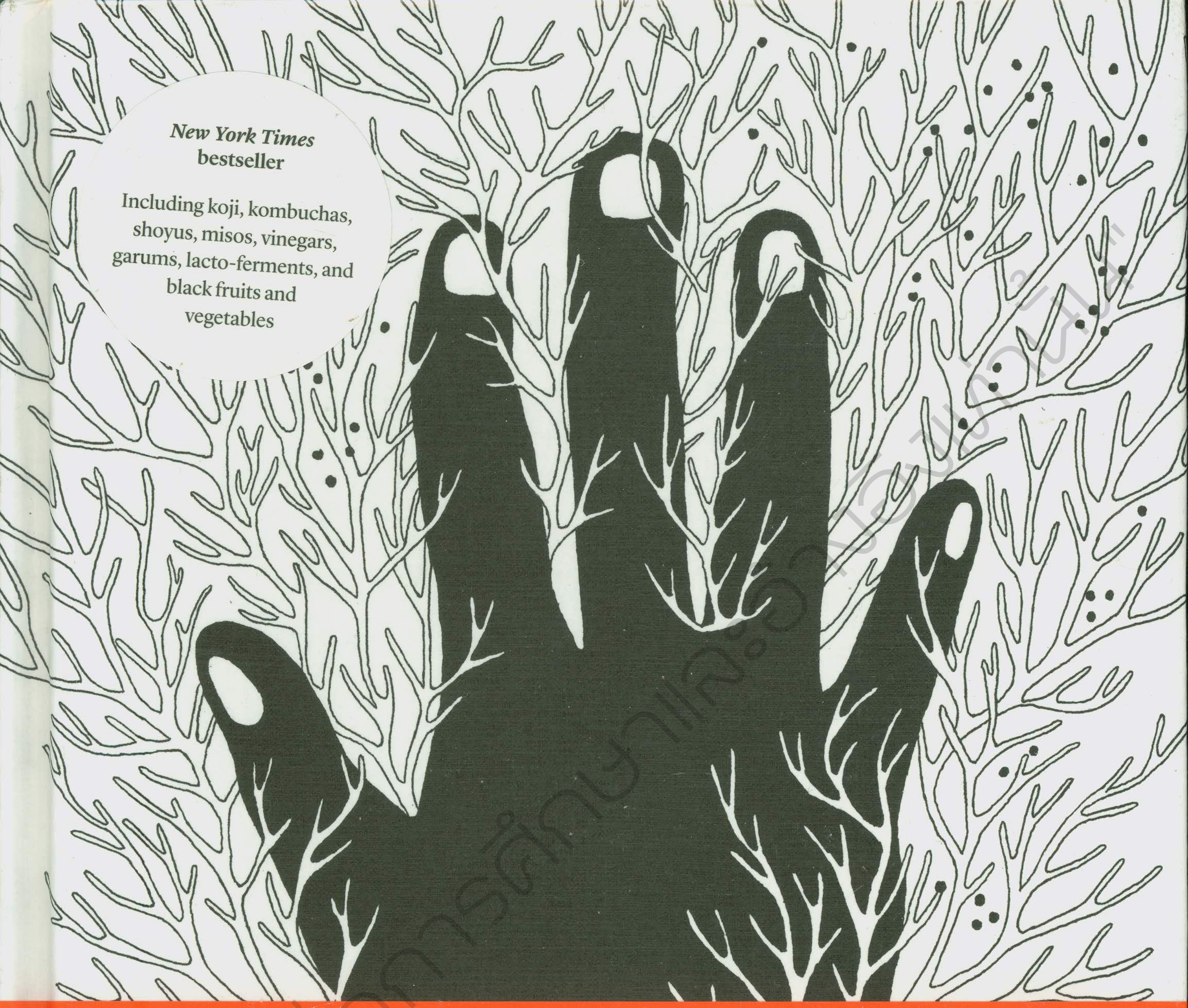
New York Times **bestseller**

Including koji, kombuchas, shoyus, misos, vinegars, garums, lacto-ferments, and black fruits and vegetables



Foundations of Flavor

The Noma Guide to Fermentation

René Redzepi & David Zilber

Noma in its new home on the outskirts
of the Christiania neighborhood in
Copenhagen. Opening week, February 2018.

