MCEN 5151-002 Flow Visualization

Riley Curry, 9/23/24

Get Wet Project Report

The Making of "Cellular Tension"

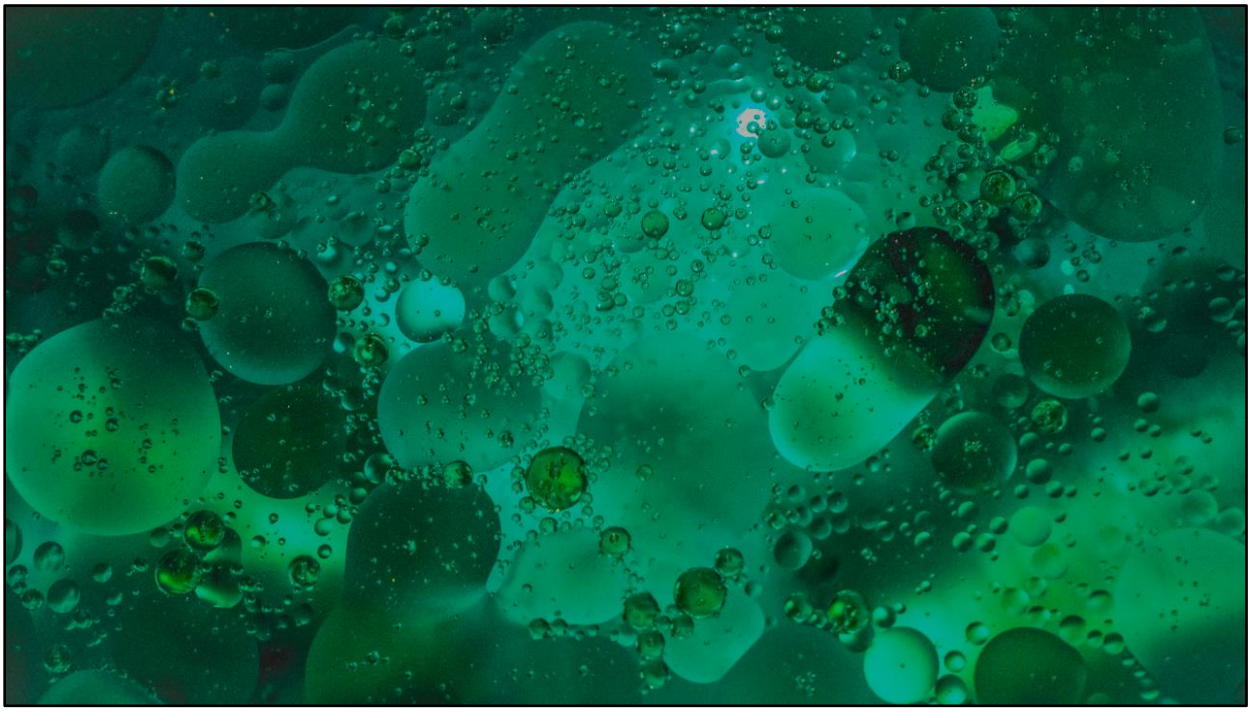


Figure I: "Cellular Tension" Final Image

(I) Project Background

The image shown in Figure I above was taken specifically for the Get Wet project; part of the Flow Visualization curriculum at the University of Colorado Boulder. The goal of the project was to create a controlled flow scenario which actively and accurately demonstrates a flow phenomenon in a controlled setting with artistic aesthetic in mind. This image is the result of several experimented techniques which did not meet desired aesthetic criterion; the initial goal was to take an image highlighting the refractive properties of different fluids by imaging the "shadow" of food dye dropped in a tank of water. Ultimately, the lighting used was not powerful enough to capture this and so I instead aimed to capture the natural diffusion of food dye in water (following a turbulent drop) from above. This led to a relatively uninteresting image, and so the focus was again shifted to capture the demulsification of oil bubbles in water, after having loosed a turbulent oil flow from height. As such the above image aims to artistically capture oil-water emulsion and particularly the subsequent breakdown of surface tension as oil-bubbles come into contact with each other.

