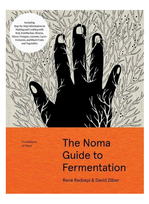

1.

Primer

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What is Fermentation?

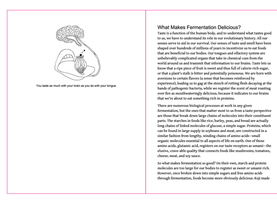
Before we dive into the practical ins and outs of fermentation, let's first clearly define what it is.

At the most basic level, fermentation is the transformation of food by microbes and their enzymes. Microbes are living, single-celled organisms that are beneficial to our bodies. Enzymes are proteins produced by those microorganisms. And finally, in the strictest scientific definition, fermentation is the process by which microorganisms convert sugar into another substance in the absence of oxygen.

The word fermentation comes from the Latin word *fervere*, meaning "to boil." The ancient Romans, upon seeing vats of grapes spontaneously bubble and transform into wine, described the process using the closest analogy they could think of, which was the boiling of water. Although it has nothing to do with boiling, they were true fermenters in the scientific sense, as yeast produced enzymes transformed the sugars in the grapes into alcohol.

However, not all the processes we consider to be fermentation fit neatly into the scientific definition. In the case of fermented fish sauce, for example, by definition, human's genes are not, in fact, the microbial superpowers whose proteinase genes of rice or barley and produces enzymes that convert the starches in those grains into sugars and then into alcohol. This is also well-known as a primary fermentation process. The process in this book, on the other hand, are the product of a secondary fermentation process. To produce garum, we rely fully with animal proteins in order to take advantage of the enzymes produced during the primary fermentation process.

We draw differentiation between primary and secondary fermentation processes in this book, but you may find it helpful to have these definitions under your belt as you find your way with fermentation.


You taste as much with your brain as you do with your tongue.

What Makes Fermentation Delicious?

Taste is a function of the human body, and to understand what tastes good to us, we have to understand its role in our evolutionary history. All our senses serve to aid in our survival. Our senses of taste and smell have been honed to detect the presence of nutrients in our surroundings and to avoid those that are beneficial to our bodies. Sugars and olfactory system are unfavorably complicated organs that take in chemical cues from the environment and send signals to our brains. Our senses of taste and smell are honed to alert us of potential danger, such as the presence of spoiled food, or that a plant's stalk is bitter and potentially poisonous. We are born with innate preferences for certain tastes, such as sweetness (which is extremely pleasurable), leading us to grab at the stretch of tasting fruits dangling at the hands of pathogenic bacteria, while we register the scent of meat rotting and decomposing as putrid and disgusting. Our senses indicate to our brains that we're about to eat something rich in proteins.

There are numerous biological processes at work in any given fermentation, but the ones that matter most to us from a taste perspective are those that break down large chains of molecules into their constituent parts. Our digestive systems do this with the food we eat, breaking down long chains of linked molecules of glucose, a simple sugar. Proteins, which can be found in large supply in soybeans and meat, are constructed in a similar manner, with long chains of amino acids linked together. Our intestines molecules essentially all sorts of food into its constituents, such as amino acids, glutamic acid, nucleotides, or our taste receptors as umami—the savory, crave-able quality that connects foods like mushrooms, tomatoes, cheese, meat, and soy sauce.

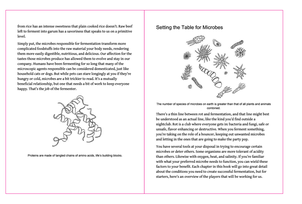
Fermentation can transform "meat-y, gross-y" foods into sweet, starch, and protein molecules are too large for our bodies to register as sweet or umami-rich. However, once broken down into simple sugars and free amino acids through fermentation, foods become more obviously delicious. Anji made

from rice has an intense sweetness that plain cooked rice doesn't. Raw beef left to ferment into garum has a savoriness that speaks to us on a primitive level.

