Rolling Cream

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MCEN 4151 Flow Visualization

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Figure 1: A screenshot from the final video of solutal convection currents in coffee liqueur.

Introduction

This image was produced by laying a small amount of coffee creamer on top of the coffee liqueur Tia Maria. The camera is pointing straight down on the flow, with a light shining underneath through a glass dish. It took a couple different tries in finding the right type of cream that would float on the liqueur and break up in the convection currents. The goal of this experiment was to visualize convection currents, in this case, solutal convection currents: convection due to differences in concentration. I would like to thank Zach Sherritt for his help in putting together the experimental setup.

Procedure

As seen in Figure 2 (a) and (b), a wide glass dish was elevated to allow for a light to be shone through the bottom of the dish. A layer of room temperature Tia Maria cold brew coffee liqueur with vanilla was then poured into the dish, about one inch deep. Once the liqueur had settled, small abouts of cold Kroger French Vanilla zero sugar coffee creamer were poured into dish off a spoon. The best results were seen when the creamer was poured from a high of about one inch, less than a third of the tablespoon was poured per drop, and the creamer was allowed to penetrate the surface of the liqueur to a depth of about one quarter of an inch. After about one-minute, clear convections cells had appeared, as seen in Figure 2 (c), where particles of cream began to rotate in rings. Approximately one or two convection cells would form per pour. The final image was taken after letting the experiment develop for at least three minutes, at which point wisps of cream began to rotate inside the convection cells. Each cell would range from about ¼ to ½ inches in diameter.

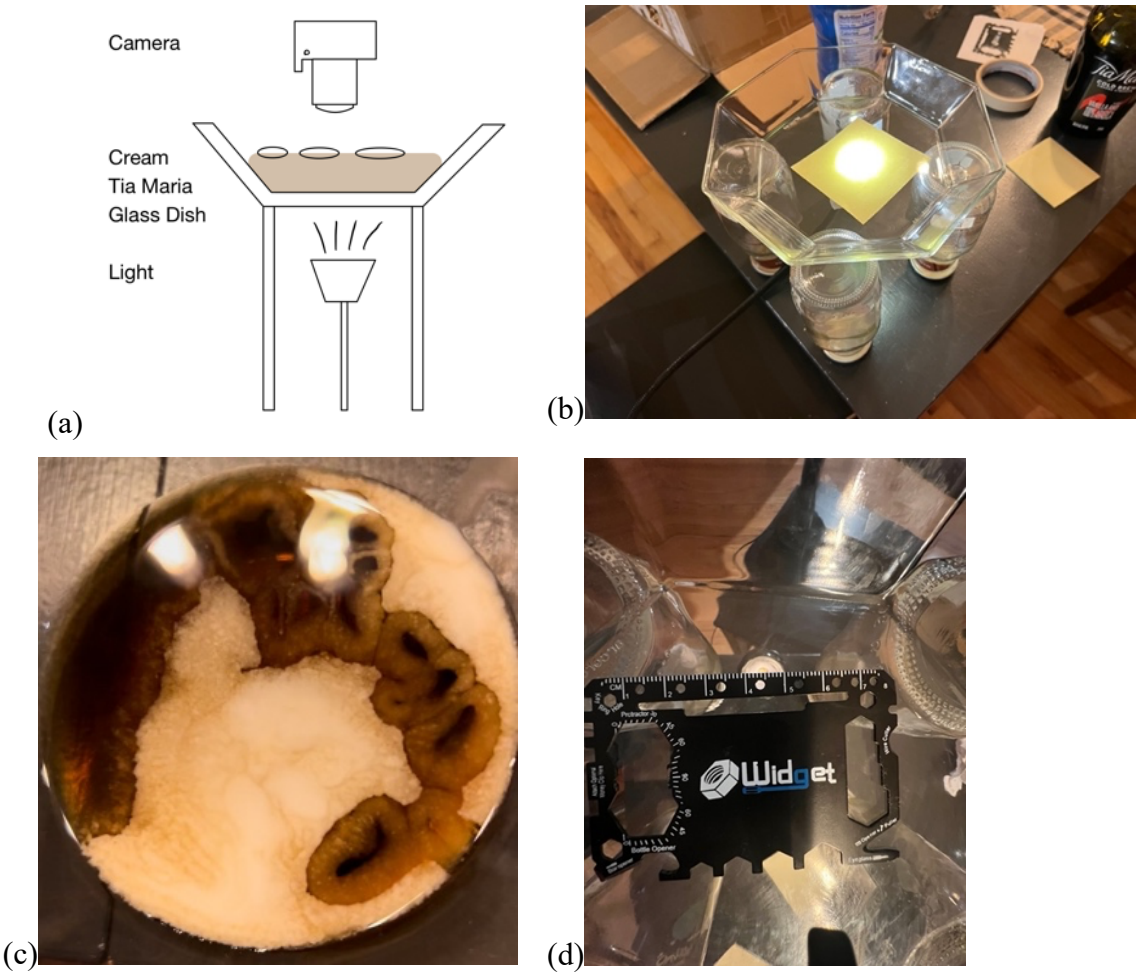

Figure 2: The experimental setup and dimensions.