(II) Image Flow

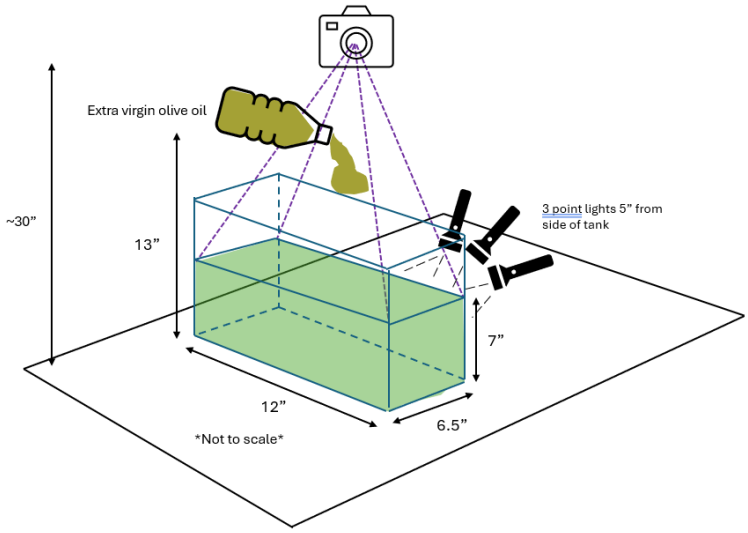


Figure II: Set-up Diagram

The image itself was captured in a darkened closet space reminiscent of the Figure II diagram shown above, with the camera providing a top-down view of the phenomenon. The 16:9 picture captures a physical area of 10” x 5.625” to avoid capturing the walls of the fluid container and other distracting features. Approximately 25mL of extra virgin olive oil was dropped about 5” above a tank of water (colored green with 2 drops of green food coloring and 1 drop of blue food coloring) and images were taken between 1 and 3 seconds after dropping. The image itself is capturing the natural demulsification of oil from the water as it rises to the surface and loses surface tension to other bubbles of oil.

(III) Flow Physics

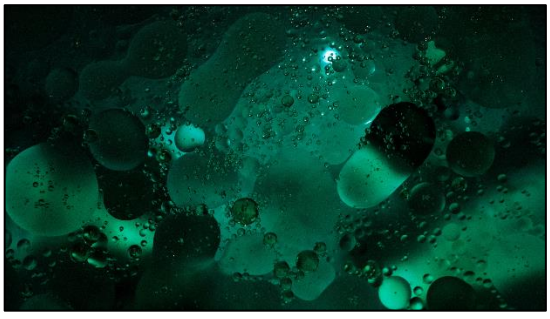
As the 25mL of extra virgin olive oil are dropped on static water, they retain ~0.074 Joules of gravitational potential energy (density = 0.917kg/L -> 0.917kg/L*0.025L=0.023kg -> $U=mgh=0.023kg*9.81m/s^2*0.127m=0.029J$). This is just enough energy to separate the oil into droplets reaching the bottom of the tank, and due to the displacement of water some extra mixing motion is provided. Shortly after, however, the disparity between low oil density and high water density leads to a natural buoyant force equal to the weight of water displaced (~0.025N total). As the oil floats to the surface, this leads to what is known as creaming (or gravitational droplet sedimentation) in which smaller oil droplets come into contact with other droplets, resulting in a drop in surface tension and the formation of a combined droplet (*Emulsions And Emulsifications Methods And Processes*, 2019). This specific phenomenon is what is being captured in Figure I.

It is possible to prevent droplets from re-forming with the addition of an emulsifier to stabilize the otherwise thermodynamically unfavorable mixture, which can be characterized in what is known as a creaming index (Zungur et al., 2015). Interestingly, slow cooling of the liquid mixture can also yield higher emulsification stability due to a higher viscosity restricting the movement of oil molecules (Lupi et al., 2011). This phenomenon may be worth studying in a future project.

