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What Volume of Low-alcoholic Beer can be Consumed Before Reaching the Legal Driving Limit?

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Abstract
Within the UK, non-alcoholic beer tends to have a 0.05% ABV. Modelling consumption to an average male of 75kg and with 5 litres of blood, it would require 51 Litres of UK standard, non-alcoholic beer. This is an equivalent of 115 standard 440mL cans of non-alcoholic beer.

Introduction
In the United Kingdom, there are three different classifications of low-alcoholic beer. These are non-alcoholic, dealcoholized and low-alcohol, categorised by the % Alcohol by Volume (%ABV) of the beverage. Non-alcoholic beer is defined as having a %ABV of less than 0.05% [1]. %ABV is defined as the volume of pure ethanol present in 100mL of beverage at 20^{o}C [2].

The legal alcohol limit in England, Scotland and Wales for drivers is defined as either 80mg of ethanol per 100 mL of blood in your body, 35µg per 100mL of breath or 107µg of per 100mL of urine [3]. These equate to consuming the same volume of alcohol but are determined by the pharmacokinetics of ethanol.

This paper aims to determine the volume of non-alcoholic beer that can be consumed before reaching the legal alcohol limit for drivers.

Assumptions
In order to produce a model that would be able to provide a value for the volume of non-alcoholic beer required to reach the legal driving limit assumptions had to be made to reduce the effects of other variables.

The assumptions made were that the person consuming the beer was a male of average build, with a weight of 75kg. This allowed the volume of blood present within his body to be approximately 5 litres [4].

Assumptions also needed to be made regarding the pharmacokinetics of alcohol. It is known that almost 100% of the alcohol from alcoholic beverages is absorbed, with 20% being absorbed through the stomach and around 80% through the small intestines. The rate of this absorptions varies with %ABV and rate of stomach emptying, however as time was not considered a factor in this model this was not considered.

The metabolism of alcohol and elimination of ethanol from the blood were also assumed to not occur within this male, again as time taken to consume the volume was not considered.

It was also assumed that the non-alcoholic beer could be modelled as a solution of deionised water mixed with ethanol, at the maximal %ABV for the classification, 0.05%, and that the volume of blood could be treated as deionised water with a starting blood-alcohol concentration of 0 mg/mL. For the purposes of this model the only volume added to the blood is the volume of ethanol present within the non-alcoholic beer, with the remainder of the solution, i.e. the deionised water not being absorbed through the proximal small intestines and colon as would normally occur [4].

Model

For the model, the UK legal driving limit was taken to be 80mg of ethanol per 100mL of blood. This gives a final blood alcohol concentration of 0.8mg/mL. The blood and beer were treated as two solutions of alcohol, with concentrations of 0mg/mL and 0.3945mg/mL respectively, as calculated using (1) and (2). Therefore the volume of ethanol required producing this final concentration could be calculated using the equation below:

$$C_1M_1 + C_2M_2 = C_FM_F$$

For the purposes of the calculations presented, C_1 and C_2 represent the concentration of ethanol initially in blood and beverage respectively in mg/mL, with M_1 and M_2 representing the volumes of the respective fluids in mL. It is assumed that blood can be modelled as having the density of water, allowing the mass of blood to be used. C_f and M_f represent the final concentration of ethanol and volume of fluid in the circulatory system.

As only the alcohol was assumed to be absorbed from the beer, the concentration (C_2) was assumed to be 1.0mg/mL. This allowed calculation of the mass of ethanol required to reach the legal driving limit as shown below. This is achieved by rearranging the equation making M_2 the subject.

$$(0 \times 5000) + (1.0 \times M_2) = 0.8(5000 + M_2)$$
$$M_2 = 4000 + 0.8M_2$$
$$0.2M_2 = 4000$$
$$\therefore M_2 = 20{,}000\ mg$$

After determining the mass of ethanol required to reach the legal driving limit for a male with 5L of blood, the volume of non-alcoholic beer to that contained this mass of ethanol was calculated. This was done by converting the %ABV into a concentration of mL of ethanol per millilitre of beverage and using the density of ethanol to obtain the concentration of non-alcoholic beer.

$$\%ABV = V_{alc}\ per\ 100mL$$
$$0.05 = 0.05\ per\ 100mL$$
$$\therefore 0.05\ \%ABV = 5 \times 10^{-4} mL\ per\ mL$$

The alcohol content of non-alcoholic beer was found to be 5×10^{-4} mL of ethanol per millilitre of beverage. The density of ethanol is 0.789 kg/L [5]. This allowed this to be converted to the concentration using the relationship:

$$Volume = \frac{Mass}{Density}$$

This was found to be 0.3945 mg/mL. Obtaining this concentration allowed for calculation of non-alcoholic beer required to reach the legal driving limit.

$$\frac{20000}{0.3945} = V_{nab}$$

$$V_{nab} = 50697mL$$
$$V_{nab} = 51L$$

This gave a volume of 51 litres of non-alcoholic beer needs to be consumed to reach the legal alcohol limit for drivers in England and Wales. In terms of 440mL cans, which is the most common packaging for non-alcoholic beers this equates to 115 cans.

Conclusion

The simple model used gives a volume of 51 litres (2 significant figures). This is equivalent to 115 cans of non-alcoholic beer.

This large volume of liquid would be unfeasible to consume due to the health risks involved, which would most likely cause dilutional hypernatraemia if attempted.

This model makes many assumptions, fixing many of the variables, as previously stated. It is known that many of these variables are known to have a profound effect on blood-alcohol levels including gender, weight and volume of blood present within the circulatory system. Therefore further work into these variables could potentially improve the model.

References

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