

Get Wet Report — Flow Visualization



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Nomenclature

D	= Container diameter, cm
h	= Drop height of the dye above the milk surface, cm
θ	= Camera/light angle above the milk surface, deg
L	= Characteristic length scale of the dye front, m
U	= Representative surface velocity of the dye front, m/s
ν	= Kinematic viscosity of milk, m ² /s
Re	= Reynolds number

I. Introduction

I set out to capture the Marangoni effect: the visible, swirling motion that appears when a surface-tension gradient is introduced across the surface of a fluid [1]. To do this I dropped a red, alcohol-based dye onto the surface of a shallow layer of milk. Milk is well suited to demonstrate the flow in this visualization because it is opaque, similar to water in density, and holds a population of fat molecules that result in any disturbance to the surface being made extremely visible as motion in color. My intent was to reveal the invisible flow created by the redistribution of the milk's surface as the surface tension is disrupted.

1.1 Equipment

The equipment used can be seen in Figure 1. A shallow glass bowl, with a diameter $D \approx 30$ cm, was filled with 2% milk to a depth of roughly 1 cm. 5 drops of red, alcohol-based food dye were introduced at the center of the milk's surface using the dye dropper tip provided.



Figure 1: Experiment Equipment

II. Discussion

2.1 Flow Apparatus

As shown in Figure 2, the dye was released from a drop height $h \approx 15$ cm above the milk's surface with a diameter of $D \approx 30$ cm. The camera and light source were both positioned at an angle $\theta = 60^\circ$ above horizontal, which increased the contrast of the resulting flow pattern against the light background.

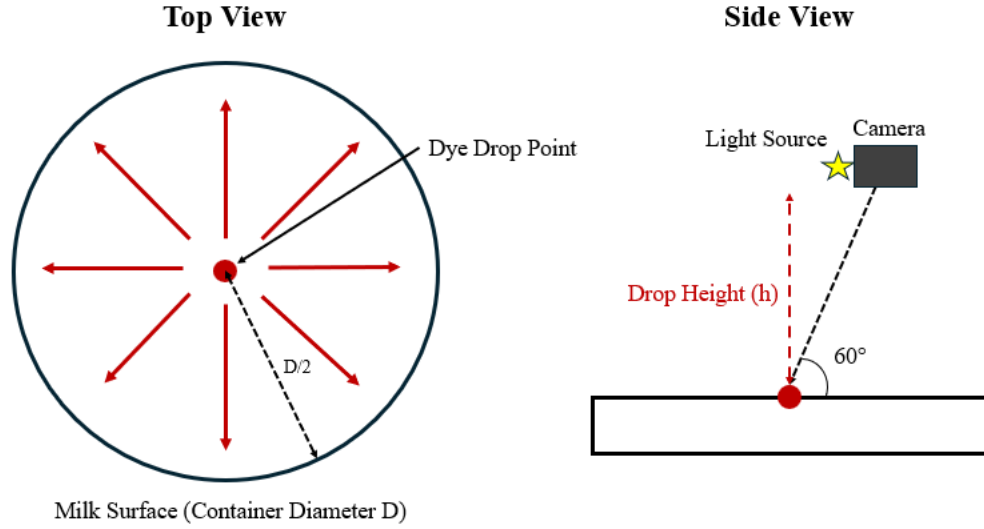


Figure 2: Milk and Dye Apparatus Visuals, dye drop point, camera, and light placement

2.2 Analysis

Milk is made up of mostly water, carrying several fat molecules that are stabilized at the surface by natural proteins, called casein micelles, at a lower surface tension. 2% milk possesses a surface tension of roughly 45–55 mN/m [2]. The alcohol included in the dye has a much lower surface tension, roughly 22 mN/m [3]. When the alcohol dye drop landed at the surface of the milk it lowered the local surface tension of the milk that it interacted with. Because the surrounding milk still possessed its higher surface tension, it pulled outward on the lower surface tension area, causing an imbalance in the surface tension along the surface of the milk called the Marangoni effect [4]. The surrounding fluid drags both the fat molecules and the red dye outward and into the vortical swirls visible in the image. As the alcohol mixes into the milk, the local tension gradient begins to relax and the flow slows, causing the pattern to gradually stall.

