JOURNAL OF
EMERGING INVESTIGATORS

Article

Ethanol levels in foods ensuing culinary preparation

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SUMMARY

People across America incorporate baking and cooking into their daily lives. Sometimes, the recipes prepared include alcohol. This may be concerning for individuals who are under 21, pregnant, designated drivers, or recovering from alcoholism. We sought to determine how much alcohol remains at the time of consumption when alcohol is used in recipes. The recipes tested included: bananas foster, mudslide ice cream, eggnog, vodka sauce, and poached pears. We hypothesized that out of the five recipes tested, only the ice cream would be classified as alcoholic. To find the leftover ethanol after cooking, we heated the prepared food for a predetermined time to evaporate all the ethanol. Then, the recipes were weighed, and the mass difference was converted to alcohol by volume (ABV). Calculated ABV levels were compared to the federal limit of 0.5% ABV as drinks with 0.5% ABV or higher must be labeled as alcoholic in the United States We found that the recipes whose preparation included flambéing (bananas foster and poached pears), the eggnog, and vodka sauce were over the federal limit, suggesting that they are unsuitable to be served to persons under 21. However, the mudslide ice cream recipe was under the limit. This is important to take note of before consuming foods prepared with alcohol as in many cases the alcohol is still retained in the food even after preparation.

INTRODUCTION

For centuries, alcoholic beverages such as wine, vodka, beer, and liqueur have been used to create a variety of foods. These beverages consist mostly of water with some ethanol and minuscule amounts of other ingredients that provide color, taste, and aroma, which make cooking with alcohol so appealing. Many recipes containing alcohol are baked, cooked, or otherwise heated to temperatures above the boiling point of ethanol (78.33°C). Because of this, many people believe that all the alcohol simply "burns off" (1). These foods are served to people of all ages because of the assumption that all alcohol evaporates during preparation. However, research has shown that, depending on the preparation method, up to 85% of the original alcohol can remain after food preparation (2). With this in mind, currently, there is no reasonable way to require households to label their food as alcoholic. This research aims to raise awareness for those who plan on consuming foods prepared with alcohol.

It has long been known that alcohol consumption by young children can have many adverse effects. At a time when brain development is crucial, alcohol can impair cognitive function and memory and even cause depression (3). These impairments can last well into adulthood, with some studies even documenting a decreased size of the frontal lobe in adults who drank alcohol as children (3). In addition, other groups of people could also be looking to limit their alcohol intake. For example, recovering alcoholics, pregnant women, designated drivers, and people of some religions that prohibit alcohol would not want to consume alcohol unintentionally. Regardless of the reason, it is important to know whether there is a significant amount of alcohol in the particular preparations of food products.

Alcohol content in food or drink is measured by alcohol by volume (ABV). This number states the percentage of the volume of the substance that is pure alcohol (ethanol). The formal definition of an alcoholic beverage is a drink that contains more than 0.5% ABV (4). If a beverage exceeds this amount of ethanol and is sold, it must state that it is alcoholic (4). For foods, the laws are less clear. The same limit exists, however, if a solid is intended to be eaten by children under six (4). We believe that this applies to the foods we are testing because they are household recipes, commonly served to people of all ages. The proposed study focused on making various foods that include alcoholic beverages in the recipe and determining if they comply with the federal standard of 0.5% ABV. The recipes made and tested included bananas foster, mudslide ice cream, eggnog, vodka sauce, and poached pears (5-9).

We hypothesized that the ice cream recipe would have the greatest ABV out of all the recipes and would exceed 0.5% ABV. This recipe calls for adding Kahlua and Baileys Irish Cream at the end while the food is cooling (6). Since the food is not heated after the alcoholic beverage is added, there are very few opportunities for the ethanol to evaporate. We predicted that most of the ethanol would remain after preparation, causing the ice cream to have a high ABV, exceeding the 0.5% federal standard. However, the other recipes require heating. Therefore, we thought they would be under the federal standard.

The purpose of this research was to determine which of the five recipes retained enough ethanol after preparation to be over the federal limit. After measuring and calculating the ABV of the five recipes, we found that bananas foster, eggnog, vodka sauce, and poached pears were over the limit. Conversely, mudslide ice cream was under the limit. This provides consumers preparing these recipes with essential information regarding the alcohol content of the prepared form of the food.

https://doi.org/10.59720/24-153

RESULTS

We prepared each food according to the instructions included in the recipe. Then, we divided each item into 100g samples resulting in 7-11 trials per recipe. For each trial, we measured the mass in grams before and after heating to the boiling point of ethanol. The amount of time each recipe was heated for was calculated using the evaporation tests run with just water and ethanol. This process was repeated for each mass loss of each trial.

