The math of brewing a better espresso



Enlarge / A new mathematical model sheds light on the optimal brewing process for espresso.
Five Senses Coffee (Australia)

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Skilled baristas know that achieving the perfect complex flavor profile for a delectable shot of espresso is as much art as science. Get it wrong, and the resulting espresso can taste too bitter or sourly acidic rather than being a perfect mix of each. Now, as outlined in a new paper in the journal Matter, an international team of scientists has devised a mathematical model for brewing the perfect cup, over and over,

while minimizing waste.

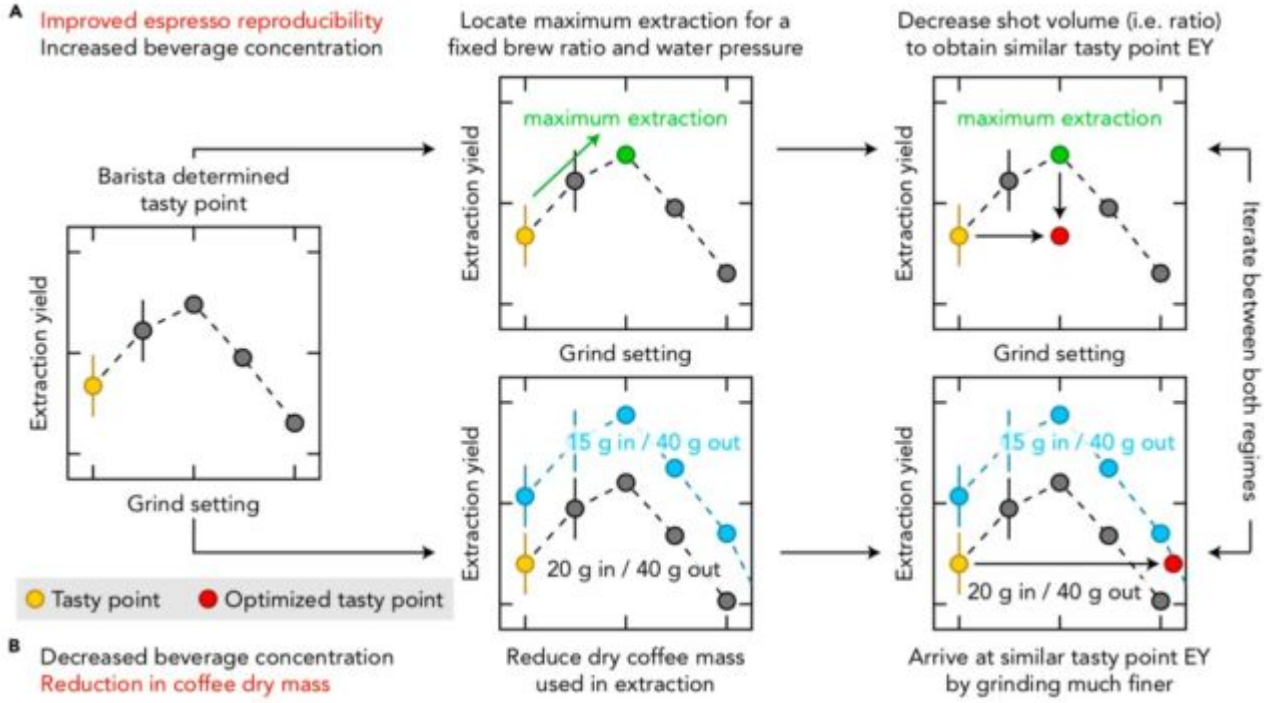
“A good espresso beverage can be made in a multitude of ways,” said co-author Christopher Hendon, a computational chemist at the University of Oregon. “The point of this paper was to give people a map for making an espresso beverage that they like and then be able to make it 100 times in a row.”

