures below 4°C. Styles of lager include the European pilsener, octoberfest, bocks, and Australian and American lagers. American lagers are brewed with barley malt, and rice, corn or wheat, and are typically highly carbonated. Steam beers are brewed using lager yeasts, but at higher temperatures. Malt liquor is a term given to high alcohol strength lagers. Ice beers are also lagers, which, after fermentation, are chilled to near freezing, at which point ice crystals forming in the beer are filtered out, leaving a higher alcohol concentration in the filtrate. Light (or "Lite") beers are almost uniformly lagers which have a lower calorie content than regular beers, and generally, although not always as discussed below, have a lower alcohol content than their corresponding higher calorie brand.

Lagers as a class ($n = 113$) had a mean alcohol concentration of 5.32%v/v, (SD 1.43, median 5.00%v/v). As with ales, the range was very broad from 4.02%v/v − 15.66%v/v. In the case of lagers, some products, i.e., bocks, malt liquors, and ice beers, are specifically brewed to have a higher alcohol content, which tends to bias the mean for this group high. Light beers have approximately two thirds the calories of regular lager, and had a lower average alcohol content, 4.13%v/v, compared to 5.01%v/v for other lagers. Some light beers however, for example Budweiser Ice Light (Anheuser-Busch Brewing Co.) and Milwaukee Best Light (Miller Brewing Co.) had the same alcohol concentration as their corresponding regular brands. For the purposes of a Widmark calculation, if a subject had been drinking regular as opposed to light beer, and if bock, ice beer, and malt liquors can be ruled out, an average alcohol concentration for lager of 5.03%v/v would be a reasonable estimate of the most

TABLE 1—*Summary of alcohol strength for various classifications of beer and malt beverage.*

	Mean (%v/v)	SD (%v/v)	Median (%v/v)	Count	Range Low (%v/v)	Range High (%v/v)
Ales						
All	5.51	1.23	5.25	256	2.92	12.69
Lambic	4.31	1.01	4.44	8	2.97	5.35
Hefweizen	4.90	0.28	4.94	14	4.43	5.54
Fruit	4.91	0.55	4.83	16	4.13	6.11
Porter	5.25	0.64	5.28	18	3.64	6.61
Bitter	5.43	0.79	5.13	19	4.15	7.02
Other Ale	5.54	1.22	5.28	135	2.92	12.69
Stout	5.78	1.43	5.44	26	3.73	10.22
Seasonal Ale	6.30	1.37	6.20	17	4.56	9.62
Barleywine	9.98	0.83	10.41	3	9.02	10.51
Lagers						
All	5.32	1.43	5.00	113	4.02	15.66
Light	4.13	0.44	4.08	13	3.61	5.41
Other Lager	4.99	0.58	4.91	70	4.02	7.59
Seasonal Lager	5.47	1.01	5.63	6	3.96	6.04
Ice	6.07	1.02	5.76	11	5.25	8.16
Malt Liquor	7.23	1.47	7.40	7	5.63	9.56
Bock	8.02	3.85	6.84	6	4.87	15.66
Malt beverage						
All	4.26	0.85	4.02	31	3.04	6.01
Non-Alcohol						
All	0.38	0.13	0.42	4	0.20	0.47

TABLE 2—*Top ten selling brands of beer in the United States (1995).*

			Manufacture		Measured	
					Alcohol Concentration	
Brand	Manufacturer	Production (Barrels)	Market Share (%)	Concentration (%v/v)	*lagers* (%v/v)	*light beers* (%v/v)
Budweiser	Anheuser-Busch	40,917,000	21.40	5.00	4.76	–
Budweiser Light	Anheuser-Busch	17,590,000	9.20	4.20	–	4.15
Miller Lite	Miller	16,060,000	8.40	4.50	–	3.99
Coors Light	Coors	13,575,000	7.10	4.20	–	4.11
Busch Beer	Anheuser-Busch	8,030,000	4.20	4.90	5.38	–
Natural Light	Anheuser-Busch	6,883,000	3.60	4.20	–	4.15
Miller Genuine Draft	Miller	6,692,000	3.50	5.00	4.62	–
Miller High Life	Miller	5,354,000	2.80	5.00	4.59	–
Milwaukee's Best Beer	Miller	5,162,000	2.70	4.50	4.43	–
Old Milwaukee	Stroh's	4,567,000	2.40	4.60	4.62	–
Total		124,830,000	65.30			
Mean				4.61	4.73	4.10

likely alcohol concentration. If no information about the specific type of lager is known then an estimate of 5.32% would be better.