Introduction

René Redzepi

Our story with fermentation is a story of accidents.

In the very early years of Noma, we were caught up in a search for ingredients, looking to stock our larder with things that could keep our cooking interesting through the colder months of the year.

I remember one day in the early summer when our longtime forager, Roland Rittman, walked through the door with a handful of odd little flower buds, round but also somehow triangular, perfectly juicy, with a flavor like ramps—not garlicky, exactly, but with that same punch and depth. We'd never tasted anything like it. Roland mentioned that these ramson "berries" used to be quite common in Nordic cuisine, and that people would preserve them for use through the winter.

And so we set out to make our own caper-like pickle of ramson buds. If you'd asked us what we thought was happening to the tiny garlicky orbs as they sat in a jar packed with salt, we would have described it as "curing" or "maturing." If you'd mentioned the concept of lactic acid fermentation, we would have cocked our heads and looked at you quizzically.

The ramson capers were a revelation. Suddenly we had this ingredient at our disposal that could bring little bursts of acidity and saltiness and pungency to any dish. And we didn't have to import it from somewhere else. It had grown in our own backyard and become something more, merely through the addition of salt.

One accidental success led to another.

I can't remember whose idea it was to salt gooseberries, but it was around 2008, so it must have been Torsten Vildgaard or Søren Westh. They were messing around with all kinds of things on the boat that was anchored in front of the restaurant.

No larger than a fishing vessel you might take out for a day on the ocean, the boat housed something we called the Nordic Food Lab. Its purpose was to investigate what could be done with the food in our region and share that knowledge freely with anyone interested. It was a place for long-term investigation, rather than a test kitchen for tinkering with next week's dishes. One of our chefs, Ben Reade, used to sleep among the ferments on that boat—that's the sort of character we had working in the lab.

One day, Torsten put a spoon in front of me with a slice of gooseberry that had been salted, vacuum-bagged, and fermented, then forgotten for a year. I tasted it and I was completely shocked. I know that probably sounds like an exaggeration—after all, we're talking about a spoonful of pickled berry. But you have to try to put yourself in my frame of mind: You've grown up in Scandinavia eating gooseberries your whole life, and now there's this thing in front of you. It tastes familiar but also like nothing you've ever had before, like an old comfortable sweater with bright new colors woven through the original fabric.

Today when I taste a pickled gooseberry, I recognize the unmistakable effect of lacto-fermentation, but that first time really changed everything for me and Noma. It was the beginning of a decade in which we would study fermentation with intense focus and enthusiasm.

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I've forgotten so many details. I regret not taking more notes in those early days. Every week held a revelation of some sort, reached by the same basic train of thought: *We need more things to cook with. We have these seasonal ingredients. What can we do to make them better? What can we do to make them last?* At first, we had no idea how fermentation worked or when we were doing it. But year by year, as more ideas worked out and more smart people came into our orbit, we learned how to talk about what we were doing, and began to see the larger tradition we were part of.

In 2011, we decided to hold our first MAD Symposium (*mad* is the Danish word for "food"), a gathering of a few hundred people with a vested interest in seeing the food world get better: people from the restaurant trade, along with scientists, farmers, philosophers, and artists. We chose the theme "Planting Thoughts," and we began thinking of potential speakers who could bring diverse thoughts about the plant kingdom.

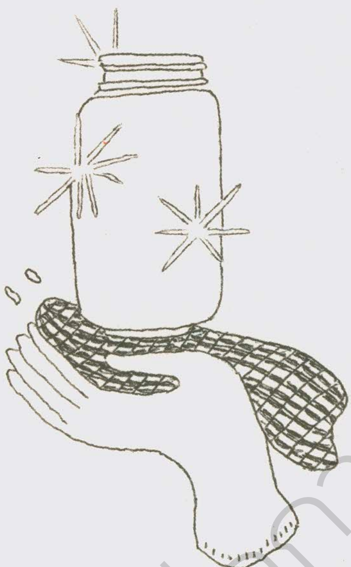
I'll be honest with you: David Chang immediately came to mind because of kimchi. He may not remember serving it, but I remember having an oyster topped with kimchi water at Momofuku Ssäm Bar and finding it absolutely incredible. He and his team were working a parallel track to our own, learning their way around fermentation and developing new products using age-old techniques. I asked him to come speak at MAD about fermentation. While onstage, he introduced the culinary community to the concept of *microbial terroir*.