Simply put, the microbes responsible for fermentation transform more-difficult-to-digest foods into easier-to-digest foods. In the process, they make them easily digestible, nutritious, and delicious. Our affection for the tastes these microbes produce has allowed them to evolve and stay in our environment, and we have evolved to be their hosts. Our bodies are a veritable smorgasbord of nutrients, and the microbes that live in our bodies feed off the scraps that we leave behind, or even take our food and digest it for us, and in return, we get to eat the fruits of their labor. We benefit from the fermentation they do in our guts, and we benefit from the fermentation they do in our food. We are symbiotic with our microbes, and we are happy to be so. Our lives are better for it. We are healthier for it. We are happier for it. We are more-evolved for it. We are more-delicious for it. And we are happier than we would be if we were not hosting our microbial friends. Fermentation is a way for us to keep our food and our bodies healthy and happy. It is a way to keep our food from rotting and our bodies from succumbing to pathogenic bacteria from our 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 you'd expect to find in your home kitchen. The level of cleanliness that you're seasoned vetting drift from the surface of objects, soap and water will clean a surface but do very little to reduce the surface's microbial population. Sanitizers will do more to reduce the surface's microbial population, but even sanitizers don't sterilize. Sterilization is the process of killing all the living—viruses, bacteria, fungi—on your equipment and your work surfaces (and sometimes even in the product you're looking to make). Sterilization is a process that is necessary in a hospital setting or in a food lab. You'll never need something as intense as an industrial autoclave for a recipe in this book. What we're looking to do for the purposes of fermentation is a sanitization process, which, in the strictest sense 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 made of plastic, however, it may not withstand such temperatures, glass, and metal containers and utensils can be boiled in the oven for 2 hours at 140°C/250°F to ensure that they're free of contaminants.

For equipment or surfaces that can't withstand such a process, the alternative is to use a chemical sanitizer. Chlorine is a good option for fermentation like fructose (available at many home brew shops), distilled white vinegar is sanitizing agent favored by grandmas the world over), and even household bleach diluted with water to 10 milliliters per liter (as little as 2 milliliters per liter if you're using a high-quality bleach without crude and bachem, we disinfect using ethanol diluted with filtered water to 40 percent alcohol by volume (ABV)—10 milliliters water for every 40 milliliters ethanol. Dim dilute it because if the percentage of ethanol is too


Proteins are made of longer chains of amino acids, like a building blocks.

Setting the Table for Microbes

The number of species of microbes on earth is greater than that of all plants and animals combined.

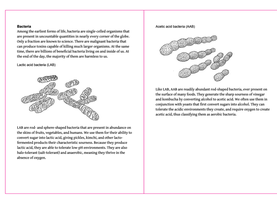
There's a thin line between rot and fermentation, and that line might feel blurry to you at first. Rot is a dirty word, and we don't want to eat anything rotten. But in a club where everyone goes to bacteria and fungi, rude or smell, flavor enhancing or destructive. When you ferment something, you're inviting in a host of new guests to your kitchen to consume ingredients and bring in the ones that are going to make the party pop.

You have several tools at your disposal in trying to encourage certain microbes or deter others. Some organisms are more tolerant of acidity than others. Likewise with oxygen, heat, and salinity. If you're familiar with the microbial environment you're working with, you can use these factors to your benefit. Each chapter in this book will go into great detail about the conditions you need to create successful fermentation, but for starters, here's an overview of the players that will be working for us.

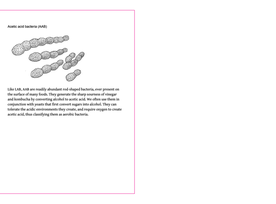
Bacteria

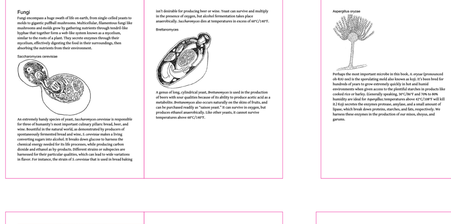
Comprise the vast kingdom of life. Bacteria are single-celled organisms that are the most numerous and diverse microorganisms on earth. Some of them are beneficial to our bodies, and others are pathogenic bacteria that can produce toxins capable of killing much larger organisms. At the same time, we wouldn't have our beloved bacteria living on and inside of us. At the end of the day, the majority of them are harmless to us.

Lactic acid bacteria (LAB)


LAB are rod- and sphere-shaped bacteria that are present in abundance in fruits, grains, and the human digestive tract. They are so called because they convert sugar into lactic acid, giving pickles, kimchi, and other lactic-fermented products their characteristic sourness. Because they produce lactic acid, they are also responsible for preserving food. They are also facultative (LAB tolerant) and anaerobic, meaning they thrive in the absence of oxygen.

