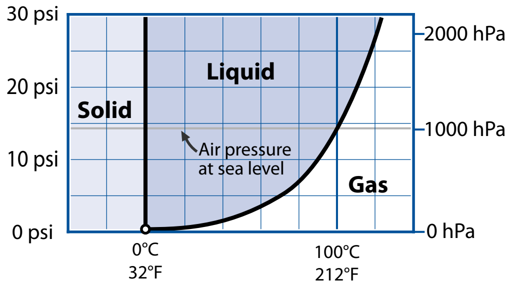
High-Pressure Situations

As I've learned more about food science, I've come to realize just how critical water is! It impacts cooking in so many different ways: transmitting heat via steam, dissolving trace minerals to change how gluten forms and yeast multiplies in breads, and altering textures in cookies (chewy or crispy) and dried foods. Water is *everywhere*.

One water variable that doesn't change much in the kitchen is its boiling point. Adding salt can increase its boiling point by a few degrees, but what could we do if we raised it even more? If most heat-related reaction rates in cooking roughly double with every 18°F / 10°C increase, then increasing water's boiling point from 212°F / 100°C to 230°F / 110°C should, in theory, cut braising times in half and cook rice twice as quickly. Raising it again, to 248°F / 120°C, would slash cooking times by up to a whopping 75%. And this is exactly what happens under pressure.

How much pressure, you ask? There's a nifty type of science chart called a *phase diagram* that shows a substance's phase—solid, liquid, or gas—at various pressures and temperatures. Here's one for water at the various temperatures and pressures normally found in the kitchen.



Phase Diagram of Water for the Kitchen

A quick primer on how to read this: consider the line at 14.7 psi (1,013 hPa—that's hectopascals) equal to one atmospheric pressure or what you'd experience at sea level on an average day. The freezing point at one atmosphere is 32°F / 0°C; the boiling point is 212°F / 100°C. Move that line down a little bit to 12.1 psi (834 hPa), equivalent to an altitude of 5,280 feet (1,609 meters) above sea level, and you'll see why water boils at 203°F / 95°C in Denver, Colorado. Go up to 30 psi (2,070 hPa), and *voilà*! Water boils at roughly 248°F / 120°C. This is the science behind what makes pressure cookers amazing. I know, I know, getting excited by the idea of keeping water liquid at a higher temperature may seem strange, but trust me, you'll love what it can do.

What else happens when we increase pressure? Water is more complicated than this simple phase diagram suggests, because nothing in the kitchen is a pure substance. Your salt has trace minerals in it—probably silica too. Table sugar isn't actually 100% sucrose; a spoonful of it includes ash, proteins, and inorganic impurities. And water, even purified distilled water, isn't actually 100% H_2O: there's gas dissolved in there. With pressure, we can dissolve more gas into liquids like water for both fun and useful purposes.

Food is always mixtures of solids, gases, and liquids. (Actually, food is almost always mixtures of mixtures, and figuring out how to separate them has its own challenges, as we'll see later in this chapter.) We talked about *humidity*—dissolved water vapor in air—in the previous chapter, but what do we call dissolved air in water? It's what fish breathe, but we don't even have a word for it!

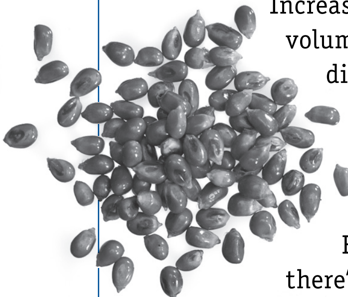
Gases dissolve into liquids all the time—think carbonated drinks, or the small bubbles you see when heating water to boil—and changes in pressure change how much gas can be dissolved. This is known as *Henry's Law*: essentially, the higher the pressure of a gas above a liquid, the more soluble that gas becomes. (Huh. There's no Potter's Law yet. Probably too late; all these laws seem to have been named about two centuries ago. The English chemist William Henry came up with this one in 1803.) You can dissolve gases into foods to make foams like whipped cream (and Aero chocolate!), and you can use a pressurized container to make wild things like carbonated fruit.

In the following sections, we'll take a look at how to cook with pressure cookers and cream whippers, covering what they are and how to use them.

Dropping the temperature of a liquid *increases* the amount of gas that will dissolve into it. If you're trying to saturate gas into a liquid, cool the liquid down first.

Why does popcorn pop?

Because of pressure! Popcorn kernels have the magic combination of a tough, airtight hull and a moist interior (~13% water) that explodes when heated. Most grains have this combination: amaranth, quinoa, and sorghum also pop. Increasing temperature in a fixed volume also increases pressure, with different results.

