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Visualizing Effects of Reducing Surface Tension with Soap in Milk

The intent of the image in this report is to capture the effect of reduced surface tension in a liquid. Common liquids, such as a glass of water, usually have pretty uniform surface tension. However, observing a liquid with non-uniform surface tension presents interesting dynamics that were desired to be captured in this image. In this case, dish soap was used to reduce the local surface tension in milk, which caused the milk to repel outwards from the dish soap.

For this experiment, milk was first poured into a small bowl. Four drops of food coloring were then dropped into the center of the milk. Lastly, a q-tip dipped in dish soap was gently placed into the center of the milk where the food coloring was dropped. The figure below shows the set up of this experiment.

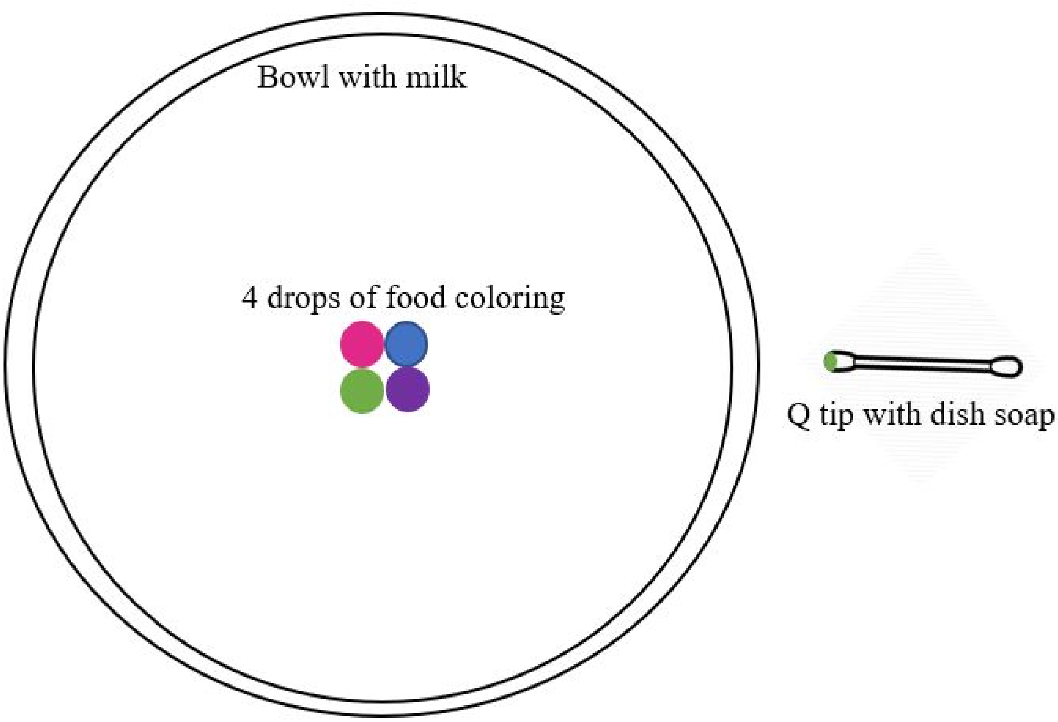

Figure 1: Experimental setup

The flow of milk moving outwards from the dish soap is driven by surface tension. The dish soap is a surfactant, which causes the fat and water in the milk to separate[1,2]. The fat is attracted to the soap and dissolves quickly in the soap, which reduces the local surface tension[2]. The surrounding surface tension is higher than that where the soap was placed, causing the milk and food coloring to be pulled outwards. The Laplace number, which is a non-dimensional number in fluid mechanics that describes the ratio of surface tension to momentum transport[3], can be estimated for this flow as shown below,

$$La = \frac{\sigma \rho L}{\mu^2} = \frac{0.048\ N/m \cdot 1{,}030\ kg/m^3 \cdot 0.15\ m}{(0.002\ Pa \cdot s)^2} = 1{,}854{,}000,$$

where La is the laplace number, σ, ρ, and μ are the surface tension, density, and dynamic viscosity of the milk, respectively, and L is the characteristic length, in this case the diameter of the bowl. While this number seems large, it is actually within a typical range for surface tension driven flows[4].

Food coloring was used for visualization in this image. Kroger brand assorted neon food coloring with pink, blue, green, and purple colors were used, specifically. This image was taken indoors during the day with some natural sunlight in the room, as well as light from fixtures. Additionally, a flashlight was used to provide more light for the image.

The purpose of the image was to just capture the spread of dye in the milk, so a large field of view was not needed. The camera, which was a DSLR Canon EOS Rebel SL, was close to the bowl when the image was taken in an attempt to mostly get only the bowl in the image. A plain, black shirt was also placed under the bowl to use as a neutral background. The final image was 3,325 x 2,921 pixels. The lens focal length is 39 mm and the image has an ISO of 800, f-stop of f/5.6, and an exposure time of 1/60 seconds. The photograph was then post-processed using Darktable. The image was cropped to frame the bowl and the color balance was manipulated in an attempt to have the food coloring stand out more in the milk.

This image reveals the interesting patterns of the food coloring due to the effects from the reduced surface tension caused by the dish soap. The layers of the different colors seen on the outer layer of the bowl formed quite beautifully in this image. In addition, the cloudiness from the slight mixing of the colors is intriguing. The final results of the fluid physics are shown well since the food coloring spread towards the edge of the bowl. This image fulfilled the intent of showing the effect of the reduced surface tension caused by the dish soap, as well as providing some aesthetics from the food coloring. This image could be improved by taking a more overhead camera angle and improving the focus. Currently, the back of the bowl seems in less focus than the front. In addition, a video capturing the dynamic process would be more interesting to see.

References

1. Ferri, J., & Stebe, K. (2000, January 11). Which surfactants reduce surface tension faster? A scaling argument for diffusion-controlled adsorption. Advances in Colloid and Interface Science, 61-97. https://doi.org/10.1016/S0001-8686(99)00027-5.
2. Buddies, S. (2014, March 13). Surfactant Science: Make a Milk Rainbow. Retrieved September 29, 2020, from https://www.scientificamerican.com/article/surfactant-science-make-a-milk-rainbow/.
3. Physics:Laplace number. (n.d.). Retrieved September 29, 2020, from https://handwiki.org/wiki/Physics:Laplace_number
4. Sen, N. (2009). Suratman number in bubble-to-slug flow pattern transition under microgravity. *Acta Astronautica, 65*(3-4), 423-428. doi:10.1016/j.actaastro.2009.02.013