Layers of Honey and Dye

Tandralee Chetia, Team Second, MCEN 5151 Flow Visualisation

November 10, 2023

1 Introduction

This study examined the dynamic interplay of colored dyes within honey, seeking to capture both scientific insights and aesthetic allure. The methodology involved pouring honey into a petri dish, layering it with red, yellow, and blue dyes, and further enriching the composition with additional honey. The dish was then intentionally tilted to elicit distinctive visual effects.

The resulting aesthetic patterns showcased in the imagery are a consequence of the layered interaction between honey and colors, the controlled tilt of the dish, and the subsequent dispersion of dyes within the viscous honey medium. This visually intricate experiment was captured by a Canon Rebel T3i DSLR camera equipped with a zoom lens. The convergence of scientific methodology and artistic expression aimed to illuminate the captivating beauty in the harmony of colors and honey within a controlled environment.

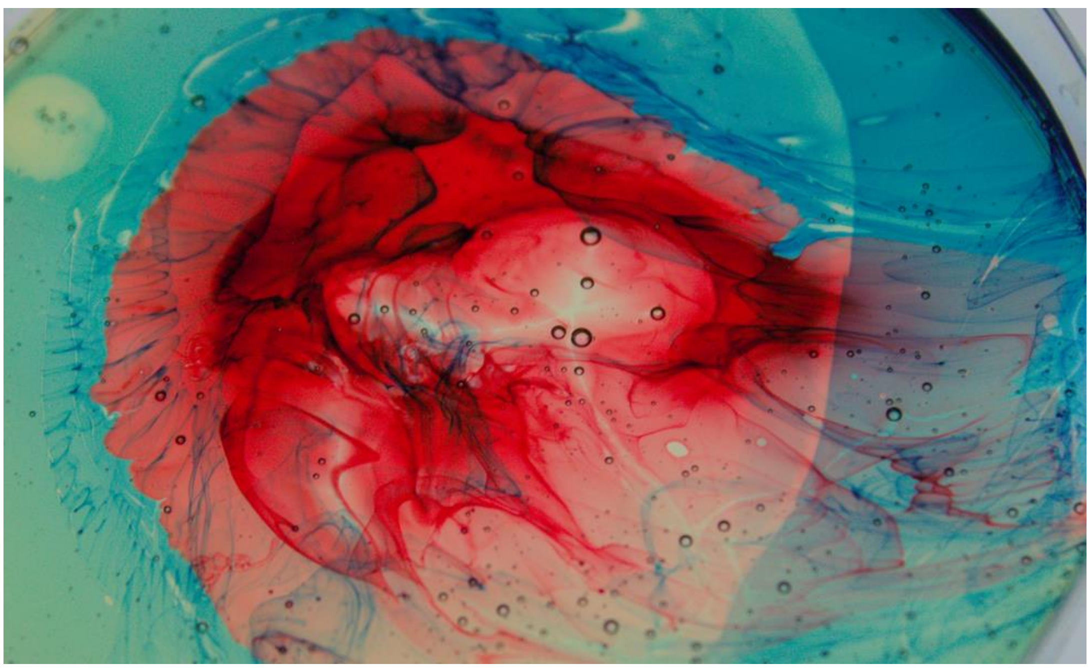

Fig 1: Honey and food dyes create an aesthetic pattern in a petri dish

2 Flow Phenomenon

When a thin stream of honey is poured into a dish from a height, a coiling effect is observed. Multiple forces come into play during the coiling, as a part of the flow is stretched by gravity, and the coil buckles and bends like a rope[1]. The combination of the coiling effect of honey and the dissipation of less viscous dyes into a more viscous fluid under directional force leads to complex patterns, as seen in the picture. Some of the fluid dynamic phenomena are explained in the following paragraphs.

2.1 Viscous Jet Buckling:

A non-Newtonian fluid is a fluid that does not follow Newton's law of viscosity, that is, it has variable viscosity dependent on stress. In non-Newtonian fluids, viscosity can change when under force to either more liquid or more solid. Non-newtonian viscous fluids such as honey exhibit viscous jet buckling in which the stream of honey hitting a flat surface buckles like a slender column[1]. Under the appropriate physical conditions, a highly viscous fluid such as honey maintains a state in which oscillations in the form of coiling or folding are observed in that region of the jet close to the stagnation surface. These oscillatory coiling and folding effects lead to the formation of vortex ring-like patterns in the image. Food dyes diffuse through the ring-like patterns to create visually stimulating patterns. The diffusion process is slow due to the resistance offered by the viscous forces in honey.

