Q&A: Illuminating physics in the kitchen

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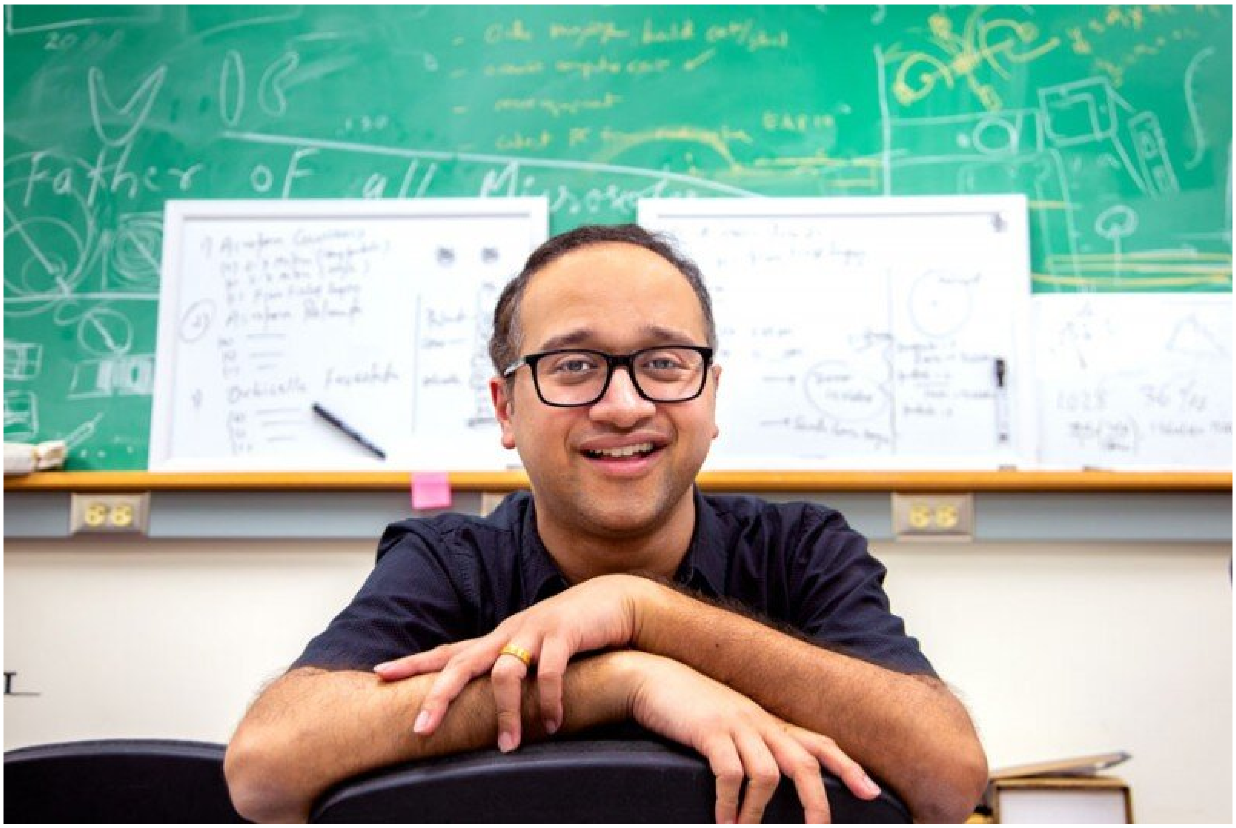

Vivek Prakash is an assistant professor of physics at the University of Miami. Credit: Joshua Prezant/University of Miami

It's a place most of us have to visit daily. Sometimes eagerly. Sometimes begrudgingly. But the kitchen also can be a place of scientific discovery.

Many scientists, engineers, and researchers have uncovered critical concepts while cooking that have helped improve transportation, manufacturing, and the food industry. Chief among these are phenomena that have helped expand the field of fluid mechanics, a subset of physics that studies the flow of liquids or gases.

Fluid mechanics research explains why airplanes lift into the air, how some cars speed along the road more efficiently, how engines utilize power, and how to create carbonated drinks.

So during the COVID-19 pandemic, when University of Miami physics assistant professor Vivek Prakash and three other fluid mechanics experts were working from home, the four decided to explore the many advances in their field that can be found in the kitchen. And this week, the team—which includes Arnold Mathijssen of the University of Pennsylvania, Maciej Lisicki at the University of Warsaw, and Endre Joachim Mossige at the University of Oslo—published an article in the *Reviews of Modern Physics* journal about all the wonders of flow in the kitchen, organized like a menu.

"At every stage of preparing a meal, we point out the fluid dynamics concepts—including those found in the kitchen sink, mixing drinks and cocktails, boiling pasta, making desserts like chocolate mousse, and making coffee and tea," said Prakash. "These are things being studied by scientists in great detail; and once we understand the phenomena better, we can use this knowledge to create other applications."