There’s actually an official industry standard for brewing espresso, courtesy of the Specialty Coffee Association, which sets out strict guidelines for its final volume (25-35mL, or roughly one ounce) and preparation. The water must be heated to 92° to 95°C (197° to 203°F) and forced (at a specific pressure) through a bed of 7 to 9 grams (about a quarter of an ounce) of finely ground coffee over the course of 20 to 30 seconds. But most coffee shops don’t follow this closely, typically using more coffee, while the brewing machines allow baristas to configure water pressure, temperature, and other key variables to their liking. The result of all those variations in technique is a great deal of variability in quality and taste.

“Most people in the coffee industry are using fine-grind settings and lots of coffee beans to get a mix of bitterness and sour acidity that is unpredictable and irreproducible,” said Hendon, a computational chemist at the University of Oregon. “It sounds counterintuitive, but experiments and modeling suggest that efficient, reproducible shots can be accessed by simply using less coffee and grinding it more coarsely.”

The flavors in espresso derive from roughly 2,000 different compounds that are extracted from the coffee grounds during brewing. So Hendon and his colleagues focused on building a mathematical model for a more easily measurable property known as the extraction yield (EY): the fraction of coffee that dissolves into the final beverage. That, in turn, depends on controlling water flow and pressure as the liquid percolates

through the coffee grounds. Modeling the actual grounds—a form of granular media—proved much too daunting. “You would need more computing power than Google has to accurately solve the physics and transport equations of brewing on a geometry as intricate as a coffee bed,” said co-author Jamie M. Foster, a mathematician at the University of Portsmouth in the UK.



Enlarge / Schematic illustrating two strategies to improve espresso reproducibility.
Cameron et al./Matter

Instead, Hendon, Foster, and their colleagues based their model on how lithium ions propagate through a battery’s electrodes, which they liken to how caffeine molecules dissolve from coffee grounds. A bunch of simulations and several thousand experimental shots of espresso later (courtesy of Frisky Goat Espresso in Brisbane, Australia), the authors arrived at some surprising findings.

For instance, conventional wisdom holds that a fine grind is best, since more surface area of the resulting tamped-down coffee bed is exposed to the hot water, thus boosting the extraction yield. But this new model, and the group’s experiments, revealed that if coffee is ground too finely, it can clog the coffee bed, thereby reducing extraction yield.

It’s also a big factor in the variability in taste. The researchers concluded that there are better methods for maximizing extraction yield, such as using fewer beans and coarser grinds with a bit less water. And the Specialty Coffee Association might be interested to hear that brew time is largely irrelevant.

> *“Though there are clear strategies, there is no obvious optimal espresso point.”*

Coffee is a multi-billion dollar global industry. In 2015 alone, according to the authors, just the US market accounted for some 1.5 million jobs and generated $225.2 billion in revenue. But climate change (along with changing customer tastes) is threatening coffee producers, sparking interest in finding ways to maintain quality while cutting costs and reducing waste. This new model should lend insight into precisely how one might accomplish that, although there is still some wiggle room to account for subjective personal preferences in the flavor profile.

“Though there are clear strategies to reduce waste and improve reproducibility, there is no obvious optimal espresso point,” said Hendon. “There is a tremendous dependency on the preferences of the person producing the coffee; we are elucidating the variables that they need to consider if they want to better navigate the parameter space of brewing espresso.”

Based on a year-long trial waste reduction protocol set up at a local specialty coffee shop in Eugene, Oregon, the authors estimate that a small cafe could save several thousand dollars per year by reducing the mass of coffee used, while the industry as a whole could conceivably save as much as $1 billion per year.

“The real impact of this paper is that the most reproducible thing you can do is use less coffee,” said Hendon. “If you use

15 grams instead of 20 grams of coffee and grind your beans coarser, you end up with a shot that runs really fast but tastes great. Instead of taking 25 seconds, it could run in 7 to 14 seconds. But you end up extracting more positive flavors from the beans, so the strength of the cup is not dramatically reduced. Bitter, off-tasting flavors never have a chance to make their way into the cup.”

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