The bananas foster had one outlier, which we omitted from the ABV calculations. We calculated this by multiplying the interquartile range by 1.5. Bananas foster, eggnog, vodka sauce, and poached pears were all above the federal limit. They had a mean ABV of 0.64%, 1.71%,1.75%, and 1.29%, respectively (**Figure 1**). Mudslide ice cream was below the limit at 0.21% (**Figure 1**). Thus, this recipe was below 0.5% ABV after preparation. It had a fold change of 0.18. All of the recipes were statistically different from the federal standard of 0.5% ABV ($p<0.05$, one-sample t-test).

One point that should be noted is the difference between the initial ABV and the final ABV of poached pears compared to bananas foster. Both were flambéed, yet the difference from initial ABV to final ABV is much larger for bananas foster. Initial ABVs were: bananas foster, 6.94; mudslide ice cream, 1.15; eggnog, 3.38; vodka sauce, 3.25; and poached pears, 3.11. The final ABVs were: bananas foster, 0.64; mudslide ice cream, 0.21; eggnog, 1.71; vodka sauce, 1.75; and poached pears, 1.29 (**Figure 2**).

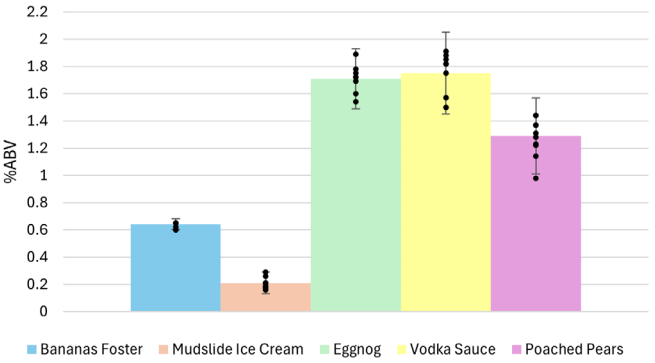

Figure 1. Mean ABV after preparation of alcohol-containing recipes. Mass loss in grams was converted to volume and taken as a percentage of total volume to give ABV. n=6 for Bananas Foster (one outlier was omitted), n=10 for Mudslide Ice Cream, n=8 for Eggnog, n=8 for Vodka Sauce, n=11 for Poached Pears. Data shown as mean ± 2 standard deviations. Single sample t-test relative to 0.5% ABV, $p<0.05$ for all recipes, all statistically significant from 0.5% standard.

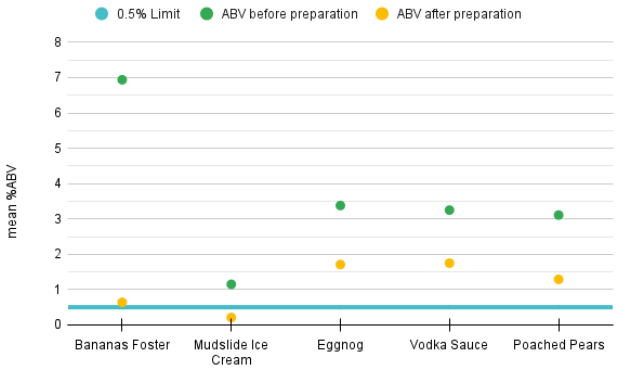

Figure 2. Comparison of ABV before and after recipes as compared to the federal standard. ABV before preparation and mean ABV after preparation for each recipe with blue line representing the federal standard of 0.5% ABV. ABVs were calculated using volume of ethanol divided by total volume. ABV after preparation n=6 for Bananas Foster (one outlier was omitted), n=10 for Mudslide Ice Cream, n=8 for Eggnog, n=8 for Vodka Sauce, n=11 for Poached Pears.

DISCUSSION

We hypothesized that the ice cream would be the only recipe to have an ABV above the federal limit after preparation. However, the data did not support this. All five recipes lost ethanol during preparation, but mudslide ice cream was the only one below the limit at 0.21% ABV, suggesting that our hypothesis was incorrect. This means that, out of the recipes tested, bananas foster, eggnog, vodka sauce and poached pears should be labeled as alcoholic if they were to be sold and should not be served to persons under 21 years of age in the US because they were above the legal limit of 0.5% ABV. It should be noted that not all these recipes require an alcoholic beverage to be made, but if one opts to include it, they should be advised about the ABV. Vodka sauce, bananas foster, and poached pears all require the alcoholic beverage for preparation. Specifically, the alcoholic beverage in the eggnog was optional. If the recipe was prepared without an alcoholic beverage, the ABV would change.

