How Significant is Alcohol Loss from Baked Food? A Case Study

Annika Nebel, Florian Veit, Gabriele Lasczkowski, Walter Martz

Justus Liebig Universität, Institut für Rechtsmedizin, Forensische Toxikologie, Frankfurter Straße 58, D-35392 Gießen; anni.n91@web.de

Aim: Based on a defendant´s claim in court we reproduced the recipe of a stollen (German Christmas cake) that contained a high amount of alcohol to prove or disprove it. The claim has been brought forward by a driver in order to explain his BAC of 1.19 per mille. **Methods:** The original recipe as introduced into evidence (400 mL of 80 v/v % rum, baking at 160°C for 50 min.) and some modifications of a rum cake were tested. By means of GC-FID in our routine alcohol laboratory we determined alcohol levels in aliquots of different cake samples. Headspace GC-MS congener analysis was also performed in order to identify losses of volatiles contained in the rum brand as claimed. **Results and Discussion:** Representative alcohol levels in one slice yielded around 30% of remaining alcohol in the cake and around 60% in the stollen. The claim was having ingested 3 slices, 3 cm thick ea. equal 900 g. Thus a total of 39 g ethanol may have been consumed from the stollen and additionally 20 g ethanol from 0.5 L beer. Applying the Widmark formula to a male of 75 kg, a BAC of 0.79 per mille to 1.01 per mille appears to be possible. Considering the degradation a BAC of 0.00 per mille to 0.70 per mille could be possible. The loss of alcohol from heated food has not been investigated systematically. Proper sampling turned out to be crucial and needs further investigations. However, there is sufficient evidence that significant amounts of alcohol will remain in heated food mostly depending on the length of baking time and temperature. **Conclusion:** Although it is possible to add a large volume of alcohol to baked food like stollen, the authors think, that the product was inedible. The remaining amount of alcohol was not high enough to create a BAC as high as the measured BAC.

1. Introduction

In the present case an alcoholised driver was stopped by the police. After one hour a blood sample was taken. A BAC of 1.19 per mille was measured in our laboratory. Thereupon the driver claimed to have consumed 0.5 L beer (7 o'clock) and three slices of stollen 3 cm each around 6 o'clock. The stollen was baked with 400 mL Stroh Rum (80 v/v % ethanol). This case study was conducted, to show if the consumption of 0.5 L beer and three pieces of stollen can explain the measured BAC, considering the evaporation of ethanol during baking. Furthermore, we tried to investigate whether it is still possible to identify the alcohol after the baking process based on its congener alcohols. Therefore different rum cake recipes and the recipe for the stollen of the driver were baked under the same conditions. The analysis of the remaining ethanol content and congener alcohols was performed using GC-MS.

2. Material and Methods

2.1. Measuring the ethanol concentration

For proper measuring, samples from different locations within the cake were taken to get a significant result (Fig. 1). Each sample of 1 g of the cake was mixed with 3 g of water at 55°C for 2 hours.

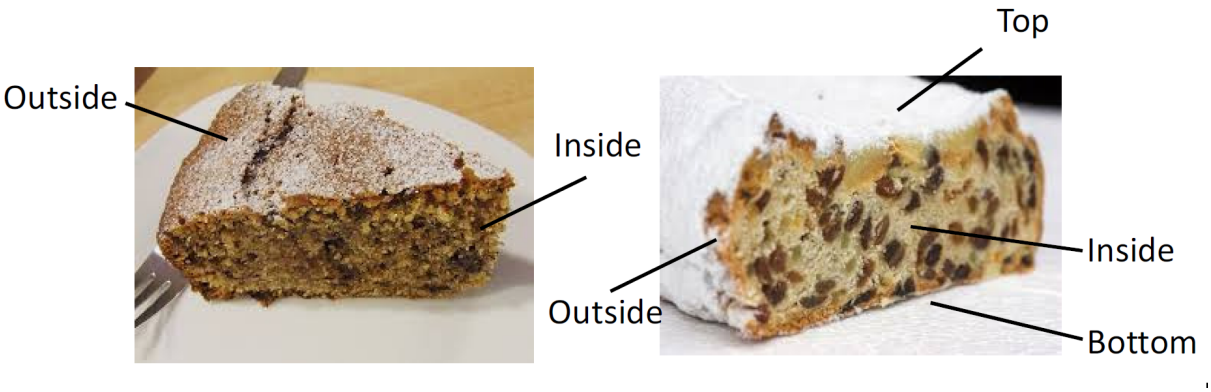

Fig. 1. Samples from different locations of the cake were taken.

Afterwards the mixture was filtered, the filtrate was diluted 1:10 with water and the dry mass of the filter residue was determined to calculate the loss of mass of the residue compared to the original cake sample. This fraction will now be present in the filtrate in addition to the 3 g of water. The ethanol concentration in the diluted filtrate was measured using GC-MS with *t*-butanol as internal standard. The diluted filtrate was measured by GC-MS with t-butanol as internal standard. To calculate the mass of ethanol in the cake sample the obtained concentration in the filtrate was multiplied with the mass of the filtrate. The calculated ethanol mass was then divided by the mass of the cake sample to result in the ethanol concentration in the analysed sample of the cake.

$$m_{EtOH} = [EtOH]_{measured} * \frac{m_{H_2O}}{density(H_2O)} = 5{,}67\frac{\text{mg}}{\text{mL}} * \frac{3{,}41\text{ g}}{1\frac{\text{g}}{\text{mL}}} = 19{,}33\text{ mg}$$

$$[EtOH]_{cake\ sample} = \frac{m_{EtOH}}{m_{cake\ sample}} = \frac{19{,}33\text{ mg}}{1077{,}4\text{ mg}} = 1{,}79\%(\text{m/m})$$

3. Results and Discussion

The obtained values for the remaining ethanol content in the different cakes were within 11% at the outside of the cake and 62% at the inside of the cake. Inside the cake was approximately four times more ethanol left than at the outside. Furthermore, more ethanol evaporated from the cake which was baked with the double amount of alcohol. Finally, to calculate the remaining ethanol content in the entire cake, the outside sample of the cake was weighted twice as much as the inside (based on a mathematical model). The results are shown in Tab. 1.