Chang was referring to the largely unseen world of mold, yeast, and bacteria responsible for fermentation. They are omnipresent, transcending countless cultures and culinary traditions. What Chang was saying was that the microbes indigenous to any given region will always have their say in the flavor of the final product, in the same way that soil, weather, and geography affect wine.

At the time, people were talking about Noma as the restaurant responsible for defining modern Nordic cuisine. From our perspective, we felt saddled with a tremendous responsibility. How could we claim to be cooking Nordic food if we used techniques from abroad? The notion of microbial terroir helped change everything for us. Fermentation knows no borders. It's as much a part of the cooking tradition in Denmark as it is in Italy or Japan or China. Without fermentation, there is no kimchi, no fluffy sourdough bread, no Parmigiano, no wine or beer or spirits, no pickles, no soy sauce. There is no pickled herring or rye bread. Without fermentation, there is no Noma.

People have always associated our restaurant closely with wild food and foraging, but the truth is that the defining pillar of Noma is fermentation. That's not to say that our food is especially funky or salty or sour or any of the other tastes that

Cleanliness, Pathogens, and Safety



Cleanliness is next to godliness (and also crucial to a safe and successful ferment).

Cleanliness is something we take very seriously in the kitchen, out of both pride for our workplace and respect for our colleagues. However, a clean and sanitary workplace is doubly important in the fermentation lab, in order to prevent unwanted pathogens from invading a ferment and causing it to taste off or, worse, become dangerous to eat. At Noma, we always err on the side of caution. If something you've made smells *wrong*—not just funky like fish sauce, but nose-stingingly rotten—trust your nose. If you taste a small sample and it turns your stomach, remember that your body is designed to reject things that may be harmful to you. When in doubt, throw it out. If you're ever unsure of a fermented product, toss it. The weeks or months of your invested time are not worth risking your health.

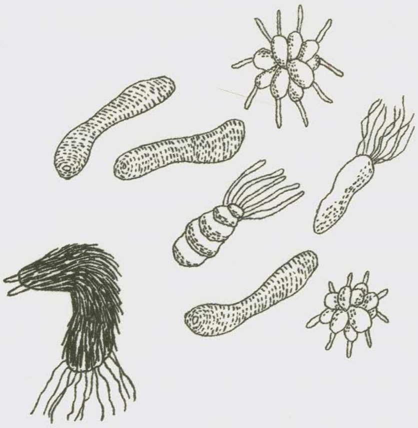
Potentially harmful microbes are ever present in the environment. Bacteria can multiply speedily, with or without oxygen, at temperatures ranging from 4.5° to 50°C/40° to 122°F, especially in moist, nutrient-rich environments. Of course, that describes the exact circumstances in which many fermented goods are produced. Both the World Health Organization and the United States Department of Agriculture recommend cooking foods sensitive to pathogenic contamination above 70°C/158°F before consumption. Now, that's a fairly severe safeguard, and obviously not possible for many ferments. That being said, you should be cautious, but not worried. Fermentation is meant to be a rewarding and exhilarating practice, but remember that you're playing with live ammo.

Throughout this book, we do our best to provide clear instructions that will produce safe and delicious products if followed closely. Don't eyeball measurements or take shortcuts. When a recipe calls for a specific salt content (above 10 percent by weight) or pH (below 4.5), it's to ensure that you're fermenting safely. But of course, the first step in preventing unwanted microorganisms from taking hold in a ferment is to make sure your equipment and hands are clean before they come into contact with food. While this is less important in certain cases, it's critical in other instances. When making koji, for example, you'll need to be sure the incubation chamber is properly sanitized before introducing the inoculated grains. And when working with your hands, wear nitrile or latex gloves to prevent contamination (except in places where a little bacteria from your skin can help things along, as with lactic-acid fermentation).