There is a possible explanation for the remaining ethanol present in each recipe. Beginning with the ice cream recipe, there is no direct heating of the ice cream after the ethanol is added, so less was able to evaporate. Additionally, ice cream started with the lowest ABV level before preparation. For this research, we opted to add the suggested optional amount of alcohol (7). Although this recipe is heated, the alcoholic beverage is added after the dessert is taken off the heat. This means it is unlikely that the ethanol reached its boiling point. Because there was a larger initial amount of ethanol, and the alcoholic beverage was not heated directly, it is not surprising to see that this recipe surpasses the federal limit after preparation. The fold change was 0.51. For both the unheated recipes, eggnog and ice cream, there was still some ethanol lost over the course of preparation. This could be due to evaporation or the starting temperature of the food when the ethanol is added. It is also possible that some of the loss might be due to error from the experiments. Some things may be not having a closed system, or all the other research happening in the same room. The next recipe was the vodka sauce, and with its larger initial ABV of 3.25%, this made it harder for the ethanol to evaporate fully. We do however see a change from the initial ABV so although it was still above 0.5%, there is still a loss of ethanol. This can be attributed to the 30 minutes of heating that occurred in the recipe (8). The fold change was 0.54. Then the bananas foster, the preparation included flambéing the dessert. However, research suggests that high percentages of ethanol can remain after preparation if the food is flambéed (1). The results from our experiment support this theory since it was calculated to be in violation of the federal limit. Lastly, the poached pears recipe also included flambéing, and the results also supported the above-mentioned article (1,9).

https://doi.org/10.59720/24-153

We also noticed that the bananas foster and poached pears, both of which were flambéed, each lost a different amount of alcohol. The fold change in ABV for bananas foster was 0.09, while the fold change for poached pears was 0.41. This is likely due to the difference in how each recipe burned. Red flames have a cooler temperature than blue flames (10). When the two recipes were lit on fire, the bananas foster had a bluer flame than the poached pears, likely causing more ethanol to evaporate. This could be due to a higher alcohol content before being flambéed (**Figure 2**). The poached pears were also in a wider pan when flambéed, which could possibly have impacted the burning. Additionally, in considering the density and makeup of the different foods we believe that could be another factor in the results obtained. Most of the recipes were very thick so they may have retained more of the ethanol due to less evaporation.

There were a few limitations to our methods that could be improved upon in future research. Firstly, the use of alcoholic beverages at our school is prohibited, so we had to use food-grade ethanol. The effects of this substitution could be eliminated in future research by using a lab located on property where alcoholic beverages are allowed for research purposes. However, we did dilute the ethanol to the correct ABV of the alcoholic beverage called for in each recipe. Secondly, there were time constraints on our experiment. The total amount of time available in the lab was around 15 weeks, directly affecting the number of recipes we could test. This limitation could be mitigated in future experiments by allocating more time for data collection. Additionally, there were budget restraints. The ideal way to measure the amount of ethanol in a sample is by gas chromatography (11). However, this process is very costly and not feasible with the funding available to us. The results obtained using the water bath method could have been less accurate, but regardless, they do align with previous research (12). Another possibility would be to calculate the density of the food manually by weighing the sample and measuring the volume instead of relying on online conversions that may not have the exact density of a specific recipe. This could affect the results because if the density was not exact, we could have had samples across recipes of slightly different volume. Another improvement that could be made is to prepare the foods without alcoholic beverages and use that as a control, instead of the water and ethanol combination. This would have been an appropriate control because some weight loss could be attributed to evaporation or loss of air in the food, especially in the ice cream.

In conclusion, our results suggest that not all the ethanol goes away after preparation. All recipes tested in this study lost ethanol during preparation, yet all of them still contained some ethanol at the end. Four of the five recipes were above the federal limit according to our calculation. This means that people should be conscious of the fact that cooking with alcoholic beverages can make the food above the federal limit of 0.5% ABV, even after preparation. The amount of ethanol that will evaporate depends on the method of cooking, as shown by the differences in ABV across the various recipes. Therefore, those who are trying to avoid alcoholic beverages, pregnant, under the age of 21, or a designated driver should be very cautious of what they are consuming and not assume that all alcohol has evaporated from foods that incorporate alcohol in the recipe.