Within the article, the four authors describe how recent innovations in the field of fluid dynamics have affected food science and how these culinary marvels have led to new inventions in many other fields, including manufacturing, biomedicine, and nanotechnology. In fact, the entire field of surface science was established from the kitchen sink, Lisicki noted.

"Historically, advances in fluid mechanics have led to better food, and innovations in cooking have inspired studies in fundamental science," Prakash said. "Since the kitchen is so accessible, it can also bring people from different backgrounds together and make science more diverse and inclusive," Mathijssen added.

In the following Q&A, Prakash, who joined the College of Arts and Sciences in 2020, shares input on everything that flows in the kitchen. He earned his doctorate studying the behavior of bubbles and turbulence at the Physics of Fluids group at the University of Twente in the Netherlands, which is one of the foremost fluid mechanics groups in the world.

What's the purpose of bubbles in wine?

One special aspect of sparkling wine or champagne is the presence of rising bubbles. It is a pleasing and beautiful sight, and the bubbles also determine the flavor and aroma of the drink.

What fluid dynamics concept does this represent?

Bubbling, effervescence, or fizzy process, which is the continuous release of dissolved carbon dioxide gas in the form of bubbles. In addition to producing alcohol, the fermentation process for wine and champagne also produces excess carbon dioxide, which gets dissolved in the wine.

What are other applications of this concept?

The bubbling process has important industrial applications in bubble reactors that are used to manufacture chemicals and steel.

How can we take advantage of this to make food or drinks taste better?

A fundamental knowledge of the bubbling process can help design very specific glass shapes and their surfaces to bring out the best characteristics of the different sparkling wine and champagnes. Some glass manufacturing companies are already doing exactly this, bringing together physicists, engineers, and wine connoisseurs.

So is that why we use tall narrow champagne flutes?

Champagne bubbles are light, so they go up in one swarm, reach the surface, expel gas and pop, while some bubbles go to the side in a vortex-like shape. You should have a constant supply of bubbles to mix the champagne, which makes it taste better. And as the bubbles keep spreading, they also release odor molecules, which is why champagne or sparkling wine has a bouquet. French physics professor Gérard Liger-Belair published several papers on this concept of effervescence, so there are many details to understand. But the shape of a champagne glass is optimized for the best taste.

What's the purpose of foam in beer?

They enhance the visual appeal and give rise to an enjoyable mouthfeel experience by providing a creamy texture.

What fluid dynamics concept does this represent?

Bubbles and foams. When beer is first poured in a glass, the bubble production rate exceeds their bursting rate. So, the bubbles accumulate on the surface and create layers of bubbles called "foam."

What are other common applications of this concept?

Foams are widely used in the food and beverage industry to make fizzy drinks, coffee drinks, like a cappuccino, and several desserts such as ice creams and cakes. Beyond the food industry, since foams also have properties that are both solid-like (stiffness) and liquid-like (ability to flow), they are also used in cosmetics, surface treatment, firefighting, and building materials.

How can we take advantage of this to make food or drinks taste better in our own cooking?

Foams can often provide a creamy texture. So, depending on the food item you are preparing, they could be a complementary addition, like if you add a layer of whipped cream to a cake.

That circle you see in the bottom of the sink when you turn on the tap. What fluid dynamics concept does this represent?

The kitchen tap is a source of several interesting fluid dynamics phenomena. When the water jet hits the sink surface, the water spreads outward and forms a thin disk. The edge of this disk is visible as a circle. Just beyond the disk, there is a jump in the water level, this is called the hydraulic jump. Leonardo da Vinci first studied this phenomenon, but this is still not completely understood theoretically and remains an active research topic.

What are other common applications of this concept?

This concept has applications to any industrial/commercial setting where a water jet is used to clean a dirty surface, such as a car wash or in a dishwasher.

Those worm-like lines that you see in a cup or pot when you boil water. What fluid dynamics concept does this represent?

The subtle squiggly structures that you see near the surface of a heated pan of water are plume structures, which indicate that what's happening is heat transfer by convection, or Rayleigh-Benard convection. In the video, you can observe plume structures at the bottom of the cup. These plumes are essentially hot (and light) parcels of fluid that rise to the top and transport heat.

What are other common applications of this concept?

In addition to cooking, heat transfer by convection is important in many applications. In nature, it is important in astrophysics and geophysics—plumes transport heat in the earth's mantle. In engineering applications, it is important in metallurgy, chemical engineering, and nuclear engineering.

How can we take advantage of this to make food or drinks taste better in our own cooking?

Plumes play a role in all convective heat transport. So, heat transfer engineers, who work to create and refine kitchen appliances, apply these concepts to design more efficient devices that can cook food faster, save electricity, and make the food taste better.

More information: Arnold J. T. M. Mathijssen et al, Culinary fluid mechanics and other currents in food science, *Reviews of Modern Physics* (2023). DOI: 10.1103/RevModPhys.95.025004

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