The flow appeared to form Rayleigh-Benard convection cells throughout the dish that were relatively stable and would last for a few minutes. One major difference from the classic Rayleigh-Benard convection cell example was that this experiment was not heated. It is believed that the cells were entirely driven by solutal convection (Mold 2024), where ethanol would evaporate off the top surface and the concentration difference would drive the flow. It is also believed that the cream has no effect on the convection cells, however, that would have to be researched further. Equation 1 was used to find the Reynolds number of the flow in the convection cells.

$$Re = \frac{UD}{\nu} \tag{1}$$

A cream particle was tracked across a ring and was found to be moving at an average velocity of $U = 1.3 * 10^{-4} \frac{m}{s}$. It was assumed that the characteristic distance from the inside to the outside of the ring $D = 1\ cm$ and that the kinematic viscosity of the liqueur is like that of ethanol at $\nu = 1.47 * 10^{-6} \frac{m^2}{s}$ (Engineering Toolbox). This gives us a Reynolds number of 0.86, meaning that the flow is very much in the laminar region.

The experiment was lit from below by a strong LED desk lamp pointed straight at the camera. The video was taken on the 13mm lens on an iPhone 13 Pro with the camera being just over an inch away from the fluid. This was done in an attempt to get the best-looking video out of the iPhone and resulted in an image that was 9.5 cm by 12.6 cm, as shown in Figure 2 (d). The ISO was set at 250, with a $1/64^{\text{th}}$ shutter speed, a fixed aperture of $f/1.8$, and it was filmed at 30 fps. Minimal color grading was used in the form of contrast and saturation boosts, as well as a few brightness tweaks, as seen comparing Figure 3 to Figure 1. Additionally, the glass dish was cropped out of the image, taking the image from 1,428 x 2,538 pixels to 1,426 x 2,238 pixels.

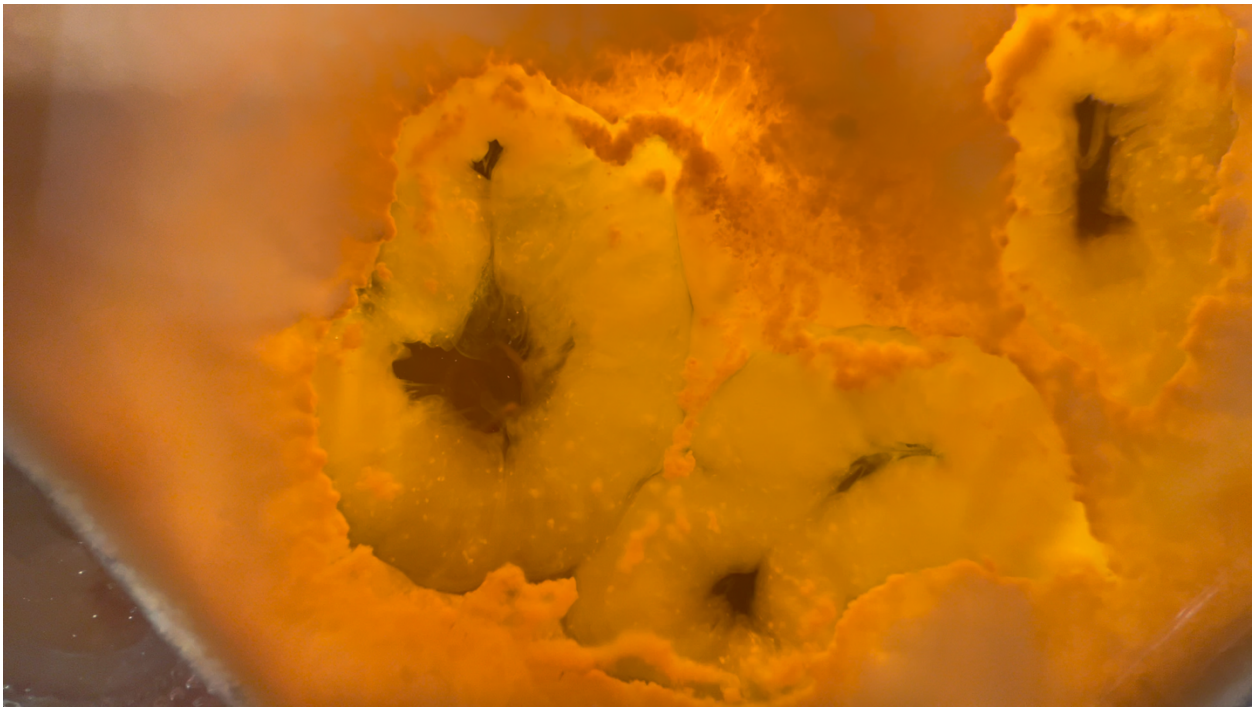

Figure 3: A screenshot from the unedited video.

Discussion

Overall, I really like the final video that I produced. I think it highlights the convection cells very well, and the lighting allowed for a very interesting color that was normally seen in the experiment. There are a few small things that I would tweak if I were to do this again, including getting a shot that didn't have the glass dish in the corners of it. Also, I had trouble getting the entire image in focus because I was so close to it, so the depth of field was extremely small. I think this could be fixed with a bigger experiment or a bigger zoom lens so that camera could be farther away. One thing that I would like to explore is other visualization techniques to understand if the cream is responsible for convection effects or not.

Work Cited

Steve Mold. (2024, February 17) The bizarre patterns that emerge when you heat ANY fluid [Video]. YouTube. https://www.youtube.com/watch?v=kuLX76g7Fec

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