Now, what do we mean by "clean"? There is a difference between the level of cleanliness you would expect to find in a university biology lab and that in a home or restaurant kitchen. Let's define some terms. *Cleaning* means that you've removed visible dirt from the surface of objects. Soap and water will clean a surface but do very little to reduce the surface's population of microorganisms, good or bad. *Sterilized* implies that you've eradicated *all* life-forms—viruses, bacteria, fungi—on your equipment and your work surfaces (and sometimes even in the product you're looking to ferment). This is a level of certainty required in hospitals and microbiology labs. You'll never need something as serious as an industrial-strength autoclave for a recipe in this book. What we're looking to do for the recipes here is *sanitize*. To sanitize a piece of equipment or work surface implies that you've removed *most* microbiological life. That will be sufficient for our purposes. Running your equipment through a hot cycle in a dishwasher or steaming or boiling it for a few minutes is more than enough to ensure that you're working clean and sanitarily. If your equipment is heatproof, dry-heat sterilization is another option. Ceramic, glass, and metal containers and utensils can be baked in the oven for 2 hours at 160°C/320°F to ensure that they're free of contaminants.

For equipment or work surfaces that you can't pop into the dishwasher, there are common sanitizers intended for food production and fermentation like StarSan (available at many home-brew shops), distilled white vinegar (a sanitizing agent favored by grandmas the world over), and even household bleach diluted with water to 20 milliliters per liter (as long as you rinse with fresh water afterward). At Noma, for large items like crocks and buckets, we disinfect using ethanol diluted with filtered water to 60 percent alcohol by volume (ABV)—40 milliliters water for every 60 milliliters ethanol.

(We dilute it because if the percentage of ethanol is too high, it can actually coagulate the proteins that make up the cell walls of many microbes and prevent them from dying.) We put the solution in a spray bottle and spray whatever needs to be sanitized, let it sit for 10 to 15 minutes, then wipe it off with a paper towel.



While many microbes are beneficial and the majority are harmless, there are still a few bad microbes that can cause illness.

Finally, while a great deal of time is spent in this book introducing the amazing microorganisms responsible for fermentation, it's equally important to acquaint ourselves with the microbes that can make things go sideways. With a thorough grasp of pathogenic bacteria and molds, and what conditions they can tolerate, you'll be better equipped to keep them out of your products.

Clostridium botulinum

C. botulinum is the sporulating bacteria responsible for botulism. It is an anaerobic bacteria that thrives in nutrient-rich, warm environments. Its spores are commonly found dormant in soil and water, waiting for favorable conditions to propagate and release potent neurotoxins. Ingesting just a microgram of botulism toxin is enough to cause serious illness. You cannot taste or smell botulism toxin, and thus the only way to guarantee safety is through careful attention to best practices.

Though cases of botulism poisoning are rare, it's usually found in improperly refrigerated animal products or improperly canned vegetable products (where canning temperatures were not hot enough and/or the canning liquid was not sufficiently acidic). Given that the spores of the bacteria are often found in the soil, special attention should be paid when fermenting roots, bulbs, and tubers. When making black garlic, for example, you're keeping a root vegetable in an anaerobic environment at a warm temperature. However, *C. botulinum* cannot survive at a sustained temperature of 60°C/140°F. Your responsibility is to ensure that your heating chamber doesn't dip below that threshold.

C. botulinum also has great difficulty growing in fluid mediums with a water activity below 0.97 (achieved by salt concentrations of 5 percent or higher) and in acidic environments with a pH below 4.6. Many ferments in this book begin with salt concentrations lower than 5 percent and a pH above 4.6. However, the combined effect of moderate salt content and a gradually decreasing pH is usually enough to safeguard against malevolent bacteria. For instance, a vegetable brined at 2 percent salt will have a high enough salt content to inhibit *C. botulinum* while beneficial lactic acid bacteria lower the pH. If a ferment reaches a pH below 5 within the first two days and ends up below 4.6 by the time of completion, it is generally recognized as safe.

Escherichia coli

Many strains of *E. coli* are actually harmless and part of a normal gut flora, but some varieties can cause severe food poisoning. These bacteria are usually transmitted through poor hygiene or contaminated meat products. Cross-contamination of work surfaces and utensils is one of the more common causes of *E. coli*–related illness. Proper and thorough washing of vegetables in cold water will greatly reduce populations of the pathogen, should they be present. For products like beef garum, salt concentrations of 10 percent or higher will kill off the microbes. On top of that, the high temperatures at which garum ferments offer an added layer of protection.