Acetic acid bacteria (AAB)


Like LAB, AAB are mostly abundant rod-shaped bacteria, ever present on the surface of many foods. They generate the sharp sourness of vinegar and kombucha by converting alcohol to acetic acid. We often use these in fermentation to add a pleasant sourness to a finished product. They are also facultative anaerobes, meaning they can tolerate the acidic environments they create, and require oxygen to create acetic acid, thus classifying them as aerobic bacteria.



An extremely handy species of yeast, Saccharomyces cerevisiae is responsible for three of humanity's most-treasured culinary pillars: bread, beer, and wine. Beautiful in the natural world, as demonstrated by producers of spontaneously fermented bread and wine, S. cerevisiae makes a living by consuming sugars and producing carbon dioxide and alcohol as the chemical energy needed for its life processes, while producing carbon dioxide and ethanol as by-products. Different strains or subspecies are responsible for different qualities in the finished product, such as the ability to flocculate (for instance, the strain of S. cerevisiae that is used in bread baking

isn't desirable for producing beer or wine. Yeast can survive and multiply in the presence of oxygen, but alcohol fermentation takes place anaerobically. Saccharomyces dies at temperatures in excess of 60°C/140°F.

Brettanomyces

A genus of long, cylindrical yeast, Brettanomyces is used in the production of lambic, Belgian ales, and wines. It is a slow-acting yeast that ferments and matures over years or even decades. Brettanomyces also occurs naturally on the skins of fruits, and can be purchased readily as "wine yeast." It can survive in oxygen, but produces ethanol anaerobically. Like other yeasts, it cannot survive temperatures above 60°C/140°F.

Perhaps the most important microbe in this book, A. oryzae (pronounced oh-RIH-zee) is the operating mold also known as koji. It's from Koji that we make miso, shoyu, sake, and amazake. It's also used in many environments when grains access to the plentiful starches to produce like cooked rice or barley. Generally speaking, 50°C/86°F and 70% to 80% humidity are the optimal conditions for koji to grow and do its thing. A. O.Koji secretes the enzymes proteinase, amylase, and a small amount of lipase, which break down proteins, starches, and fats, respectively. We harness these enzymes in the production of our miso, shoyu, and garum.

A relative of Aspergillus oryzae, Aspergillus tuberensis (pronounced too-OHSH-en-sis) metabolizes starches and proteins and produces citric acid as a by-product. We use it in the production of our tonnato, which is based on a Korean dwaeju and Japanese miso-mori, as the distillation of the alcohol leaves the citric acid behind. Though it's a lesser-known species, it's extremely delicious.

Enzymes

Enzymes are not microbes—they aren't even alive—but rather biological catalysts that facilitate chemical transformations within organisms or organic matter. You can generally identify them by the suffix -ase, as in proteinase (which breaks down proteins), amylase (which breaks down starch), lipase (which breaks down fats), and so on. They are a class of proteins built through evolution to serve specific but vital functions. Enzymes are the tools that our microbial friends use to carry out the work of the ones featured in this book as a cross between knives and scissors. They're keys in the sense that they are tailored to fit specific locks, acting on one organic molecule while leaving others alone and they're scissors in that they can cut ribbons into shorter lengths. Generally

speaking, enzymes work most efficiently in warm, fluid environments, but if human lives high, they can be "cooked" to a point where they no longer function.

Beta amylase is an enzyme capable of breaking down starches into their constituent sugar molecules.

Wild Fermentation

The ferments we undertake at Noma all depend to varying degrees on wild fermentation. That is to say, we create environments that are conducive to the growth of certain microbes, and we rely on those microbes to transform our raw materials into delicious products. With our lactic ferments, for instance, we depend entirely on a wide set of lactic acid bacteria in the environment—on the surfaces of our tools, our fermentation vessels, our hands, our kitchen—to turn sugar into lactic acid and other flavorful metabolites. By allowing nature to do its thing, we get layers of nuance and complexity in our ferments that wouldn't be possible if we declared exactly which microbes were allowed to work. Wild fermentation is a non-inoculated and often multi-phasic fermentation. Unlike a beer, it's a three fermentation vessel first performed, and it's still tried and true.

