“A‘a i ka hula, waiho i ka maka‘u i ka hale.”

Dare to dance,
leave shame at home.

Fermenting

Modern eating chocolate is made with fermented cacao seeds. To be accurate, the cacao seeds themselves are not fermented, since microbes never pass through the seed coat. Molecules made by the microbes of the fermentating fruit enter and chemically alter the seeds. These processes mitigate the bitterness, increase the acidity, and create a greater complexity of flavors. The flavor we call “chocolate” is not one molecule or even a simple mix of molecules, and it is not found in raw cacao seeds. This rich flavor is created through the processing steps of fermentation, drying, and roasting.

In the fermentation step, microbes eat the fruit pulp and make food to support other kinds of microbes, building a complicated, minute ecosystem. Some of the molecules created by the microbes penetrate into the seed. The heat created by microbial metabolism also transforms the seed, killing it and releasing a cascade of enzymatic reactions that cause chemical changes. All of these processes together turn cacao into cocoa.

It is impossible to overstate the complexity of reactions in a fermentation, which is still largely a black box to science. Still, to be a helpful concierge to the process, it is useful to be familiar with the major players. The ferment is an ecosystem with a staggering complexity of organisms and connections between them. Dozens of species of yeast, acetic acid bacteria, lactic acid bacteria, other bacteria, and molds are part of the community. Different species are present depending on geographic location, care, other species in the growing environment, time of the year, and many other variables. Each of these factors can impact the flavor compounds in the cocoa beans. Science is far from understanding this micro-world, apart from broad pathways. Often called "microbial succession," it is both helpful and misleading to consider fermentation as a series of simple and discrete steps. All of these relationships and so many more are happening all the time and unevenly throughout the ferment.

Here in Hawai'i, large scale fermentations are usually carried out in wood boxes lined with banana leaves.

1. Yeast: The sugars in the cacao pulp feed yeasts, just like you'd expect in a fermentation turning grape juice to wine. In an anaerobic process, yeast break down sugars creating alcohol, which you can smell and taste, and carbon dioxide, which you can observe as bubble formation.

2. Lactic acid bacteria (LAB): Eating both the citrate in the cacao pulp and the ethanol from the yeast, lactic acid bacteria make lactic acid and cause an increase in pH (decrease in acidity). Heat is not generated from these reactions, so a ferment dominated by LAB does not naturally become hot enough to trigger seed enzymatic processes.

Banana leaves or pieces of pod are great ways to inoculate your fermentation.

3. Acetic acid bacteria (AAB): As the yeasts create alcohol, the acetic acid bacteria are there to eat it, transforming it into acetic acid. This is an aerobic process that creates the heat necessary to kill the seeds.

4. Seed transformation: Heat generated by the ferment kills the seed, which causes an enzymatic breakdown of molecules. Fermentation products including acetic acid and ethanol enter the seed causing chemical changes, and phytochemicals like alkaloids, tannins, catechins exit the seed. Bitter and astringent molecules are broken down and flavor molecules are created in this phase, which requires a few days at temperatures over 40°C (113°F).

Tiny Fermentation

In traditional, large fermentations, the main parameters people control are volume, container material and shape, and frequency of turning (mixing) the batch. The mass of beans develops its own heat, like a compost pile, and the process is tracked by measuring the internal temperature and pH changes.

The main problem with small fermentations is the lack of mass to accumulate heat. To get around this problem, home growers provide external heat sources to their tiny fermentations.

These industrious pioneers have been quite inspired and inventive! Some put the ferment in a warm spot in the kitchen (like above the refrigerator), in an oven with the pilot light on, in a sous vide, or in a yogurt maker. If you are handy (or fortunate like me to have a skilled partner), a homemade incubator consisting of an insulated box (small chest freezer or cooler) with a heating element and a thermostat makes a fully controllable experimental space for tiny fermentations.

Here, I will focus on a method that should be accessible to everyone. All you need is an old (but clean) cooler, like the kind you take to the beach or camping, and large Mason jars or other food safe containers.

Of course, fancier options exist, and you will craft your own method as you find what works for you. My best advice is to observe and record, so that you gradually acquire an intuitive understanding of your ferments. You'll know the look, feel, taste, and smell of each stage. Also, make sure that everything you use (equipment and hands) are clean. If a fermentation goes bad, sterilize everything to minimize the chances of that happening again.

Minimum Ferment

A small professional-scale fermentation might be around 100 kilograms (about 200 pounds or 1,000 pods), and a "micro lot" starts around 25 kilograms. The question of the minimum number of pods you need for a ferment doesn't have an absolute answer. I've fermented 4 pods, with reasonably OK results. The fewer the seeds, the more trouble holding a temperature that allows the fermentation to progress, and the greater risk for mold growth.