Salmonella

Salmonella is a genus of rod-shaped bacteria often found in raw poultry products and unpasteurized milk and on unwashed fruits and vegetables. Doing everything you can to avoid cross-contamination from raw poultry is paramount in avoiding *Salmonella* food poisoning. For example, if you're cooking chicken wings for chicken wing garum, be sure to clean and sanitize any utensils before putting them back into action with the final, prepared ingredients. Like *E. coli, Salmonella* has a minimum water activity level of 0.95, meaning that salt levels above 10 percent will kill it off.

Pathogenic molds

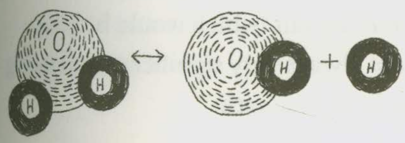
There are thousands of wild and invasive molds that would jump at the opportunity to eat your fermentation project before you get the chance. Many microscopic mold spores are airborne, while others travel in water or on the backs of insects. Not all of them will necessarily be harmful, but if you didn't put the mold there yourself, it's best not to take the chance.

There are many instances in this book where we are trying to create the ideal environment for beneficial mold growth, so the best preventative measures you can take against pathogenic molds are cleaning and sanitizing. By eliminating any unwanted guests at the outset, you ensure that they won't spoil the party later. Another method is to overwhelm competing molds. With koji, we inoculate steamed barley heavily with *A. oryzae* spores in order to elbow out the competition. With ferments like garums and shoyus, the salt content retards mold growth. Frequent stirring and cleaning of the container walls will bring any spores on the surface out of contact with the air and drown them in a salty sea. For kombucha, keeping the surface of your SCOBY moist by basting it with liquid is often enough to keep it acidified and mold-free. Last, molds are easier to spot than other pathogens. When making something like miso, you can simply scrape away any mold that forms on the surface.

Potential of Hydrogen (pH)

Potential of hydrogen, or pH, is a hugely important measurement in chemistry, and a key factor to consider in fermentation. Simply put, it helps you measure acidity. The pH scale was first conceived in the Carlsberg Labs in Copenhagen near the turn of the twentieth century. It measures the difference in concentration in an aqueous solution between hydrogen ions (H^+) and hydroxide ions (OH^-), with every increase in numerical value from 0 to 14 indicating a tenfold change in ionic concentration.

In distilled water (pure H_2O), hydrogen and hydroxide ions sit in exact balance with each other. It has a pH of 7, right in the middle of the scale, and is neither alkaline nor acidic, but neutral. When hydroxide ions outnumber hydrogen ions, the substance is said to be basic or alkaline, and has a pH above 7. When hydrogen ions outnumber hydroxide ions, the substance is acidic, and has a pH below 7. The most acidic substances you can find, like hydrochloric acid (a component of stomach acid) and sulphuric acid (found in car batteries), have a pH near 0. The most basic substances, like sodium hydroxide (found in lye or drain cleaner) have a pH close to 14.



The ratio of hydroxide ions (negatively charged) to hydrogen ions (positively charged) in an aqueous solution determines its pH.

At times in this book, we seek to control or change the pH of a ferment, which affects everything from microbes' ability to thrive and propagate to an enzyme's ability to function properly to the taste of the final ferment. Sometimes, we're seeking to lower the pH in a ferment—thus making it taste more sour—through the creation by microbes of lactic, acetic, or citric acid. We use alkaline solutions too, as in the case of our miso made from masa, where we boil corn in a calcium hydroxide solution to coax out floral and fruity notes from the kernels.

You can track pH using a few tools, including test strips or digital meters. More exacting fermenters may find these tools helpful, but taste is your best guide. Ultimately, what you find palatable should dictate what you think the "right" pH is.