MATERIALS AND METHODS

To begin, the evaporation process of water and ethanol was studied. To do this, a water bath was used to heat samples of water, ethanol, and both. The boiling point of ethanol is 78.33°C. To ensure that the samples were always at or above the boiling point of ethanol, the water bath was set to 79°C . Each sample of food was 100g, and, using the recipe, the grams of pure ethanol per 100g of raw ingredients was calculated. Also during this stage, we calculated the starting ABV of each recipe. As ABV is a measure of volume, conversion constants were used to convert grams to milliliters. The density of ethanol is 0.79 g/ml and the density of water is 1 g/ml. Using this formula, we divided the ml of ethanol by the total ml. This is the ABV of the water/ethanol solution which we used as an estimate for the ABV of the foods before preparation. Then, we evaporated the water and ethanol. Beginning with bananas foster, the amount of pure ethanol that would be in a 100g sample of the recipe, 5.2g, was heated to 79°C until fully evaporated, taking note of the exact amount of time this took (4). Then, 94.8g of pure water was heated for that same amount of time to determine how many grams of water would evaporate in our time interval. This experiment was repeated five times, once for each actual alcohol concentration used in the five different foods (**Table 1**). Finally, the water and ethanol for each recipe was mixed and heated for the amount of time it took for just the ethanol to evaporate. The total mass loss of ethanol and water for each experiment was recorded.

Then, we prepared the food. Each recipe was followed exactly, except for minimal changes due to a lack of materials (5-9). The recipes used here were found online and their ABV before preparation was calculated to be above the federal limit. In the ice cream, 14 oz of sweetened condensed milk was used instead of 14.5 as directed because no 14.5 oz was available. For the vodka sauce, asiago cheese was substituted for parmesan. Additionally, the alcoholic beverage in each recipe was replaced with an appropriate mixture of water and ethanol. Due to restrictions at our school, the study was not able to use alcoholic beverages in the recipes as suggested. Instead, the study was conducted using food-grade ethanol. 200-proof ethanol, which is 100% ABV was used. Alcoholic beverages are primarily water and ethanol, so food-grade ethanol is a valid substitution, even if it would not be as suitable for consumption. The ethanol was diluted with water to achieve the ABV of each alcoholic beverage specified in each recipe. For example, the bananas foster recipe required half of a cup of dark rum, which is 40% ABV. Consequently, half of a cup of water/ethanol mixture that was 40% ethanol was used. This same process was repeated and adjusted for each of the alcoholic beverages required in each recipe, as most have different ABV values.

Then the amount of alcohol in each prepared dish was measured. Each recipe was divided into as many 100g samples as possible. Each sample was microwaved to reach the boiling point of ethanol. Due to the various natures of the recipes, each required a different microwave time. This was determined by trial and error for the first sample of each recipe, using a thermometer to measure the temperature and omitting if heated for too long. The samples were then heated for the time required to evaporate the ethanol in each recipe, calculated beforehand in the water bath experiments (**Table 1**). Mass of the prepared food was measured before

https://doi.org/10.59720/24-153

Recipe	Ethanol (g) per 100g food	Time for ethanol evaporation (seconds)	Mass of water evaporated	Average expected mass loss (g)	Observed mass loss (g)
Bananas Foster	5.2	1,946	15.1	20.3	17.5
Mudslide Ice Cream	0.9	289	5.5	6.4	5.0
Eggnog	2.6	791	8.7	11.3	8.7
Vodka Sauce	2.5	852	7.8	10.3	9.3
Poached Pears	2.4	629	6.6	9.0	6.8

Table 1. Average expected mass loss versus observed mass loss for each recipe. Average expected mass loss and the observed mass loss for each recipe. Also included are the numbers used to calculate expected mass loss including the grams of ethanol in the food, average time it took for that ethanol to evaporate (n=3), and the amount of water that was evaporated in that same time interval (n=3). The mass of the ethanol was added to the amount of water that evaporated in the time interval and averaged to obtain the expected mass loss. The same amount of water and ethanol was mixed and heated for the same time interval, the amount that evaporated giving the observed mass loss (n=1, representative trial for each recipe).

and after heating. The difference indicated how much water and ethanol evaporated.

