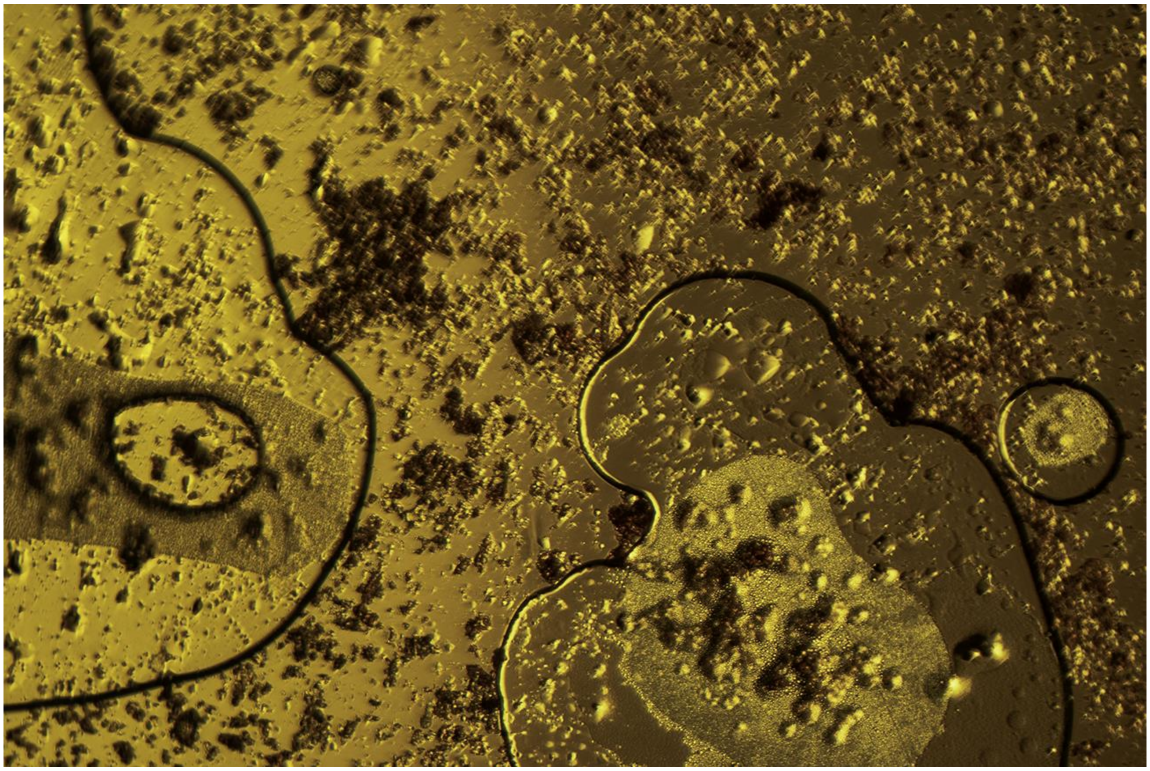
Microscopic Brew



Team Third Report
MCEN 5151
12/12/2019

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Introduction:

In our team third project, our team worked to investigate coffee at the microscopic scale. In our experimentation we looked a coffee once grinded and brewed at 10X to 40X scale under an illuminated microscope. This project was initially inspired by a lecture in another engineering class called Design for Coffee. During the lecture we discussed the impacts of Darcy's Law and filtration as part of the coffee brewing process. In the lecture I was inspired by the imagery that he had produced under the microscope showing the fluid relationship between the solid particulate, coffee oils, and water within the brewed fluid. With help of Professor Bordon, our team was able to perform an experiment in his with Black coffee and an lympus BX60 Compound Microscope in his lab equipment.

Scientific Phenomena

There are many intriguing flow phenomena within coffee at macroscopic level but within the image above and the imagery on the website I was interested in two scientific phenomena: Buoyancy and Brownian Motion. During the brewing process water in some shape or form interacts with the roasted coffee. When the water interacts with the coffee grounds during the brewing process is dissolves soluble particle within the grounded coffee that are transferred through the brewing apparatus with part of the water into the liquid coffee. Note these soluble from the coffee ground come in many in sizes and types and can vary dramatically in percentage based on the brewing process, the roast, and the bean itself. The soluble are molecules including Acids, Lipids, Melanoidins and Carbohydrates which make up the distinct flavor profile of the coffee. This also includes caffeine which is extracted from the coffee ground in this brewing process.