For cool kombuchas, vinegars, and koji, we do introduce bacteria, yeast, or mold to the process. We do so because we want to ensure that we don't let wild allow and encourage wild fermentation. The same goes for especially large batches of lactic-fermented products. For instance, when we're fermenting hundreds of kilos of asparagus at a time, we add powdered lactic acid bacteria (LAB) to the brine. If for some reason the LAB don't take hold, we can't let the product sit and ferment for fear of the risk of some other undesired microbes taking hold, a boost to the LAB population is a nice bit of insurance against losing all that product when you're working on a large scale.

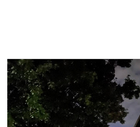
Backslopping goes a boost from one generation of a ferment to the next.

Backslopping

Backslopping is a vital technique in prepping microbial environments for fermentation and will come up numerous times in this book, especially in the fermentation of vegetables. Backslopping is the practice of using an advance you intend to ferment a boost of beneficial microbes by adding a dose from a previous batch of that same ferment.

By pouring a healthy amount of, say, pickle vinegar into a jar of fresh pickles, we both lower the pH of the solution and add a healthy dose of lactic acid bacteria. The lactic acid bacteria will multiply, ensuring that no slowing or stopping any unwanted microbes that aren't acid-tolerant from acting on the pickles, and ensures that there's a healthy population of LAB to ferment the sugars in the vegetables. Backslopping stacks the deck in favor of the microbes we want to succeed.

Of course, if this is your first time making one of the ferments in the book, you won't necessarily have a previous batch to use for backslop. In that case, you'll have to find a similar substitute. For our vinegars, we suggest using kombucha, which is a fermented tea that's readily available. If you can use a similarly flavored unpasteurized kombucha or the liquid that your SCOBY (the "mother" culture of yeast and bacteria that produces kombucha) is sitting in, you can use that as backslop. The kombucha is that you're going to dilute the pure flavor of the vinegar of kombucha you're making. That's fine, though, as it gives you a perfect reason to make the same vinegar or kombucha again—this time using a portion of your first batch as backslop.



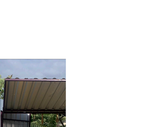
Cleanliness, Pathogens, and Safety

Cleanliness is something we take very seriously in the kitchen, out of both pride (nobody wants to be called out for a dirty kitchen) and fear (no one wants to be responsible for a food-borne illness). We want to do our best in order to prevent harmful pathogens from invading a ferment and causing it to turn off or, worse, become dangerous to eat. At Noma, we always err on the side of caution. If something you've made smells wrong, tastes off, or looks like it's growing something you don't want to eat, throw it out. If you ever a small sample and it scares your stomach, remember that your body is designed to reject things that may be harmful to you. When in doubt, throw it out. It's better to be safe than sorry when it comes to food. The series 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 between 4°C/40°F and 60°C/140°F, which is the range of most kitchen 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 have published food safety guidelines to pathogenic contamination above 70°C/158°F before consumption. Now, that's a fairly severe safeguard, and obviously not something we want to do with our ferments. It's good to be cautious, but not worried. Fermentation is meant to be a nourishing and exhilarating practice, but remember that you're playing with fire sometimes.

Cleanliness is now in guidelines and also crucial to safe and successful ferments.

Throughout this book, we do our best to provide clear instructions that will ensure that you're working safely and cleanly, but there are no guarantees against contamination. When a recipe calls for a specific salt content (above 10 percent by weight) or pH (below 4.5), it's to ensure that the environment is safe for you to work in. If you don't have the requisite amounted microorganisms from taking backslop or ferment to make sure your equipment and hands are clean before they come into contact with your food. Some ferments require a starter culture to ensure safety. For instance, when making koji, for example, you'll need to be sure that 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


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

C. botulinum is the operating bacteria responsible for botulism. It is an anaerobic bacteria that thrives in moisture-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 or death. Fermentation is a wonderful, delicious, and fun 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 canned products or improperly canned vegetable products (where canning temperatures were not hot enough and/or the processing time was not long enough). Because C. botulinum and its bacteria are often found in the soil, special attention should be paid when fermenting roots, bulbs, and tubers. When making black garlic, for instance, we bake whole bulbs of garlic in a low-temperature oven for several a warm temperature. However, C. botulinum cannot survive at a sustained temperature of 60°C/140°F. Your responsibility is to ensure that your baking chamber doesn't drop below that threshold.