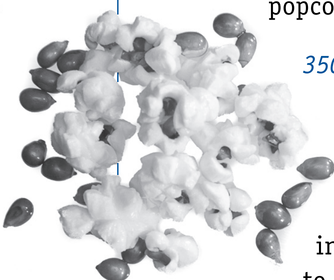


Below 300°F (150°C)

As kernels heat up, water inside them also heats up. Because the water can't boil—there's very little space for the water to expand into water vapor—the pressure inside the kernel increases.

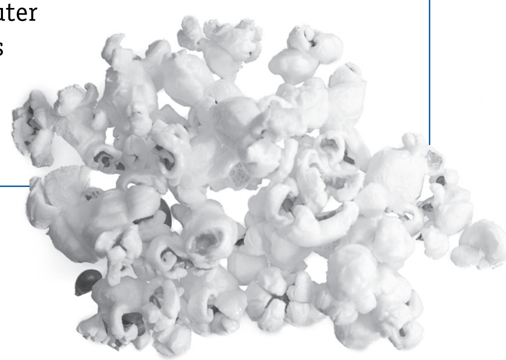
310–340°F (155–170°C)

Some weak kernels rupture, but there's not enough pressure built up to explode the kernel's starches out very far, making small, not-really-delicious popcorn pieces.



350°F (177°C) and up

At 135 psi—nine times atmospheric pressure!—the kernel's hull ruptures. With the drop in pressure, the water inside instantly boils and converts to steam, expanding ~1,500-fold and dragging the outer layer of starches along for the ride.

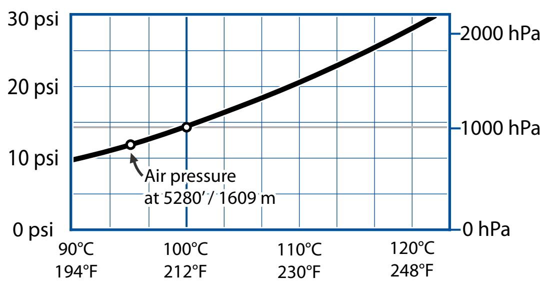


Pressure Cookers

Pressure cookers are like an old-fashioned version of the microwave: a convenient appliance that speeds up cooking. Our grandparents used a manual version, essentially fancy pots with locking lids that went on the stovetop. Manual versions are still available today—now enhanced with safety locks and over-pressure release valves to prevent accidents—and are a worthwhile investment for the serious pressure cooker enthusiast. Manufacturers also make electric units, which can safely be left unattended and are what I suggest for first-time buyers. If you have a tiny kitchen, get an electric unit that has modes for slow cooking and cooking rice.

It's not the pressure itself that changes how foods cook, but the impact of pressure on physical and chemical processes. Increasing pressure always increases the boiling point of water. In wet cooking methods, the temperature differential between the food and the liquid heating it is what determines how quickly the food heats up. (See page 139 for more.) Increasing the pressure increases the boiling point of water, but it's not boiling water per se that does the cooking—it's the larger temperature difference between the higher-temperature liquid and colder food that results in a faster rate of heat transfer.

How much faster heat will transfer into food depends on the maximum temperature at which the liquid can boil. Depending on the make and model, a pressure cooker can increase the pressure by 11–15 psi (758–1,034 hPa). There's no formal standard for how much pressure a cooker should operate at, but most recipes are written assuming a high pressure of 15 psi (1,034 hPa) and low pressure of 8 psi (550 hPa). (Underwriters Laboratories won't certify units above 15 psi, which is why you don't see higher pressures than that.) You will need to adjust cooking times based on the pressure at which your model operates!



Pressure vs Boiling Point of Water

Figure out your starting air pressure, add the operating pressure of your cooker, and check the boiling point of water for that absolute pressure.

Pressure increases are relative to your current atmospheric pressure, so the maximum boiling point of water is based on your current air pressure plus the additional pressure your unit adds to it. If you live at sea level and have a higher-pressure unit, you'll be able to get water up to 29.7 psi (2,048 hPa) for a boiling point of 250°F / 121°C, but a mile up and with a unit that only adds 11 psi (758 hPa), you'll only raise the boiling point to 236°F / 113°C. Take a look at this zoomed-in part of the phase diagram of water from the previous section, cropped to the starting and maximum pressures possible in pressure cooking. Add the operating pressure of your pressure cooker to the air pressure at your elevation to look up how hot (and thus how quickly!) your foods will cook.