You can try with as few pods as you'd like, if you don't mind putting the time in. The more volume you have, the greater are your chances to have well-fermented, mold-free beans at the end.

Turn an old cooler into a fermentation incubator by adding jars with warm water. Thermometers inside and outside the jars are optional.

If your ferment is incomplete but doesn't have extensive mold contamination, you can still dry and roast the beans. If you don't like the flavor for chocolate, the nibs can be used in cooking or for flavored drinks. Consider the recommendations in the Unfermented and the A Bad Batch? chapters.

Fermenting in a Cooler

The following instructions will take you through a tiny fermentation using a cooler and large Mason jars. Fermentations take about 6-12 days and then another week to dry the seeds. Plan on 2-3 weeks of daily babysitting to transform seeds to dried cocoa beans.

During the first couple of days of fermentation, you will see the pulp break down and smell alcohol and other volatile molecules.

Put your freshly harvested cacao seeds in a colander to allow any excess juice to drain. Make sure to collect this delicious nectar to drink or make into jelly or fruit leather. For a small amount of fruit, you may not have any juice run off.

While you are waiting, prepare your inoculant. Collect a piece of a young/clean banana leaf and rinse it off. Line clean glass jars with pieces of the leaves. Wrapping cacao beans in banana leaves is a traditional way to contain a ferment that also brings in environmental microbes. If you don't have leaves, or in addition to the leaves, you can mix in a few clean chunks of nice-looking cacao pod. Or use something else. Or just skip it. Microbes are everywhere.

Weigh the wet beans and record the measurement. Smell, feel, and taste the mucilage and write down your observations. Put the seeds in the jar and put the lid on loosely. If you need more than one jar, divide them approximately evenly. I've found that about 4 pounds or 1800 grams of wet beans fit in a half-gallon Mason jar. That's about 15 to 18 pods' worth, depending on the amount of seeds per pod. Filling the container to the very top may result in juice spilling out as the yeasts release carbon dioxide bubbles. One gallon glass jars, often sold for brewing kombucha, can hold about 30 to 35 pods' worth of seeds. Put the jar or jars in the cooler.

Next you need heat. Warm some water on the stove to just below simmering and carefully pour into half gallon Mason jars. These jars are made to tolerate hot liquids, so they are a good choice for this. I usually use two jars of hot water. Place in the cooler and close the lid. For extra insulation, drape a towel or a blanket over the cooler.

Purple and brown spots often develop halfway through a fermentation.

After 3-6 hours, check the level of heat by feeling the jars with your hands. At the start of fermentation, the temperature should be about 100°F to support the yeasts, which is just about hot tub temperature. When needed, usually 3-5 times a day, reheat the cooler by reheating the water in the jars.

On Day 2, keep the cooler heated, but leave your cacao seeds alone. Hopefully yeasts are hard at work. You may see some bubbles released in the jar. Record how often you added heat, whether the temperature dropped, whether you see bubbles, what you smell, and any other observations.

On Day 3, we assume that the yeasts have done their job and that there is plenty of food available for the next phase of fermentation. The new microbial wave (AAB) needs oxygen, and we provide that by mixing the ferment.

Place a colander over a large bowl and dump out the seeds. Mix them while observing their texture and smell. Cut open a seed or two to look for signs that the fermentation juices have entered the seed. Look for browning of the cotyledons, a build-up of brown liquid I call "gravy," and a separation of grooves within the seeds. Nibble on a bit of seed to determine its bitterness and astringency. Lick your hands to taste the fruit pulp. Write down your observations. Put the ferment back in the jar and place it in the cooler. Keep the cooler heated by periodically reheating the water in the jars.

Near the end of fermentation, the pulp usually looks darker, tastes more sour and bitter, and smells a bit more mellow.

Use any drained juice for mixing into cocktails and mocktails, or making vinegar (see recipe in this chapter).

Day 4 to pau, repeat Day 3. You will witness changes in your beans. Mine usually go from fluffy to gooey to pasty to spotted (purple and brown). The mucilage turns pinkish then darkens to brown when they are just about done. When the sweetness is gone from the pulp, you can keep the incubator at a higher temperature, aiming for above 113°F, to trigger the enzymatic reactions inside the seeds.