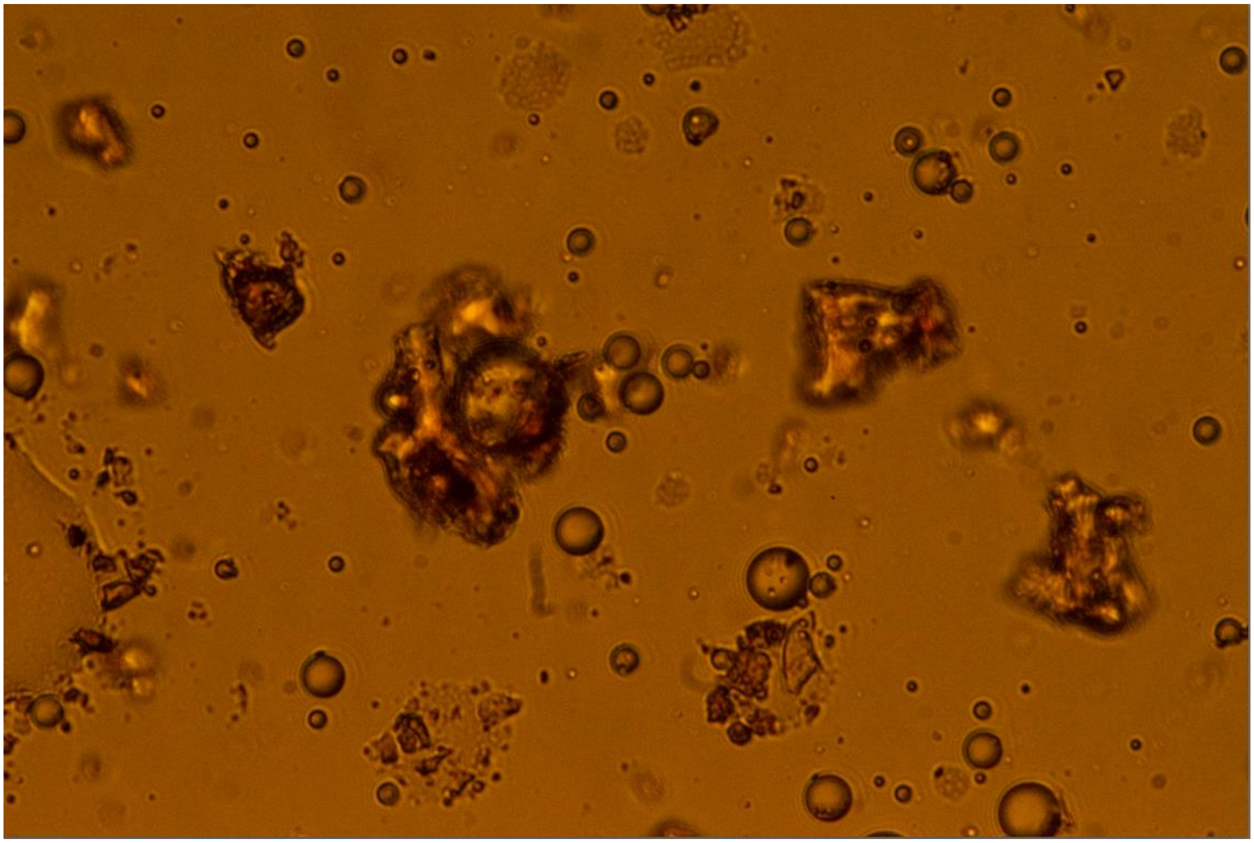
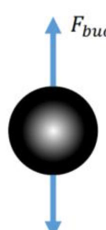


Image of a Combination of Fluids and Particulate within a Brew of Coffee

Now when viewing the image above you obviously see the differences in size for different compounds. One you also see in that under the microscope not all the of the compound remain in focus. This is difference in buoyancy properties for each compound compared to the base liquid water leads to it static or variable position on the slide. Air bubbles which are highly buoyant float to the top of the slide while small solid particles like coffee ground typically fall to the bottom. The most interesting particles are the ones that lie in between. Small fluid molecules like oils are slightly more buoyant then water but do to thermal effects within the coffee they continually move within the coffee liquid and do not rise to the top. These particles are small enough particles they essential balanced between the force of buoyancy forcing them upwards and the forces resisting them from moving up.