One fun science comment: Maillard reactions don't readily occur in most wet cooking methods. It's not that water inhibits the reaction itself; there actually needs to be some water present in the food (see page 213). The limiting factor is that water, when used as a source of heat, prevents the necessary temperatures from being reached, at least at atmospheric pressure. Some combinations of amino acids and reducing sugars will begin to undergo Maillard reactions just above water's normal boiling point. Lysine/glucose, for example, will combine at around 212–230°F / 100–110°C in a solution with a pH between 4 and 8, reacting much faster at the hotter and more basic ranges. A few novel recipes use this quirk to create Maillard reactions in soups using baking soda, but it's not even a minor part of most pressure cooking. Fortunately, Maillard reactions don't happen too much at the pressures used in pressure cooking (you'd need to go to ~70 psi / ~4,800 hPa to really see them). If they did happen, foods would have Maillard reactions center-to-edge and taste disgusting—too much of a good thing, in this case, gives horrible flavor.

The French scientist Denis Papin served the very first pressure cooker meal way back in 1679 to a group of scientists in London, calling it a *bone digester* and serving bones rendered to something like jelly (along with cooked meats). Oh, 17th-century British cooking…

Pros

- Speed! Raising the boiling point of water from 212°F / 100°C to 248°F / 120°F roughly quadruples how quickly culinary reactions can occur, cutting cooking times by ~60–70% (it takes some time to heat up the food; otherwise, it'd be closer to 75%). Pressure cookers are fantastic for cooking slow-cooking grains and legumes (rice and lentils in 5–8 minutes instead of 30), beans (30 minutes for dry, unsoaked beans to be ready to serve), and higher-collagen meats (ribs, pot roast, and pulled pork can all be cooked in under an hour are deliciously easy).
- Electric units are extremely energy efficient, meaning they're great for summer cooking where you want something that's normally slow-braised for hours—say, pulled pork—but don't want to adds lots of heat to your kitchen.

Cons

- You won't be able to poke at food while it cooks to adjust seasoning or check if it's done. What goes in the pot at the start is what you're going to get at the end, as when baking a cake. If you're an intuitive cook, winging it as you go, treat pressure cooking as a way of cooking one ingredient that you'll then use as a component in your meal.
- With the faster rate of reactions, overcooking will happen much more quickly. It's better to slightly undercook something and continue cooking it "off pressure." Take notes on cooking times on your recipes. (Use the low-pressure setting on vegetables to avoid overcooking.) Different pressure cookers will run at slightly different pressures, so treat times for recipes as starting points and take notes.

- Pressure cookers rely on boiling water or steam for transmitting heat—it's a wet cooking method—and trap and condense most of the moisture, making it hard to reduce sauces. You may need to reduce the liquids after cooking. On the flip side, don't skimp on the liquid: make sure that you have at least a cup or two of water in the unit; otherwise, there won't be anything to turn into steam and you'll end up burning the bottom of whatever you're cooking.

Pressure frying uses oil instead of water to cook at even higher temperatures, creating crispy, browned outsides and moist interiors on foods like breaded chicken drumsticks. Pressure frying is how Harland Sanders made his original "Kentucky Fried Chicken," and why it was so successful! Unfortunately, pressure fryers are industrial appliances; there's no safe consumer version for the home. This is one you don't want to try hacking: using oil in a standard pressure cooker can melt the sealing gaskets and lead to explosive decompression with hot oil spraying everywhere.

Tips and tricks

- If you want to adapt other recipes to a pressure cooker, think about things that normally cook via steaming, braising, or any wet cooking method, and try cooking for a third of the suggested time. Make sure not to fill the cooker more than two-thirds full; some ingredients will expand as they cook, and blocking the release valve is bad. If using ingredients that foam while cooking—applesauce, barley, oatmeal, pasta—don't fill the cooker more than one-third full. Be aware that dairy curdles under pressure, so add any dairy ingredients after pressure cooking.
- If you have a stovetop unit, you can rinse it under cool tap water to cool it down quickly after cooking; this is useful for quick-cooking foods like vegetables or polenta where the residual heat would continue cooking them.
- Many electric pressure cookers operate at 12 psi (830 hPa) instead of 15 psi (1,034 hPa), meaning cooking times for recipes based on the slightly higher pressure may need to be extended by 15–20%. Check the manual for the operating pressure, not the rated air pressure—manufacturers tend to list the maximum pressures their units reach and bury the true pressures at which they cook.

- Steam vegetables and artichokes using a metal steaming tray to raise them above the water level. You can also cook small quantities of food in a small glass or metal bowl this way—just remember to pour a cup or two of water into the pressure cooker! Don't use plastic containers in a pressure cooker; they'll melt.
- Pressure cookers are great for making stock. Save bones from meals in a container in the freezer. Once the container is full, transfer the contents to the pressure cooker, cover them with water, and cook for 30 minutes. Cool and strain the liquid.
- Try using your pressure cooker to render tallow or lard: toss chopped-up fatty meats into a jar, cover them with water, add a cup of water to the pressure cooker, and render for about 2 hours. Let the fat cool to a safe-to-handle temperature and pour through a strainer.