Tab. 1. Ethanol content calculated for the entire cake of 1370 g.

Cake	Ø Ethanol content calculated from 1:10 dilution	Remaining ethanol content
1 (40 g rum)	12.4 g	31%
2 (80 g rum)	18.2 g	23%

In the entire cake baked with 40 g rum, 31% of ethanol remains after baking and it is equivalent to two 2 cl glasses rum. In the entire cake baked with 80 g rum, 23% of ethanol remains after baking and it is equivalent to three 2 cl glasses rum. Assumed that each cake would be divided into twelve pieces, one piece from the first cake would contain 1 g of ethanol which is equal to one and a half Mon Chéri®. One piece of the second cake would contain 1.5 g ethanol which is equal to two Mon Chéri®.

The remaining ethanol content of the stollen was within 11% on the outside and 79% on the inside. The huge variation is due to the fact that the stollen was baked according to the recipe as introduced into evidence and the baking time was not long enough, thus the stollen was not baked through. For the calculation of the remaining ethanol content for one slice of 290 g the outside was weighted with factor one, the bottom and the top were weighted with factor two and the inside with factor four. Under this assumption, 60% of the ethanol remains in one slice after baking. The entire stollen of 3.5 kg is then equivalent to 12.5 2 cl glasses of the used Stroh Rum and each slice, containing 12.9 g ethanol, is equivalent to one glass Stroh Rum or 19 Mon Chéri®.

Applied to the present case the driver has consumed 39 g ethanol from the stollen and 20 g ethanol from beer. Considering a body weight of 75 kg and a Widmark factor of 0.7 the reduced body weight would be 52.5 kg. With an absorption deficit of 10% 53.1 g ethanol could lead to a BAC of 1.01 per mille. With an absorption deficit of 30% 41.3 g ethanol could lead to a BAC of 0.79 per mille. Including the possible degradation in 3 hours and 7 minutes the blood sample could have reached a BAC between 0.00 per mille and 0.70 per mille. Thus, the measured BAC of 1.19 per mille could not be completely explained by the consumed amount of stollen and beer.

Furthermore, we tried to investigate if it is still possible to identify the consumed alcohol based on its congener alcohols after the baking process. We measured the congener alcohols of the two rum brands which were used for the cake and the stollen. The congener alcohols we found fit the literature data.[1,2] Thereupon, we measured the congener alcohols in the cake and stollen samples. In the rum cakes, all congener alcohols could still be identified after the baking process. As expected, inside the cake the concentrations are higher than at the outside and the rum cake baked with more alcohol contains higher concentrations of congener alcohols.

In case of the stollen the two congener alcohols methanol and 1-propanol from the Stroh Rum could be detected in all samples after baking. Additionally, we found small amounts of *iso*-butanol, 3-methyl-1-butanol and 2-methyl-1-butanol. The detected congener alcohols of the stollen, the blood sample and the Stroh Rum are shown in Tab. 2. Nearly every fruit contains 2-methyl-1-butanol thus in this case it could result from the raisins in the stollen. 3-methyl-1-butanol can be formed in the yeast dough.

Tab. 2. Concentration of congener alcohols of the stollen.

Congener alcohols	Blood sample	Stroh Rum	Inside	Bottom	Top	Outside
Methanol	2.76 mg/L	16 mg/L	55 mg/L	32 mg/L	19 mg/L	6 mg/L
Acetone	-	-	-	-	-	-
2-Propanol	-	-	-	-	-	-
1-Propanol	0.31 mg/L	10 mg/L	7 mg/L	2 mg/L	1 mg/L	0 mg/L
2-Butanon	-	-	-	-	-	-
2-Butanol	-	-	-	-	-	-
Iso-Butanol	-	-	3 mg/L	3 mg/L	1 mg/L	1 mg/L
1-Butanol	-	-	-	-	-	-
3-Methyl-1-Butanol	-	-	2 mg/L	1 mg/L	1 mg/L	0 mg/L
2-Methyl-1-Butanol	-	-	1 mg/L	1 mg/L	1 mg/L	0 mg/L

Comparing the analysis of the blood sample with our results it could not be disproved that the driver has consumed Stroh Rum from stollen but not enough to completely explain the BAC of 1.19 per mille.

4. Conclusion

Although the stollen produced according to the recipe as introduced into evidence was inedible, it is possible to consume a significant amount of alcohol with cake or stollen. The remaining amount of ethanol was in the range of 30% to 60% of the amount used for baking.

In contrast to the common misconception, a noteworthy amount of alcohol remains in a cake or stollen during the baking process. Nevertheless, it is rather difficult to get drunk by eating usual amounts of a common rum cake. Furthermore, performing a congener alcohol analysis is possible to identify the used alcohol even after the baking process based on its congener alcohols.

In the present case the alleged consumed amount of stollen and the 0.5 L beer could not completely explain the measured BAC.

5. References

[1] Bonte W. Begleitstoffe alkoholischer Getränke. Schmidt-Römhild, 1987.

[2] Schulz K. Nachweis, Metabolismus und Eliminationskinetik getränkecharakteristischer Aromastoffe in Serumproben zur Überprüfung von Nachtrunkbehauptungen. Shaker Verlag, 2015.