To estimate the character of the flow, I used Equation 1 [5].

$$Re = \frac{UD}{\nu} \quad (1)$$

Taking a representative surface velocity $U \approx 5$ cm/s, estimated from the dye's displacement, a characteristic length $D \approx 3$ cm estimated from the radius the dye traveled in the first second, and the kinematic viscosity of 2% milk, $\nu \approx 1.5 \times 10^{-6}$ m²/s the Reynolds number was calculated.

$$Re = \frac{(0.05 \frac{m}{s})(0.03 m)}{(1.5 \times 10^{-6} \frac{m^2}{s})} = 1 \times 10^3$$

The Reynolds number computed above is of the order 10^3 , this indicates a transitional flow as inertial effects are becoming more significant relative to viscous damping effects. This analysis is consistent with the rolling vortices visible in the image rather than a more smooth laminar spreading front of the dye [6]. This type of flow was first described by Scriven and Sterling, who showed that a lower local surface tension is unstable and causes rolling convection at the surface [4,6].

2.3 Visualization Technique

The dye used was an unbranded, concentrated, alcohol-based red resin dye, applied undiluted directly to the milk's surface. This dye was chosen for two reasons: its alcohol content locally lowers the milk's surface tension and its saturated red color provides a strong contrast against the pale milk background. Because the footage was recorded as video rather than a single still, a continuous light source was needed to keep the flow evenly lit across every frame, rather than a single camera flash. The scene was lit using a single continuous LED panel positioned approximately 15 cm above the experiment at an angle of 60° to avoid the glare of external light reflecting directly into the lens of the camera. The bowl was set on a dark surface, in order to reduced external reflections and to keep the viewer's attention on the color motion of the flow.

2.4 Photographic Technique

The field of view of the video was approximately 25 cm across, with the camera positioned 15 cm above the milk's surface. The video was captured using an iPhone 16 Pro Max with a 24 mm, $f/1.78$ main lens, at an resolution of 3840×2160 px (4K UHD) [7]. The main lens has a fixed aperture of $f/1.78$ and the shutter speed and ISO were set by the phone itself [7]. The video was recorded at 60 fps and is played back at 60 fps. Minimal post-processing was done, limited to only a slight increase in exposure to better show the dye pattern against the milk.

III. Conclusion

The video successfully reveals the Marangoni effect: the expanding swirls of red dye make the otherwise invisible surface-tension gradient much easier to see and the structure of the flow vortices is consistent with the transitional Reynolds number computed. I fulfilled my original intent of visualizing this flow and I appreciate how visible the flow is due to the stark contrast of the interacting fluids. I believe the interacting physics between the two fluids is made extremely visible due to this contrast. I am curious how the pattern would change with an added surfactant, such as a drop of dish soap, added alongside the dye, since the alcohol in the dye may only be producing a small amount of the tension gradient that a true surfactant could create. In future experiments I would like to focus on resolving the frame rate issue that occurred while recording by recording at a 120 or 240 fps and cropping in tighter on the drop point. Additionally, in future attempts I would like to try multiple dye colors introduced at different points simultaneously to visualize the interaction between separate flow fronts, and to compare a directly overhead camera angle against the current 60° angle to see which better captures the vortex structure without losing the visuals that side lighting provides.

References

- [1] Buddies, S. (2024, February 20). *Surfactant science: Make a milk rainbow*. Scientific American. <https://www.scientificamerican.com/article/surfactant-science-make-a-milk-rainbow/>
- [2] A. J. Bertsch, “Surface tension of whole and skim-milk between 18 and 135°C,” *Journal of Dairy Research* 50(3), 259–267 (1983).
- [3] KRÜSS Scientific, “Surface Tension Values of Some Common Test Liquids for Surface Energy Analysis,” [surface-tension.de](https://www.kruss.com/en/surface-tension-values-of-some-common-test-liquids-for-surface-energy-analysis/) (accessed September 2026); isopropanol listed at 23.00 mN/m, 20°C.
- [4] L. E. Scriven and C. V. Sternling, “The Marangoni Effects,” *Nature* 187, 186–188 (1960).
- [5] *Report guidelines*. Canvas - University of Colorado Boulder. (2026, September 7). <https://canvas.colorado.edu/courses/143429/assignments/2869546#submit>
- [6] C. V. Sternling and L. E. Scriven, “Interfacial turbulence: Hydrodynamic instability and the Marangoni effect,” *AIChE Journal* 5, 514–523 (1959).
- [7] *iPhone 16 Pro - Tech Specs*. Apple Support. (n.d.). <https://support.apple.com/en-us/121031>