$$F_{buoyancy} = (\rho_f - \rho_g) \cdot g \cdot \frac{4}{3}\pi R^3$$



$$(\rho_f - \rho_g) \cdot g \cdot \frac{4}{3}\pi R^3 = 6\pi\mu R v$$

$$\boldsymbol{v = \frac{2}{9} \cdot \frac{g\Delta\rho}{\mu} R^2}$$

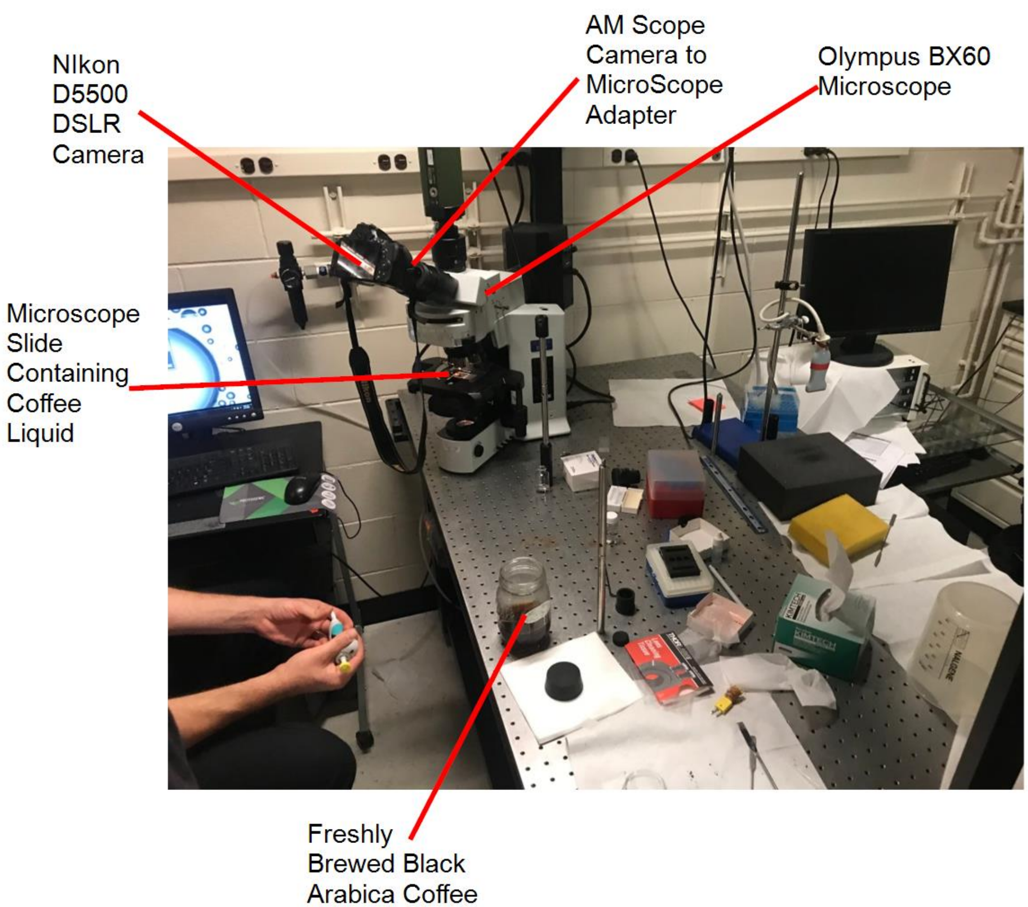
$$F_{drag} = 6\pi\mu R v$$

Image of equation taken from Dr. Borden Slides from Design from Coffee Lecture #8 CU- Boulder

In the equation above v = velocity, R is radius of the ball of fluid g = gravity, μ = dynamic viscosity, ρ = density (f = fluid , g = gas or density of ball of fluid within different fluid). The Stokes Rise Velocity quantifies the speed at which the "ball" of fluid will rise. But as discussed above a particle if small enough can be balanced in between these two forces essentially being "suspensed" with in the base fluid. In the image above you can see many small particles suspended in the fluid.