Another approach to estimating the likely alcohol content of an unidentified beer in the US would be to assume that it was one of the more commonly available domestic beers. Table 2 shows industry estimates for 1995 for the market share of the top ten brands of beer sold. These products (all lagers) constitute 65.3% of the US beer market in terms of quantities produced. The distinction between regular and light beer is important since the average alcohol concentration of these most popular domestic US regular and light beers was 4.73%v/v, and 4.10%v/v respectively. Although none of the containers of these mass produced beers was labeled with respect to alcohol content, the measured alcohol content agreed more closely with the manufacturers estimate of the alcohol content than all beers as a whole, on average 0.13%v/v (SD 0.28) less than the manufacturers estimate, suggesting better quality control with respect to the target alcohol content.

Malt beverages (as distinct from malt liquors discussed above) are products derived from fermented grains, but from which the color and flavor are removed by charcoal filtration or distillation. Fruit juices or flavorings are then added. Again there was a considerable range of alcohol concentrations in these products from 3.04 to 6.01%v/v, with an average of 4.26%v/v.

Four so-called non-alcoholic beers tested all had an alcohol concentration of less than 0.5%, as required by law. This is about 10% of the alcohol content of a regular beer. The quantity of non-alcoholic beer required to produce symptoms of intoxication in an average adult is so large as to exclude that possibility for all practical purposes. These products are, however, packaged to resemble regular beer, have a characteristic beer-like odor, and one could be mistaken for the other on a cursory examination.

The labeling of beverage containers with alcohol concentration is useful because in theory, it allows the user a degree of informed decision making about consumption, although practically this is beyond the expertise of most lay beer drinkers. In this sample of beers and malt beverages, however, only 56 (19%) of 296 domestic brands, and 12 (11%) of 108 foreign brands were labeled with respect to alcoholic strength. All ice beers however ($n = 11$), and 40% of malt liquors ($n = 7$) were labeled.

Excluding one barleywine, which was measured at 10.00%v/v compared to 7.00%v/v posted on the label, the data showed that the average difference between the measured content was 0.03%v/v (SD 0.40) less than the labeled alcohol content. The range, however, was from 0.98%v/v less than indicated, to 1.62%v/v greater than indicated. In terms of relative differences, the average measured concentration was 0.85% less than the labeled concentration, and the range was 16.5% less than the label, to 17.0% greater.

There has been no uniformity in the United States with respect to labeling of beer for alcoholic strength. In 1995, the United States Supreme Court ruled (Rubin v. Coors Brewing Co., 514 U.S. 476 (1995)) that manufacturers did have a first amendment right to publish the alcoholic strength on the label, however, individual states still maintain their own regulations about whether labeling is mandatory.

The confusion surrounding this issue could readily be resolved if manufacturers were required to clearly label their products in terms of the number of standard drinks contained in a bottle, rather than simply alcohol content. If for example, a standard drink is defined as 1 ounce of 80 proof liquor, then a 12 ounce, 5%v/v beer would contain 1.5 standard drinks. Similarly a 750 mL bottle of 14%v/v wine would contain 8.9 standard drinks. Without this uniformity, guides issued by many states, including Washington, which purport to relate the number of drinks consumed to a specific blood alcohol level are of limited use.

Conclusions

The data presented here should be of value to forensic toxicologists in performing Widmark-type calculations for hypothetical examples involving the consumption of beer. Our findings suggest that the assumption of a strength of 5%v/v for beer, in the absence of any specific information is reasonable and defensible. However, in the event that more specific information is available, for example whether ice beer or light beer was consumed, a more appropriate value can be used, as indicated in Table 1. The differences in alcohol strength between different brands of beer are not trivial to the accuracy of Widmark calculations. As an example, using in a hypothetical calculation the concentration of the strongest (5.38%v/v) and weakest (3.99%v/v) beers from the 10 best selling brands listed in Table 2, could produce estimates of BAC as far apart as 35%. While there are other variables not accounted for here which can influence the accuracy of this calculation, using an accurate rather than estimated alcohol concentration for the beer consumed, at least reduces one source of possible error. The differences between the labeled alcoholic strength and the actual strength in the samples tested, suggests that there is some batch to batch variability even within brands in the alcoholic strength of beer, and manufacturers may change the target alcoholic strength of their product for marketing reasons. Toxicologists should be aware of these limitations and consider uncertainty in the alcoholic strength of a beer or malt beverage, when performing Widmark calculations or commenting on the accuracy of resulting estimates.

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