C. botulinum also has great difficulty growing in fluid mediums with a water activity (aw) of 0.93 or less. Because most fermentations are well below that and in acidic environments with a pH below 4.6, Many ferments in this book begin with salt concentrations lower than 1 percent and a pH above 4.6 and then become acidic and salty enough to inhibit the growth of botulism by decreasing pH is usually enough to safeguard against most bad bacteria. For instance, a vegetable brined at 3 percent salt will have a high enough aw to allow C. botulinum to thrive. Botulism will not be produced, however, because the pH of ferment reaches a pH below 5 within the first two days. Since C. botulinum is killed 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 equipment and surfaces, and the use of a sanitizer when necessary, should keep the presence of products like food guards, 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. Being everything you can to avoid cross-contamination from raw poultry products and unpasteurized milk products is important, but it's also worth 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 0.93, meaning that salt levels above 10 percent will kill it off. Salmonella is killed at 60°C/140°F.

There are thousands of mold 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 they can ruin a ferment by consuming the nutrients you want to consume.

There are many instances in this book where we are trying to create the ideal environment for beneficial mold growth, or the best preventative measures against contamination. Koji, for instance, is a mold that's 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 allow out the competition. With Brownie Ale garum and chojuu, 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 chojuu, the liquid is also high in acid, which helps to keep mold at bay. The 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)

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

Potential of Hydrogen, or pH, is a hugely important measurement in fermentation. It's a measure of the concentration of hydrogen ions and 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 ratio of hydroxide ions (negatively charged) to hydrogen ions (+) and hydroxide ions (OH-) and hydrogen ions (H+). A ratio every increase in numerical value from 0 to 14 indicating a tenfold change in ionic concentration.

In distilled water (pure H2O), hydrogen and hydroxide ions sit in exact balance. The ratio is 1:1 and the pH is 7. This is considered neutral. Below 7 and is neither alkaline nor acidic, but neutral. When hydroxide ions outnumber hydrogen ions, the substance is said to be basic or alkaline, and above 7 is acidic. Lemon juice, for instance, is acidic because 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.

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 product. Sometimes we want to lower the pH of a ferment, and we do so by a team more sour—through the creation by microbes of lactic, acetic, or citric acid. We can alkalize solutions too, as in the case of our miso made with chickpea, or we can add a food-safe hydroxide solution to cause our floral and fruity notes from the kermesh.

You can track pH using a few tools, including test strips or digital meters. Were exacting fermentation 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 the growth of undesirable microbes. Microbes, like all living creatures, are thirsty and water will fill you if you're stranded at sea) lack in an ionic compound of sodium and chloride, which breaks apart into a sea of ions when dissolved in water. When salt is introduced to a fermentation, sodium ions, 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 cell will flow outward, which will cause the cell to shrivel and die. Bacteria, for instance, need a certain amount of water to survive and reproduce. 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") Knowing the ideal 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 Kimeu nature lab at Noma, we use Baker' percentages—where we tell you to add 2% salt to a kilogram of cabbage, for instance, we mean that you should add 20 grams of salt (2 percent of the total weight of the plants and the salt (which would be 20 grams). The difference is not always very significant, but using baker's percentages makes it easier to do 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 supermarket. Be wary of using fine sea salt, which is not great, too, and can actually impede the bottom of lactic ferments.

Gemüse

zutaten.

für den aufguß:	BIOLOG	G & L
1ltr. (1Pk.) Wasserkringel	1	10 g
Wasser	1	1 ltr
Fermiva, 1Pk.Natrosol	1	10 g
	1	1 Pk
	10	15 g

Lactobacillus plantarum

Lgl. eine Reinsprektschale Knoblauch / 5Rpfln / Lorbeerblätter

Flüssiwurz / Salzsimsel 3ltr Brühe

Pfeffer, Senfsamen, Suppenkraut, Bockshornklee, Kerbel, Salbei, grüne Bohnen

5 Eßl.(1Pk.Brühe Pfeffer, Zwiebeln und Gewürz

5 Ltr