Title: Creating Colorful Flow Patterns in Milk Using Surfactants.

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In this image, I tried to visualize colourful intricate flow patterns in milk mixture with the help of surfactants and food dyes. My goal here was to analyze the flow dynamics and changes in surface tension when surfactants are introduced to the milk mixture. I wanted to analyze what flow-related changes take place when low surface tension entities (surfactants) are combined with high surface tension entities (milk).

For my experiment, I took a shallow plate and poured milk enough to fill the plate. Then I added a few drops of red dye in the horizontal directions and green and brown dye vertically in the middle. I poured half a cup of body wash in a container and dipped a cotton bud (Q-Tip) inside it. And, When I dipped the cotton swab into the milk mixture with food coloring, I witnessed a sudden burst of colors, creating dynamic, flowing patterns as depicted in my picture. The flow physics I was witnessing there was due to the effect of surface tension property of fluids. Milk is an emulsion of proteins, facts and mostly water. Water molecules have strong hydrogen bonding between them, and this leads to the creation of a tight surface layer that corresponds to high surface tension. When molecules having lower surface tension such as surfactants are introduced to the milk mixture, the tight cohesive force due to hydrogen bonding is disrupted which reduces the surface tension of the milk and thus we were being able to see such dynamic burst of colours and flow patterns(Are Surfactants Toxic? The Dangers & Alternatives | Branch Basics, n.d.). Due to the difference in surface tension between milk and surfactant I was able to observe a dynamic colourful flow patterns and this type of flow driven due to the gradient of surface tension is known as Marangoni flow(Chang, n.d.; Schmitt & Stark, 2016). Surfactant was introduced in the middle section of the milk mixture with green and brown dyes, which is why the middle section might have stronger surface tension gradient compared to other regions and the surface tension in the middle section is comparatively lower which might play a role in drawing more fluid there, resulting in more pronounced swirling flow patterns.

For this experiment, for visualizing flow, I have used food-grade dyes, and I sourced these online from amazon. Since, it's a food-grade dye, there is a very little chance of damaging the environment when it was disposed through washing sink. To click my picture, I used an iPhone 15 pro camera and used normal room lighting to click the photo.

The extent of observable area (field of view) captured by the camera is 124.68 sq inch, which is the area of the shallow plate, used in this experiment. I tried to keep a moderate distance between the object and the lens, because I tried to capture all the flow patterns. However, it would have been better if I tried to take the picture from far, but I was having trouble to dip the cotton-bud with surfactant in the milk mixture and click the picture at the same time. To click this picture, I have used iPhone 15 pro. The main camera of this phone has a focal length of 24 mm. The dimensions of the original image and edited image are 3024*4032 and 1989*2052 respectively. This image was clicked with an aperture of 2.2, shutter speed of 1/60 s and ISO of 160. I wanted to create more focus on the dark coloured swirling flow patterns which is why to post-process my image, I cropped it, increased the exposure to 38, reduced shadows and made it -100, and increased the contrast to 65.

The image reveals the development of colourful Marangoni flow patterns by introducing surfactant molecules in milk. I like the contrasting dark and light colour palette of this picture, because it helps to get a more detailed view of the developed flow patterns. However, the picture does not have a good focus, using a digital camera instead of a phone camera would help me adjust the focus a bit better. My experiment aimed to analyze how flow physics changes due to sudden change in surface tension, and it provided a good visual demonstration of that flow physics. I had questions on improving the picture quality. I have fulfilled my intent in this experiment. I would like to learn more about clicking an image with a good focus, and image post-processing to enhance the quality of the image. To analyze vortex structures and flow patterns more precisely, microbead particles can be added in the milk and their movement can be captured using particle image velocimetry when surfactant molecules are introduced.

References:

1. (Are Surfactants Toxic? The Dangers & Alternatives | Branch Basics. (n.d.).
2. Chang, J. K. (n.d.). S Sample Handling Microfluidic Sample Manipulation Sample Pre-Fractionation Biosample Preparation by Lab-on-a-Chip Devices Sample Preparation Microfluidic Sample Manipulation Sample Purification Lab-on-a-Chip Devices for Sample Extractions Sample Purification Using Magnetic Particles.
3. Schmitt, M., & Stark, H. (2016). Marangoni flow at droplet interfaces: Three-dimensional solution and applications. Physics of Fluids, 28(1). https://doi.org/10.1063/1.4939212