

SCIENCE COURSE

Fermentation and Food Preservation

12 Chapters

Philip Osztromok

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Fermentation and Food Preservation 🏆

Chapter 1 · Why Food Spoils

Every food-preservation method you have ever met, from a jar of pickles to a freezer to a packet of biltong, is an answer to one question: what is going wrong with this food, and how do I stop it? Before you can preserve anything you have to know what spoilage actually is. This course treats food as a small system with inputs (water, nutrients, oxygen, warmth), a state (fresh, spoiling, spoiled) and failure modes, and treats each preservation method as a controlled change to one or more of those inputs. This chapter names the three causes of spoilage, introduces the four conditions that control them, and ends with the **levers model** that every later chapter reuses. You need only arithmetic: percentages, a power of two, and a kitchen scale.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: the US Department of Agriculture Food Safety and Inspection Service describes a "danger zone" of 40 to 140 °F (about 4 to 60 °C), says bacteria can double in as little as 20 minutes in it, and advises not leaving perishable food in that range for more than two hours (one hour above 90 °F). **Not verified by the search:** the water-activity thresholds in the table below and the pH 4.6 line are quoted from general food-science teaching and should be checked against a food-microbiology reference or national food-safety guidance before you rely on them. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed.

Three Ways Food Goes Wrong

Fresh food is biological material, and biology does not stop when the food is picked, slaughtered or harvested. Three separate processes degrade it, and they need different defences, so keep them apart in your head.

CAUSE	WHAT IT IS	WHAT YOU NOTICE	MAIN DEFENCE
Microbes	bacteria, yeasts and moulds growing on the food and using it as fuel	slime, sour or rotten smells, fuzzy mould, gas; some produce toxins you cannot see or smell	starve, dry, acidify, cool, heat or out-compete them

CAUSE	WHAT IT IS	WHAT YOU NOTICE	MAIN DEFENCE
Enzymes	the food's own proteins that keep working after harvest, softening and ripening it	over-ripe fruit, mushy vegetables, brown cut surfaces, bitter greens	cold, heat (blanching) or acid, which slow or switch the enzymes off
Oxidation	oxygen reacting with fats, pigments and vitamins	rancid nuts and oils, faded colour, flat flavour, brown apple flesh	exclude air, keep cool and dark, add antioxidants such as vitamin C

Microbes are the dangerous cause, because they can make you ill and because they multiply. Enzymes and oxidation mostly spoil *quality*: an over-ripe pear tastes poor but is not poisonous. That distinction matters throughout the course. A method that stops microbes protects safety; a method that only slows enzymes protects the eating quality.

Microbes Multiply: The Arithmetic of Doubling

A bacterium grows, splits in two, and each half does the same. Growth by repeated doubling is exponential, which our intuition handles badly. If one doubling takes 20 minutes, the best case quoted by the USDA for the danger zone, a single cell becomes 8 after an hour and about 16.8 million after 8 hours. The simulation below starts with 100 cells (assumed; real foods start with a mix of species and numbers) and uses an assumed 20-minute doubling time for warm, moist conditions, then repeats the 8-hour case for a fridge with an illustrative 5-hour doubling time.

```
# Exponential growth of bacteria on food. All numbers are assumed, for illustration.
doubling_min = 20          # minutes (best case, warm and moist)
start = 100                # cells on the food at time zero
for hours in (0, 1, 2, 4, 8):
    n = start * 2 ** (hours * 60 / doubling_min)
    print(f"{hours} h: {n:,.0f} cells")
fridge_doubling_h = 5      # assumed illustrative doubling time near 4 C
n8 = start * 2 ** (8 / fridge_doubling_h)
print(f"8 h in the fridge: {n8:,.0f} cells")
# 0 h: 100 cells
# 1 h: 800 cells
# 2 h: 6,400 cells
# 4 h: 409,600 cells
# 8 h: 1,677,721,600 cells
```

```
  # 8 h in the fridge: 303 cells
```

Look at the shape. Over the first two hours the population grows 64-fold; over eight it grows by a factor of sixteen million. Cold does not stop growth in this model, it stretches the doubling time, so the same eight hours gives about a threefold rise instead. That is why a cooked dish left on the counter overnight is a worse risk than the same dish in the fridge, and why the two-hour rule exists: the early hours are cheap, the later ones are not. In real life bacteria also have a lag phase before growth starts and run out of food or space at the end, so the true curve flattens, but for the first few hours the doubling picture is a fair guide.