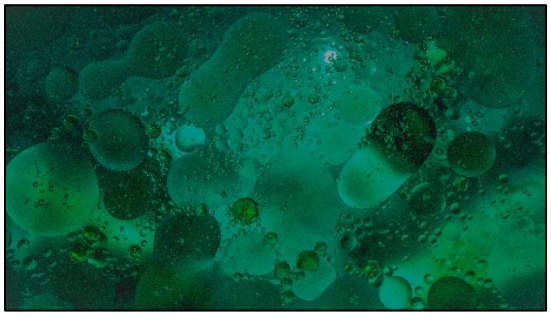
(IV) Visualization Techniques

The experimental set-up follows the diagram shown in Figure II, taking place in a small dark room with no outside light allowed in. The tank itself is a 12”x6.5”x11.5” clear plastic file organizer from Michaels, which I filled with 8.95L (7”) of tap water. The water itself was colored with 2 drops of green “Satin Ice” food color gel food dye and 1 drop of blue “Satin Ice” food color gel food dye, which was then mixed with a spoon and allowed to settle. Below the “tank” I placed plain white posterboard to increase reflection, and on the sides, I taped black posterboard to avoid light reflecting on top of the mixture and creating a glare. On one side of the “tank” I placed a 2” book 2” away to raise 3 light sources off the ground and provide better lighting. The lights were composed of 2 LED 400 lumen headlamps on either side and a 50 lumen iPhone flashlight in the middle. These were the only items I had available for point light sources, as the flash on my camera was not used to avoid glare. Before dropping the olive oil, I prepared my camera settings and optical zoom and familiarized myself with its position so I could capture as much of the tank as possible. I did not have a large enough tripod and so I dropped the oil in with my left hand and took a photo with my right shortly after. The oil used was “Kroger” Extra Virgin Olive Oil, of which I transferred 25mL to a measurement cup. I placed the measurement cup at roughly 13” off the ground, poured the oil into the tank, and (with my camera roughly 30” off the ground) I pressed the continuous shutter button on my camera to take roughly 20 shots of the next 5 or so seconds.

(V) Photographic Techniques



Unedited Image



Edited Image

Figure III: Image Comparison

The image captures the majority of the tank with a captured area of 10”x5.625” provided by the camera approximately 23” from the surface of the mixture. The unedited image shown in Figure III above was taken on a Fujifilm XT30 II digital mirrorless camera with f/5.2 (given the low light conditions). The image was not cropped to maintain maximum resolution and the unedited image size is 6240x3512, as is the edited image size. A shutter speed of 1/180 with an ISO of 4000 was used with an XC15-45mm interchangeable lens and 38.5mm focal length. This shutter speed was chosen for clarity and the ISO was chosen to counteract the low light conditions that came with the faster shutter speed. A dynamic range of 200% was also used for exaggerated color as well as a 9100 K white balance to counteract the sterile lighting. In post-processing, using Adobe Lightroom, the highlights and shadows were balanced for visibility and the image was saturated slightly.

(VI) Conclusion

The image reveals, in my opinion, a relatively strange phenomenon in which a natural order (demulsification) is imposed on a chaotic (emulsified) state in a way that is reminiscent of cellular mitosis. I enjoy how the image captures a diversity and large quantity of oil droplets and the scientific clarity of the breakdown of surface tension between each oil grouping, shown by the several elongated bubbles. That said, while I enjoy the way the light bounces off the experiment, I think it could have been more carefully controlled, and I think the image could be more visually interesting with the addition of coloring to the oil. I believe it would be worthwhile exploring how to add stable nonpolar coloring to olive oil to expand the realm of possibilities in creating this image. I would also appreciate guidance on better options for point lighting to explore my initial goal of capturing the refraction of the phenomenon. That said, I am overall satisfied with the image that was captured in terms of aesthetic and think it adequately captures the phenomenon of demulsification.

Bibliography:

Emulsions And Emulsifications Methods And Processes | Agno Pharmaceuticals. (2019, October 28). https://agnopharma.com/technical-briefs/emulsions-and-emulsifications/

Lupi, F. R., Gabriele, D., de Cindio, B., Sánchez, M. C., & Gallegos, C. (2011). A rheological analysis of structured water-in-olive oil emulsions. *Journal of Food Engineering*, *107*(3), 296–303. https://doi.org/10.1016/j.jfoodeng.2011.07.013

Zungur, A., Koç, M., & Ertekin, F. K. (2015). *Physical Properties of Olive Oil in Water Model Emulsion: Effect of Aqueous and Oil Phase Concentration and Homogenization Types*.