Salt and Baker's Percentages

Salt is one of the most important factors in a safe and successful fermentation. For starters, it has the remarkable ability to inhibit biological processes of both microbes and humans. (There's a reason why drinking salt water will kill you if you're stranded at sea.) Salt is an ionic compound of sodium and chloride, which breaks apart into a sea of ions when it dissolves in water. Nature abhors imbalance, so anywhere they can, water and the salt ions dissolved in it will try to spread out into an even distribution. Put a piece of meat or a bacterial cell in a solution of salt, and water from inside will flow outward while salt ions flow inward, until eventually equilibrium is reached. It's how brining works, and it's also the mechanism by which pathogens like *Salmonella* can be killed with salt. Salt draws water out of the bacteria's cells until they shrivel up and die. (For a more detailed explanation of this, see "Salt/Water," page 367.) Knowing the salt tolerance of different microbes can make a world of difference in a ferment.

For that reason, we stress precise salt measurements, usually expressed in percentage by weight. Note that in the fermentation lab at Noma, we use baker's percentages—when we tell you to add 2% salt to a kilogram of plums, we mean 2% of the weight of the plums (which comes out to 20 grams), not the total weight of the plums *and* the salt (which would be 20.4 grams). The difference is not always very significant, but using baker's percentages streamlines the math.

Last, the type of salt makes a difference. We call for non-iodized salt, because iodine is mildly antimicrobial. While using standard table salt won't stop a ferment cold, it can impede helpful microbes from gaining a strong foothold. Kosher salt will work well, and should be available in your local grocery store. Mineral-rich sea salts like fleur de sel are great, too, and can actually improve the texture of lacto-ferments.

Building a Fermentation Chamber

Beginning with the koji chapter, you'll find that some recipes in this book require specific temperature and humidity conditions. There are myriad options for constructing a fermentation chamber, depending on how much product you intend to make, and how elaborate you want your rig to be. At Noma, we have rooms dedicated to fermentation, with accurate and precise temperature and humidity controls. During our pop-up restaurant in Sydney, we crafted a fermentation chamber out of a broom closet. You can use a decommissioned refrigerator, a speed rack with a vinyl cover, Styrofoam coolers, or wooden boxes. The two basic criteria for a good container are insulation and water resistance. The chapter on koji (page 211) explains what factors you need to control and why they matter.

While you're getting your feet wet in the world of fermentation, an appliance such as a rice cooker or slow cooker will suffice for some processes in this book. (Note that you'll need a model without an auto-off function, as some recipes call for incubation times that last for weeks.) But once you're hooked on fermenting, building a larger, more accurate chamber is a game changer.

Here we've outlined two paths, designed for small-scale projects, built using components that are available online or at a hardware or restaurant supply store. It can all be done for less than the cost of a stand mixer.

Covered Speed Rack

For this fermentation chamber, you'll need:

- A speed rack: The bones of your chamber. Speed racks are used in restaurants to hold trays of ingredients or food coming out of the oven. They're made of lightweight but sturdy aluminum and are equipped with rails onto which you slide sheet pans or gastro/hotel pans. They come in varying heights, ranging from 1 to 1.75 meters. Look for one that comes with a heavy plastic or vinyl cover with zippers running up two sides. The cover will retain heat and humidity, and the zippers allow easy access to the interior. You'll also need a few sheet pans that are the correct size for the rack; the style and quantity will depend on which ferments you choose to make.

- A small space heater: The kind you might use to keep your feet warm underneath your desk. If the heater is equipped with a fan, all the better; if not, buy a small simple fan.

- A temperature controller, such as a PID (proportional-integral-derivative) or thermostat: This will adjust the temperature of the chamber as it varies according to external influences. You want a prewired version that you can plug a heater directly into. It's a specialized bit of gear, but it's not complicated or expensive. It will include a probe that you set either in the chamber to measure interior temperature, or into the ferment itself, such as when you're making koji.

- A small humidifier (only when making koji): The type you'd put in a child's room to help with a stuffy nose. Plus, a simple hygrometer to gauge humidity; it will look a bit like an oven thermometer. Or use a humidistat, which functions much like a thermostat. While slightly more expensive, it will simplify things by regulating the humidity in the chamber for you.

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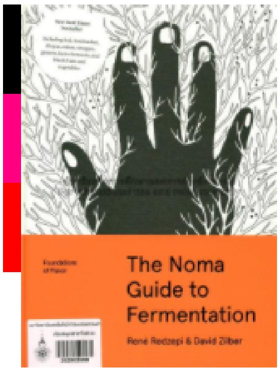

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