Knowing when to end a fermentation is an art. In professional fermentations, white beans usually go 3-4 days, purple beans for a week, and mixed beans somewhere in between. Tiny ferments at home are usually slower, and yours might go for 10 or 11 days. If you have enough beans, you can take out samples over the course of a few days and dry/roast/grind them separately to compare. Using this method on a 100 pod batch allowed me to realize that I would have stopped the fermentation too early. I now let ferments go longer than I used to.

When your fermentation is done, the inside of the seeds should ooze brown gravy liquid when cut open.

Fermentation juices penetrate the seed making a brown "gravy." Seeds turn brown during fermentation but also after being exposed to air, so check the color immediately aftercutting open.

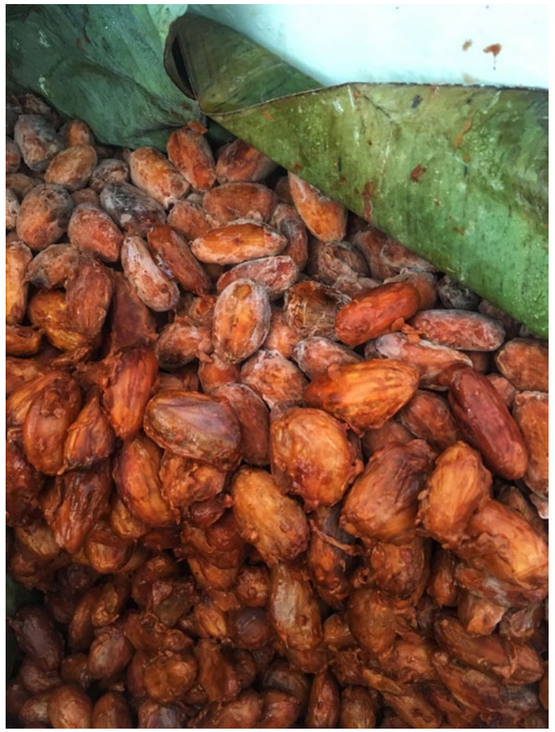
The grooves in the cotyledons will be more cavernous and the color more brown. They should taste less bitter and astringent, less raw, more sour, and possibly flirt a hint of chocolate bar scent and flavor. In my ferments, I find that the color of the mucilage changes from white to brown and the smell becomes more and then bit less pungent, sometimes with an overlay odor of roasting cacao beans.

Unusual fermentations can still be OK. This "slime-out" ferment, with messy, stringy mucus, still made delicious chocolate.

A danger of letting a ferment go on too long is mold. Not only is mold potentially dangerous from a food safety perspective, it may also give your beans off-flavors. If you find a bit of white mold at the end of fermentation, you can discard the affected beans and start drying the rest right away. In a pinch, you can store it in the refrigerator overnight and start drying the next morning. If you find a dark or colored mold, it is best to discard the batch and be consoled by knowing you have an amazing learning experience now under your belt.

Each fermentation is its own thing. Sarah Bharath, a fermentation expert, says she enters every fermentation like a new experience. If professional-level fermentations have some uncertainty, this is magnified in our tiny, home fermentations. Your results can be affected by countless variables, including important ones like the sugar concentration in the fruit and the ambient microbes on harvest day.

We are collaborating with the microbes and not controlling them. If something strange happens, just keep going. (And make notes.) But stop if it looks or smells putrid. No one get sick! I've had to compost a batch or two. It hurts, to be sure, but collecting some failures means you are learning.



Over-fermentation or cold can lead to mold growth. A tiny bit of white mold is not a huge problem. Remove the affected beans and start drying as soon as possible.

Occasionally I find that the mucilage turns stringy and brown, like Japanese natto. I call this "slime out," and it's probably due to particular conditions allowing some weird microbe to thrive. It's not a perfect ferment, but it is also not so wrong that it needs to be discarded. Even though the inside of those beans do not show the proper signs of fermentation, the nibs taste good and make delicious chocolate.

Fermentation is a partnered dance. Be responsive to what you observe, but know you are not in total control. Enjoy the ride. It's a thrill!

Smelling the Path

Your sense of smell can be a huge help in understanding which microbes are active. To train your nose, you can put together a kit with ethanol (vodka) to smell and taste, acetic acid (vinegar) to smell and taste, lactic acid (a common brewing supply) to taste but not much odor, and ammonia (smelling salts) to smell only.

This harvest of 200 pods fills up the cooler. Fresh banana leaves line the container and will fold over the top of the seeds.

Temperature Tools

You can make great tasting cocoa beans using the above sensory-based method augmented by a bit of intuition and practice. If you would like harder numbers, you can set up an instant read probe thermometer nestled into the center of the ferment. To prevent heat being lost from repeated openings of the cooler for temperature checks, try a Bluetooth temperature probe and monitor the progress from your smart phone.