2.2 Cohesive and Adhesive Forces:

Cohesive forces make similar particles or surfaces stick together whereas adhesive forces make dissimilar particles or surfaces cling to one another. Surface tension is directly related to cohesion. Since the surface tension of honey is low, it has lower cohesion forces. However, honey easily sticks to the surface implying a higher adhesive force. This adhesive force binds honey easily to other food dyes and the lower cohesive force results in the separation of the honey ring from layers of honey[2].

2.3 Non-Newtonian Fluid Dynamics:

Wilson *et al.*[3] discussed a turbulent model applicable to non-Newtonian fluids, emphasizing heightened viscosity effects at small time and length scales within dissipative micro-eddies. According to their analysis, this predicts a thickening of the viscous sub-layer, potentially leading to increased throughput velocity and facilitating drag reduction. This proposed model aligns with our observed vortex-type structures in the image, a phenomenon commonly associated with turbulent flows. The presence of these structures suggests a connection between the enhanced viscosity effects described by Wilson et al. and the dynamic patterns captured in our experiment.

3 Methods

The materials used in the experiment are as follows:

- An 8 cm petri dish
- DSLR Camera
- Backlight sheet
- Honey
- Food coloring dyes: yellow, red, blue

3.1 Procedure

1. Preparing the Experiment: We began by placing the petri dish on the light sheet. A layer of honey was then poured over the petri dish, followed by a layer of blue dye. Another layer of honey was poured, resulting in the formation of honey coils and vortices within the layer. Finally, a layer of red dye was added, and the dish was tilted to cover the entire dish in honey and dye layers

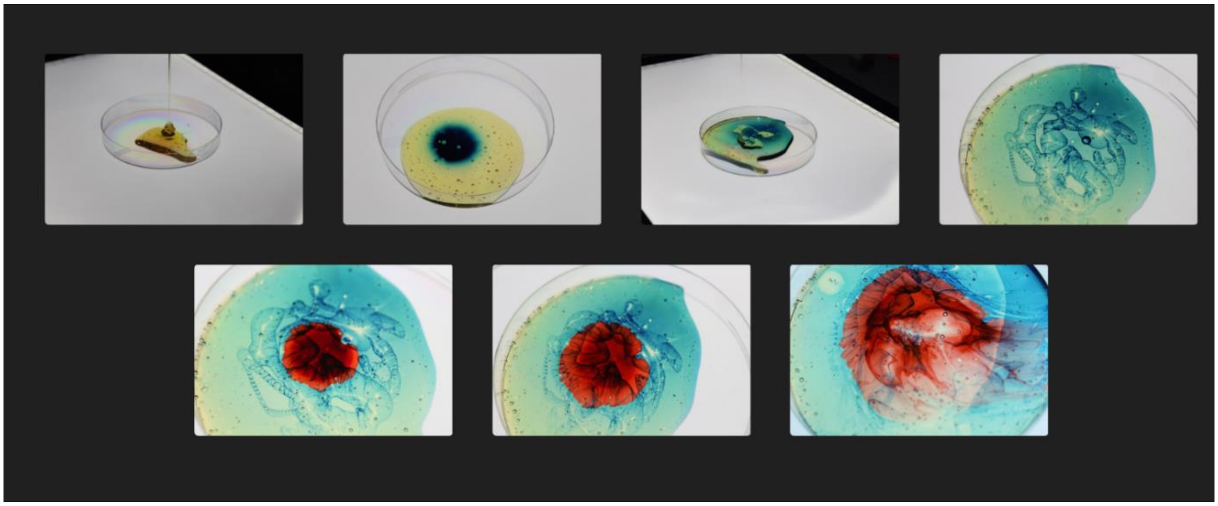

Fig 2: Step-by-step process of pouring the honey and colored dyes

2. Camera Setup: The camera was set to maximum zoom, and the flash was turned off. Photos were captured after every step of the experiment in manual focus mode, with auto shutter and ISO settings

3.2 Camera and Lighting

The camera used was a Canon Rebel T3i 600D 18.MP Digital SLR Camera with an 18-55 mm zoom lens. The camera settings for the final image are as follows:

Table 1: Camera Settings

Lens	Canon EF-S 18-55mm f/3.5-5.6 IS II
Focal Length	55 mm
Aperture	f/5.6
Exposure	1/80
Focus Distance	0.31 m
ISO	1000

The lighting used was an A4-sized Ultra-Thin Tracing Light Box with a USB Port. It has options for adjustable brightness and uses an LED light source.