Using this difference in grams, we determined the ABV of each food. The mass loss in grams was multiplied by the ethanol (g)/actual mass loss (g) from the water and ethanol trials (**Table 1**). This gave the amount of ethanol in grams that evaporated from each food. Thus, the remaining grams out of 100 were the food. Using density constants, we converted the grams of ethanol and the grams of food to ml. Then, we divided the ml of ethanol by the ml of food to get the percent ABV. This was repeated for each sample of each recipe (**Figure 1 and 2**). For the density constants, some foods already had a calculated density available on the Internet. These include bananas foster (1.10 g/ml), vodka sauce (1.04 g/ml), and eggnog (1.08 g/ml) (13-15). Ice cream density varies so the average across brands of ice cream, 0.72 g/ml, was used. Information on poached pears was not available, but considering it was blended, applesauce density was determined as an appropriate substitute (0.89 g/ml) (16).

ACKNOWLEDGMENTS

We thank Dr. Kurt Guter, chemistry specialist, for his advice throughout this project.

Received: June 5, 2024
Accepted: January 7, 2025
Published: September 23, 2025

REFERENCES

1. Gordon, Barbara. “No Worries, the Alcohol Burns Off During Cooking—But, Does It Really?” *Idaho State University,* 2 Dec. 2019. https://www.isu.edu/news/2019-fall/no-worries-the-alcohol-burns-off-during-cookingbut-does-it-really.html. Accessed 9 Jun. 2024.
2. Augustin, J., et al. “Alcohol retention in food preparation.” *Journal of the American Dietetic Association,* vol. 92, iss. 4, 1992, pp. 486-487, https://doi.org/10.1016/S0002-8223(21)00661-1.
3. “Alcohol’s Effects on Health.” *National Institute on Alcohol Abuse and Alcoholism*, Dec 2023. https://www.niaaa.nih.gov/publications/alcohol-and-adolescent-brain. Accessed 9 Jun 2024.
4. “CFR - Code of Federal Regulations Title 21.” *U.S. Food & Drug Administration*, 22 Dec 2023. https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=328&showFR=1. Accessed 9 Jun 2024.
5. Drummond, R. “Bananas Foster.” *Food Network*, 2012. https://www.foodnetwork.com/recipes/ree-drummond/bananas-foster-recipe-1977801. Accessed 9 Jun 2024.
6. “Mudslide no-churn ice cream.” *Delish,* 4 Jun 2021, https://www.delish.com/cooking/recipe-ideas/recipes/a46135/mudslide-no-churn-ice-cream-recipe/. Accessed 9 Jun 2024.
7. Allen, L. “Homemade eggnog.” *Tastes Better from Scratch*, 5 Feb 2024. https://tastesbetterfromscratch.com/homemade-eggnog/. Accessed 9 Jun 2024.
8. Katya. “Vodka sauce recipe.” *Little Broken,* 6 Aug 2022. https://www.littlebroken.com/vodka-sauce-recipe/. Accessed 9 Jun 2024.
9. Anna. “Poached pears with apricot sauce.” *Allrecipes,* 24 Aug 2023. https://www.allrecipes.com/recipe/146929/flambeed-vanilla-poached-pears-with-apricot-sauce/. Accessed 9 Jun 2024.
10. “Flames Different Colors Explained.” *Fire Control Systems,* 9 Jan 2020. https://firecontrolsystems.biz/news/flames-different-colors-explained/. Accessed 9 Jun 2024.
11. Seo, Hyun-Beom, et al. “Measurement of ethanol concentration using solvent extraction and dichromate oxidation and its application to bioethanol production process.” *Journal of Industrial Microbiology and Biotechnology*, vol. 36, iss. 2, 1 Feb 2009, pp. 285-292, https://doi.org/10.1007/s10295-008-0497-4.
12. U.S. Department of Agriculture. “USDA table of nutrient retention factors release 6.” 2007, https://agdatacommons.nal.usda.gov/articles/dataset/USDA_Table_of_Nutrient_Retention_Factors_Release_6_2007_/24660888. Accessed 21 April 2025.
13. Flavor West. “Bananas Foster.” 2024, https://www.flavorwest.com/bananas-foster.html. Accessed 21 April 2025.
14. Aqua-Calc. “Density of Vodka Sauce.” 2025, https://www.aqua-calc.com/page/density-table/substance/vodka-blank-sauce-coma-and-blank-upc-column--blank-855691001009. Accessed 21 April 2025.
15. Aqua-Calc. “Density of Eggnog.” 2025, https://www.aqua-calc.com/page/density-table/substance/eggnog.

https://doi.org/10.59720/24-153

Accessed 21 April 2025.
16. Aqua-Calc. "Density of Apple Sauce." 2025, https://www.aqua-calc.com/page/density-table/substance/apple-blank-sauce-coma-and-blank-upc-column--blank-075450127782. Accessed 21 April 2025.