You can make a simple temperature-controlled incubator by putting a thermostat and heating element into a cooler. This saves you the labor of having to constantly replace jars of hot water and allows the microbes to enjoy more stable conditions.

A sous vide warmed water bath should work, too. You just mix once a day starting at Day 3, and write down your observations.

Messy? You're probably doing it right. This seven-day-old fermentation is almost ready to dry. It helps to use a second container for thoroughly mixing the beans.

The University of Hawai'i CTAHR published a method for home fermentation for six pods or more using a temperature-controlled incubator. They suggest setting the temperature to 95°F for the first three days and 113°F for the rest of the fermentation. You can experiment with higher temperatures, too. I sometimes nudge it to 120°F around day five or so.

Turning the Ferment

Mixing the ferment has (at least) four major effects: it temporarily lowers the temperature, mixes the beans to homogenize the environment, decreases acids by oxidizing and off-gassing, and provides the acetic acid bacteria with needed oxygen, which leads to increased heat and acid.

Cacao Juice Recipes

Cacao juice drained during fermentation is super delicious and worth collecting to use. You can drink it fresh or after a few days of fermentation. In the refrigerator, fresh juice turns slightly alcoholic and delightfully fizzy after a week or so. You can use the juice for a tangy jam or flavoring in water ganache (recipe in the Grinding chapter).

Cacao Juice Vinegar

Turning your partially fermented cacao juice into a fruity vinegar is particularly rewarding. The results are more consistent if you use a starter, like apple cider vinegar with the mother. Enjoy it as a drinking vinegar after a few days, or it leave longer for a stronger vinegar perfect for a dressing or condiment.

Ingredients:

- 1/2 cup strained cacao juice (drained from ferment after 2 days)
- 1/2 teaspoon raw cider vinegar (with mother)

Directions:

1. Mix cacao juice and vinegar in a quart size Mason jar. Cover with cheesecloth or a lightly screwed on lid.
2. Leave on the counter for 3-7 days. Taste after each day.
3. When it sours to your liking, skim off any scum, bottle it, and keep it in the fridge.

Use cacao juice vinegar like you would apple cider vinegar: for salads, shrub drinks, baked goods, quick pickles, or soups.

For a balsamic style that makes a great bread dip, reduce by gently simmering with a bit of sugar until it is dark and thick. About 4 tablespoons of coconut sugar per cup of vinegar works for me.

Formal and informal experiments have demonstrated that the frequency and number of your turns affects the flavor, so this is an easy parameter with which to experiment. In general, it's best to not turn for at least the first day or two, since this will disrupt the yeast dominance in the ferment. If you find your ferment is getting quite vinegary, you might want to turn it more often to help off-gas the acetic acid.

Colin Hart's thesis work at University of Hawai'i evaluated chocolate flavor resulting from different turning methods for large Hāmākua ferments. His results informed his recommendation to leave the ferment untouched for two days, then turn once each day thereafter. The method I described above is based on this. He also achieved good results using other turning protocols, so feel free to play and modify.

Cacao Juice Jam

This one ingredient recipe makes a tiny bit of jam, yet the precious golden jell is so delicious you will want to gather more pods to drain more juice to make more jam. You can add simple syrup to sweeten to taste, but you really don't need any. While you can make this jam on a stove top set to low heat, I prefer gentle dehydration to preserve the fresh flavors of the fruit. Depending on the level of dehydration, the juice turns into a sauce, then a jam, then a fruit leather. You can use fresh cacao juice or strained from a one or two day old ferment. The older juice may get bubbly as the yeast go to work in the dehydrator, trapping the bubbles in a champagne-like jam.

Ingredient:

- as much cacao juice as you have, one cup becomes about 3 tablespoons of jam.

Directions:

1. Put the cacao juice in the widest bowl that will fit in your dehydrator. Maximizing the surface area will speed the dehydrating process. I like to use a silicone bowl so the jam doesn't stick to the sides.
2. Dehydrate using low heat, around 110°F, for about 4 hours to get it started.
3. Stir the juice and dehydrate another 1-2 hours.
4. Repeat the previous step until it reaches your preferred consistency. As it becomes more dehydrated, a skin forms on the top. Break this up as you mix it in.
5. When it achieves your preferred consistency, use immediately or transfer to a jar and refrigerate.