Fig 3: Ultra-thin Light Box

3.3 Post-Processing

Post-processing was done in Darktable to crop out the image to get the desired frame. The pixels in the original image are 5344 x 3516 (pixels) and those in the final edited image are 990 x 599 (pixels).

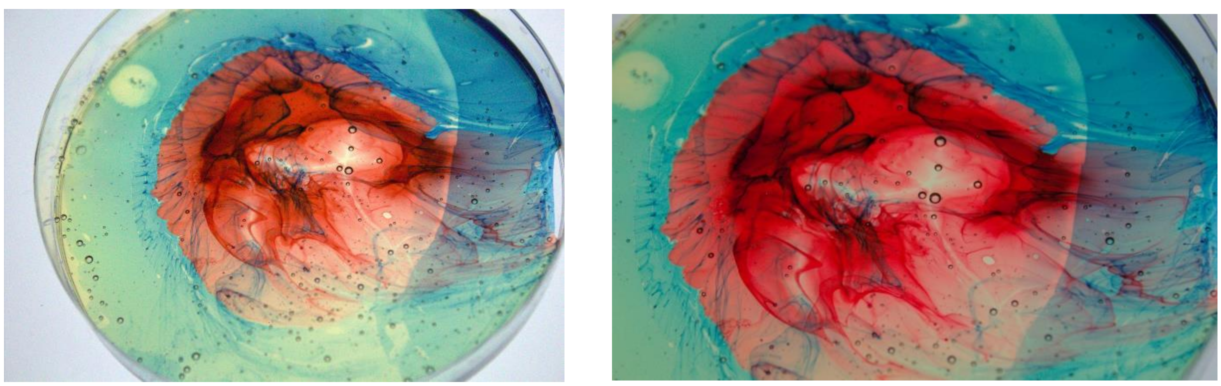

Fig 4: a) Original Image b) Final edited image

4 Observations

The photograph effectively captures the intricate formation of viscous rings, illustrating the oscillatory coiling and folding effects in the honey stream. These visual patterns, resembling vortex structures, highlight the complex interplay between highly viscous honey and the dissolving dyes. The dissipation of the less viscous fluid within the honey adds a layer of elegance to the overall composition.

The captured image reveals fascinating scientific details, showcasing the formation of viscous rings, vortices, and the interaction of cohesive and adhesive forces. The outcome not only met but exceeded my initial expectations, presenting a visually striking depiction of dynamic fluid phenomena.

A primary challenge faced during this exploration was capturing both honey coiling and dye dissipation within a single frame. While the results are compelling, future efforts will focus on refining this aspect through careful planning in terms of timing and frame selection. The goal is to enhance the clarity of the captured phenomena for a more cohesive visual narrative.

5 Conclusion

Beyond its aesthetic appeal, the experiment holds significance by contributing to our understanding of non-Newtonian fluid behavior. The observed phenomena, including viscous ring formation and the impact of cohesive and adhesive forces, offer valuable insights into fluid dynamics. This dual perspective, blending artistic exploration with scientific inquiry, underscores the potential for interdisciplinary approaches to communicate complex scientific concepts in a visually accessible manner.

In summary, this exploration has been a blend of artistry and scientific curiosity, unveiling nuanced details in fluid dynamics. The image stands as a testament to the potential for visually striking representations to convey scientific complexities. It fuels a commitment to future endeavors that bridge the gap between art and science, fostering a deeper appreciation for the intricacies of fluid dynamics.

Acknowledgements

I would like to acknowledge the efforts of my team members, Rachel Marbaker and Riley Menke, as we recorded the images together.

References

[1] Cruickshank, J. O., & Munson, B. R. (1981). Viscous fluid buckling of plane and axisymmetric jets. *Journal of Fluid Mechanics*, 113(1), 221. https://doi.org/10.1017/s0022112081003467

[2] Betts, A. D. (1928). Some physical properties of honey. *Bee World*, 9(11), 175–176. https://doi.org/10.1080/0005772x.1928.11096280

[3] Wilson, K., & Thomas, A. (1985). A new analysis of the turbulent flow of non-newtonian fluids. *The Canadian Journal of Chemical Engineering*, 63(4), 539–546. https://doi.org/10.1002/cjce.5450630403