Cooking Flawless Pasta

Scientists have pinpointed energy-efficient ways to cook *al dente* pasta and developed an infallible recipe for the perfect *cacio e pepe* sauce.

By **Katherine Wright**

A bowl of steaming hot pasta covered in your favorite sauce and dusted with a healthy dose of parmesan cheese comes high on the list of ultimate comfort foods. But cooking that pasta to perfection can be more difficult than seemingly simple recipes imply. Now two separate teams of researchers have explored two different aspects of executing a flawless dish. In one study, Phillip Toultchinski and Thomas Vilgis of the Max Planck Institute for Polymer Research, Germany, studied whether perfectly *al dente* spaghetti could be prepared in a more energy-efficient way [**1**]. In a second study, Matteo Ciarchi and Daniel Busiello of the Max Planck Institute for the Physics of Complex Systems, Germany, Giacomo Bartolucci of the University of Barcelona, Spain, and colleagues developed a recipe for making perfect *cacio e pepe*, a three-ingredient cheese sauce that is surprisingly easy to mess up [**2**]. "It is very difficult to make this sauce," says Busiello. "You are almost always doomed to fail."

A bowl of pasta *cacio e pepe*, a traditional Italian sauce made with cheese and black pepper.
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The study by Toultchinski and Vilgis was inspired by a brouhaha over a 2022 Facebook post by physics Nobel laureate Giorgio Parisi. In that post, Parisi suggested that chefs could reduce the energy needed for cooking pasta using a "heat-off-lid-on" method. In this method, after the pasta is added to boiling water, the heat source is turned off and the pot is covered with a lid. The pasta is left to cook in slowly cooling water. Studies indicate than a significant fraction of the cooking energy could be saved this way. But chefs questioned whether this method could achieve *al dente* pasta—pasta that is soft on the outside and crunchy at its core.

To put a scientific answer to this question, Toultchinski and Vilgis studied three methods of cooking pasta. The first method is the most familiar one: Add pasta to boiling water and keep that water roiling until the pasta is perfectly cooked. The second method, which the team terms presoaking, involves soaking the pasta in cold water for one and a half hours prior to cooking. The soaked pasta is then cooked in boiling water. The third method was Parisi's heat-off-lid-on method. For all experiments, the team used the same pot and the same amounts of dry durum-wheat spaghetti (150 g) and water (1.5 l). For the heat-off-lid-on method, the lid was a sheet of aluminum foil.

Toultchinski and Vilgis show that the heat-off-lid-on method used the least energy, while the traditional method used the most. Roughly 60% of the energy needs for cooking pasta comes from keeping the water roiling while the pasta cooks, so eliminating this step leads to significant energy saving, Vilgis says. Presoaking also considerably reduced the energy needs, as it lowered the cooking time from 13 minutes to 3 minutes. "Presoaked pasta cooks very fast," Vilgis says. But do all three methods achieve perfect *al dente* pasta?

To explore this question, the duo studied the mechanical properties of the pasta after it was cooked. These tests put numbers to the chewiness, gumminess, and hardness of the pasta, properties that all impact how the food feels when chewed. The results show that, overall, traditionally cooked pasta had the firmest texture and exhibited the greatest resistance to deformation. “It has a ‘crunchy’ texture,” Vilgis says. Both the other two cooking methods produced gluey pasta that was softer and mushier. For the heat-off-lid-on method, *al dente* pasta could be achieved, but the outside of the pasta was soggy. “The mouthfeel of the pastas is very different,” Vilgis says.

Vilgis says that the difference in the mechanical properties of the pastas from the three methods comes from differences in what happens to the proteins and starches in the pastas during cooking. For the traditional method, the cooking process is gradual. As water diffuses from the outside inward the proteins partially swell and cross-link and the starch gelatinizes and swells with water. Close to the core, the water content rapidly decreases, leading to less cross-linking and swelling. Right at the core, the proteins and starches are untouched by water, remaining in their glassy and semicrystalline phases, respectively.

The heat-off-lid-on method leads to a similar profile for protein and starches within the pasta, but the longer cooking times leach starch from the pasta into the water, giving its outside a stickier feel. The *al dente* core is also much thinner with some cross-linking and gelatinization occurring, leading to overcooking. Similar results were seen for the presoaked pasta, but the *al dente* core no longer existed. The cross-linking of the proteins was also much weaker. Vilgis says that while these results show that pasta can be cooked in a more energy-efficient way, when it comes to taste and texture, there is no substitute for the tried-and-tested method. “If you want perfect *al dente* pasta, you have to cook it the traditional way,” he says.

“It’s really great that this simple topic of how to cook pasta can bring in so much science,” says David Fairhurst, a soft-matter researcher at Edinburgh University, UK, who has also studied the energy efficiency of different methods of cooking pasta [**3**, **4**]. He notes the new work by Toultchinski and Vilgis brings in mechanical testing that wasn’t previously done. Rather than just doing a taste test, “they’ve taken a scientific approach to figuring out how the pasta ends up being different mechanically,” he says. “I’ve not seen that done before.” Fairhurst notes that in the taste tests he and his group performed, the presoaked pasta got more of a thumbs up than Toultchinski and Vilgis did. “If you like it, you like it.” he says.

The second pasta study by Ciarchi, Busiello, Bartolucci, and colleagues focused on how to make a popular but tricky sauce called *cacio e pepe*. For this sauce, pecorino cheese is mixed with pasta water and black pepper to make a glossy emulsion that coats the pasta in cheesy goodness. The sauce, however, is easy to get wrong—the cheese can become stringy or the sauce can be too runny.

In experiments, the team mixed grated pecorino cheese, gelatinized cornstarch, and water. When the cooking temperature was above 70 °C and the starch below 1%, the researchers found that the cheese became stringy, with the sauce forming a so-called mozzarella phase. Adding more cornstarch increased the stability of the sauce, but when the weight went above 4%, the sauce turned into a stiff gel that had an unpleasant mouthfeel.

For the perfect sauce, the researchers found that they needed 2%–3% cornstarch by weight. This amount of starch is above that typically found in the water where the pasta is boiling, which is why making the sauce can easily fail. The researchers recommend that, instead of using pasta water, chefs use a solution containing cornstarch. They find that a sauce made from such a solution is extremely stable and can be reheated to 80–90 °C without any cheese agglomeration. “This ensures the dish can be served hot, allowing diners to enjoy it at its best,” the team says.

“The team came up with a really practical recipe to getting the perfect sauce every time,” Fairhurst says. He adds that these kinds of studies—where physicists apply their knowledge to food problems—can really help consumers engage in science. “It’s everyday science you can do in the kitchen; you can’t do that with particle physics problems.”

As to what role the starch plays in stopping the denaturation of the cheese proteins and the formation of the mozzarella phase, the researchers don’t yet have an answer, Ciarchi says. One possibility is that when there is enough starch, the network it creates in the water has holes sufficiently far apart to stop the cheese proteins from getting close enough to agglomerate. But Ciarchi and Busiello both say that their model could fit other possibilities. Bartolucci agrees. “The interactions between the starch and the cheese proteins are collective phenomena that involve the interactions of many different species,” he says. “It’s a very complex problem.”

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