Bigger-Than-Tiny Fermentation

Once you have about 100 pods or more, you can change your method to not bother with a container within the cooler. Line the bottom of the cooler with banana leaves, put in the seeds, and place more banana leaves on top. You can then lay the jars of hot water on the top and/or the side of the heap. When it is a time to mix the ferment, you may prefer mixing it in place. If so, make sure to reach into the corners and mix it well. The seeds tucked into the corners can be cooler than the rest and first to show signs of mold. Transferring the seeds to another container can make mixing easier.

Fermentation Additives

Some people like to boost their small-scale ferment by adding ingredients. You can add sugar or ripe fruit like banana, ensuring that the wild yeasts have plenty of food. Using a refractometer to measure the sugar content of the juice can give you an indication

of whether to add sugar. Be aware that the content of the sugar source (*e.g.* sucrose, glucose, fructose) will impact which microbes flourish. You could be unintentionally manipulating the microbial balance and not just the overall abundance of the ferment.

To make sure your ferment has enough yeast to start with a bang, you can add brewer's or baker's yeast. Some people add bespoke starter cultures that enrich certain microbial species. You can experiment with this, but I suspect that in our tiny ferments, wide-ranging microbial diversity is the superpower that easesthe stress of non-ideal conditions.

If you prefer to drain the juice during a ferment, you can use a silicone Mason jar lid with holes, like those made for flower arrangements. Put a tray under the inverted jar to catch the juice while it incubates in the cooler.

A current trend in the chocolate industry is toward more controlled fermentations, reminiscent of the adoption of similar techniques in wine making many years ago. Yet every movement has a backlash. For the heavy-handed control of wine fermentations, the backlash called "natural wine" is increasing in popularity. Instead of controlling every factor of the ferment and fine tuning flavors after fermentation, natural wine allows the wild processes to be in control. This leads to non-uniform products, seen as special and valued for uniqueness. Your tiny, wild fermentations will also result in unique and special batches. I've chosen to embrace that, but you may opt to follow a different path.

If adding sugar sources and microbes can be termed supplementation, you can also play with augmentation. This is your hobby and there are no rules (other than food safety, of course). Adding vanilla beans, cinnamon leaves, or other flavorings during fermentation may allow flavors to be picked up by the cocoa butter in the beans during the fermentation. Since many of the plants we use for flavor also have antimicrobial properties, you will likely affect the balance of microbes. Is that good or bad? Try, and observe.

Was It a Good Ferment?

If you like the outcome and the beans are not moldy, it was a good ferment! It's really OK if the flavor of your beans does not align to your or industry expectations. You have something rare and interesting. That is great, because this would be a lot of work to go through to make something that you could easily buy.

For reference, here are some industry standards for fermented, dried, and unroasted beans.

Signs of well-fermented beans:

- The seed coat is loose on the seed and breaks when pinched.
- The smell is pleasant.
- They sometimes have a reddish-brown color. A bit of surface mold may or may not be OK.
- They don't taste overly acidic or astringent.

Signs of under-fermented beans:

- A shriveled seed coat sticks to the seed.
- They smell acidic or sour.
- They may have a pale color outside.
- They may have a purple or blue color inside.
- They taste sour and astringent.

Signs of over-fermented beans:

- They smell moldy, like barnyard, or just bad.
- They may have a dark color of black, brown, or gray.
- They taste of mold, milk, or yogurt.

During the fermentation, cacao pulp breaks down and darkens. This photo shows time points over eight days of fermentation.

Take these as general guidelines, since cacao is a trickster who enjoys breaking norms. Even cacao experts are confused by ferments some of the time, and horrible looking cocoa beans can be unexpectedly tasty.

Did your ferment not get up to temperature? Do the beans lack a bronzed look? Did the pulp become slime? Do not despair! As long as it is fine from a food safety perspective, keep going and take notes.

Fine-Tuning Your Ferment

A "one best way" to ferment does not exist, yet fermentation hugely affects the flavor of your cocoa. Different fermentation protocols on the exact same beans lead to very different flavor profiles. As tiny batch fermenters, we don't have the luxury of tons of beans to make controlled experiments and taste tests. On top of that, even large producers find that the best researched protocols can sometimes result in strangely-behaving ferments.

Instead of being daunted by all the uncontrollable variables, I encourage you to be inspired by the knowledge that changing how you ferment makes a huge difference. Play with parameters like allowing the pods to sit before cracking, using ripe fruit or yeast in the ferment, adding more or less external heat, turning the beans at different times, and choosing when to end. Remember that every ferment is its own beast, and every experience will help you intuit responses to future ferments.

Fermentation Record Forms

To assist with your record-keeping, I've created fill-in-the-black forms for keeping track of harvesting, fermentation, and drying. You can download these at https://onecacaotree.com.