The most intriguing thing when viewing some of these small particles suspended in the coffee fluid is how they move. If you look at the gif closely on my post online, you can see small particles in the background shaking around randomly and moving about in unexpected manners. This motion is called Brownian motion, which is defined as the random motion of particles suspended within another fluid body that results from the colliding of fast moving molecules within the fluid. Brownian motion is an incredibly intriguing and highly complicated phenomena that helped Einstein through the observation of help prove the existence of atoms and molecules as we know it.

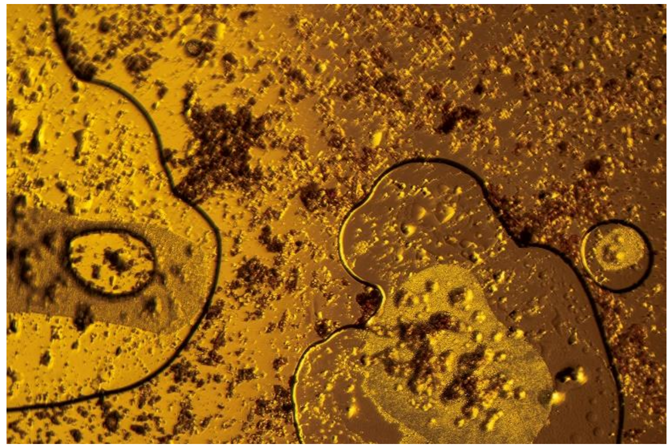
Visual Technique



This image was taken using a multi-step process performed in a Mechanical Engineering Department lab at the University of Colorado Boulder run by Professor Mark Borden. The first step in our experimental process was to brew a cup of coffee. For this test we used a set of dark roast beans from King Supers which was then grinded and brewed using the French Press brewing method. We chose the French Press Method as we now that small solid Coffee bean particulate would be present in the coffee and in turn be viewed under the microscope. Bring the cup of coffee into the lap a very small amount of coffee was a placed on a microscope slide. This slide was then covered with a protective clear sheet and place under the microscope. To enable images and video to be taken through microscope a AmScope Camera to Microscope Adapter lens was used to connect my Nikon D5500 DSLR. Once the adapter was attached to the Camera the adapter could be slid directly into one of the two eyepieces on the Olympus BX60 Microscope. Once the microscope slide is in position and the camera attached to the microscope, a back light under the subject slide was turn on illuminating the coffee fluid and particulate. As no true lens was present on the camera an f stop could not be determined but the microscope lens used to focus on the image is a 20X magnification lens. The full list of camera settings for this image are listed below.

Camera Settings	
Property	Value
Type	Nikon D5500
Shutter Speed	1/ 200 sec
F-Stop	NA (Magnified 30X)
ISO	1000
Focal Length/Lens Type	AM Scope Nikon to Microscope Lens Adapter
Image Size	6000 X 4000
Flash Used	No
Cropped?	No
Distance to Subject	2 mm

As seen in the images below the image was edited with its RAW format in Adobe Lightroom. To reveal the distinct details and textures within the photo I darken the image adding contrast and detail to the shadows. To bring out more distinct shapes within the image and give the strong golden hue to the image, sharpness, clarity, dehaze and highlight values were increased in the image. The edits to the photo hep reveal the different material components within the fluid that are unclear in the in the original photo

Original (left) and Edited (right) Images

Self Reflection and Future Projects

As unique view of common day fluid that a part of many engineers lives, it was incredibly interesting to look at coffee from a distinct scientific perspective. Looking at interactions of the different particulate and liquid conglomerates present in brewed coffee under the microscope help me acknowledge the complex but beautiful world we live in. With its gold like puddles and their interaction with miniscule coffee grounds around it, the image seems to portray the profound worth of coffee has as a resource in our society which like gold interacts with many hands before ending up in our cup. I would like to thank Professor Borden and Professor Pacheo Borden for letting our team using your labs Coffee brewing and microscopic equipment and lab technician Connor Slagle for teaching us how to use our microscope. I would also like to thank team members Robbie Giannela, Max Armstrong, Evan Blake, and especially Byron Pullatasig for their assistance on this project and lastly Professor Hertzburg for allocating the resources for a new DSLR camera to microscope lens adapter. This image and the experiment in general reiterated to me again the important lesson that to find beauty in the world sometimes you just have look close enough!

References:

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