Indian Moong Dal Khichdi

There are a million ways to make khichdi*—an Indian dish that mixes lentils and rice with spices.* Khichdi *translates to "mixture," and that's exactly what this is. Here's a recipe based on how I first had it, but experiment! Try adding other spices, such as fennel seeds, cumin seeds, garam masala, or curry powder.*

Sauté in a skillet, manual pressure cooker pan, or electric pressure cooker on sauté mode:

- **2 tablespoons (30g) of cooking oil (e.g., butter, olive oil, ghee, or coconut oil)**
- **1 medium red onion (110g), chopped**
- **1 tablespoon (5g) coriander seeds (either whole or ground)**
- **1 tablespoon (7g) turmeric powder**
- **½ teaspoon (1g) cayenne pepper**

Don't fill a pressure cooker more than halfway full when cooking rice or grains; they expand.

Add and stir to coat, and transfer to pressure cooker if necessary:

- **½ cup (80g) white basmati rice**
- **1 cup (190g) moong dal (yellow split mung beans) or red lentils**
- **6–12 (18–36g) garlic cloves, peeled**
- **1–2 tablespoons (6–12g) ginger root, peeled and diced**

Add **3 cups (710 mL) of water** and close the pressure cooker. Cook under high pressure for about 5 minutes.

Allow the mixture to cool, then open and stir it. Add **juice from one lemon** and **salt** to taste.

Serve with **cilantro** or **parsley**.

The first time I had this, it was served with lots of fresh raw arugula, which added a nice flavor and texture.

Pulled Pork Under Pressure

We covered collagen earlier (see page 164), but it's worth taking another look here to see what a difference a pressure cooker can make. Collagen is a tough protein and meats that are high in it need to be cooked for lengthy times to properly break it down. Pressure cookers, as you'd guess, speed up that process, turning an all-day project into an after-work one.

In a bowl, mix together:

- 2/3 **cup (150g) brown sugar, unpacked (that is, press the sugar down to fit as much into the cup as possible)**
- 1/4 **cup (60 mL) red wine vinegar**
- 1/4 **cup (60g) ketchup or tomato sauce**
- 1 **tablespoon (7g) paprika**
- 2 **teaspoons (4g) freshly ground black pepper**
- 1/2 **teaspoon (3g) salt**
- 1/2 **teaspoon (1g) ground coriander (optional)**
- 1/2 **teaspoon (1g) cayenne pepper (optional, of course)**

Feel free to improvise and add (or drop) whatever spices you like, and then mix to combine.

Add:

- 3–4 **pounds (1.5–2 kg) pork shoulder or pork butt, with or without bone (make sure to buy something that'll fit in your pressure cooker; if in doubt, have the butcher saw it in half or quarters)**

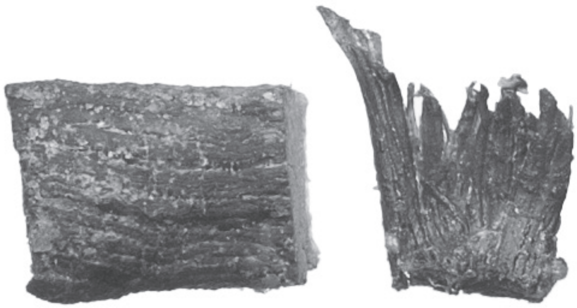
Remove any skin from the pork, then coat the pork on all sides with the seasoning. Transfer it to your pressure cooker, add any remaining sauce, and cook under high pressure for 45–60 minutes (possibly longer if your pressure cooker doesn't go to 15 psi).

After it's done cooking, transfer the cooked meat to a large bowl and pull the bone out (it should just fall out; if not, cook it longer!) along with any large chunks of fat, discarding them (or saving them for some other culinary project, such as rendering your own lard as described on page 311). Use two forks to pull the pork apart, tearing and shredding it.

Pour the liquid from the pressure cooker vessel into the bowl—it should be just enough to submerge the meat—and mix together to thoroughly incorporate the sauce into the meat.

Notes

- *Here are some ideas of what to do with pulled pork: serve on toasted hamburger rolls, on a potato pancake, in a French baguette sliced down the middle, or on top of rice. Mix into chili, use in tacos, add on top of pizza, toss into nachos. Or, do what I invariably do: grab a fork and just pig out (pardon the pun).*



Undercooked *Cooked*

If your pressure-cooked meats are coming out tough (left), it's because they're undercooked. Cook longer and the collagen will break down to give that great texture in pulled pork. If your meats are coming out shredded but dry, then cut back on the cooking time the next time.