Four Conditions That Control Microbes

Microbes are not magic. Like any living thing they need conditions to be within a range they tolerate. Four of those conditions are ones we can change in a kitchen, and each becomes a lever.

CONDITION	WHAT IT MEASURES	TYPICAL LEVER	USED IN
Water activity (a_w)	how much of the food's water is free for microbes to use, on a scale from 0 to 1 (pure water is 1)	salt, sugar, drying	jerky, jam, cured ham, dried fruit
Acidity (pH)	how acid the food is; lower numbers are more acid, and each step down is ten times more hydrogen ions	vinegar, lactic fermentation	pickles, sauerkraut, yoghurt
Temperature	how fast the cells grow and whether they survive	fridge, freezer, cooking, canning	refrigeration, pasteurisation, canned goods
Oxygen	whether air-loving moulds and bacteria can grow, or only those that tolerate none	sealed jars, brine cover, vacuum	fermentation crocks, vacuum packs, oil-covered preserves

Water activity

Water activity is not the same as moisture content. A jar of honey is only about a fifth water, but nearly all of it is tied up by sugar, so little is free for microbes. General food-science teaching gives rough minimums below which groups of organisms stop growing: most ordinary spoilage

bacteria need roughly 0.90 or more, yeasts a little less, and moulds can grow down to around 0.80. Salt-tolerant and sugar-tolerant species push lower still, which is why very salty and very sweet foods can eventually mould. Treat these as ballpark figures (not verified in this chapter). The practical lesson is that you do not need to remove *all* the water, only enough to push the food below the point where the dangerous organisms can grow. Salt and sugar do this by binding water; drying does it by removing it. Chapter 3 returns to this in detail.

Acidity

The pH scale runs from 0 to 14 with neutral water at 7. Most fresh meat and vegetables sit close to neutral, which is friendly to bacteria. Lowering pH slows or stops many of them. A line you will meet again in the canning chapter is pH 4.6: foods more acid than this are generally treated as "high acid" and safer to process at boiling-water temperature, while less acid foods need more careful handling (also not verified here). The arithmetic is worth seeing once. Going from pH 7 to pH 4.6 is a change of 2.4 steps, a rise in hydrogen-ion concentration of about $10^{2.4}$, roughly 251 times. A little vinegar therefore has a very large effect.

Temperature

Temperature has two jobs. Between roughly 4 and 60 °C (the USDA danger zone, verified above) growth is fastest. Colder slows growth without killing most organisms, so fridge food keeps longer but not for ever, and some bacteria still grow slowly in a fridge. Hotter kills: cooking and pasteurisation reduce microbe numbers, though a few produce heat-resistant spores that survive ordinary boiling. Chapters 8 and 9 take these two directions in turn.

Oxygen

Moulds generally need air. Many bacteria grow with or without it, and a few of the most dangerous ones grow only where oxygen is absent, such as deep in a sealed low-acid jar. So removing air is a lever that helps against moulds but can be dangerous if used alone on low-acid food. Fermentation uses oxygen exclusion cleverly: under a layer of brine, harmless lactic bacteria thrive and the spoilers cannot.

The Levers Model

Put it together. For each food, a microbe is held back when at least one condition is outside its tolerance, and the strongest preservation uses two or three at once, which food scientists

sometimes call “hurdles”. The picture below shows the model used in every later chapter: four levers, each a slider between “microbes thrive” and “microbes blocked”.



Illustrative settings for a salted, pickled, refrigerated jar; the dots are not measurements.

Every method in this course sets some of those sliders. Dry sausage pushes water activity down and uses salt; sauerkraut pushes pH down and removes oxygen; a canned tomato pushes heat up and uses acid; a freezer pushes temperature low enough to halt growth. The model also tells you what can go wrong: if a lever slips (the brine is too weak, the fridge is too warm, the jar was not sealed), a hurdle drops and growth resumes. Keep a record of which levers your method relies on and you will always know what to check when something looks wrong.

FAMILIAR FOOD	LEVERS DOING THE WORK	WHY IT IS NOT SHELF-STABLE FOR EVER
Fresh milk	cold only	neutral pH, high water, so spoils fast once warm
Cheddar	lower water, some acid, salt, cool store	mould can grow on the surface; cut it off with a margin
Honey	very low water activity	keeps very long, but absorbs moisture if left open
Dried pasta	water removed	fine until it gets wet, then spoils like fresh food
Pickled onions	acid, sometimes heat and seal	safe only if the acid stays strong enough and the seal intact

Reading the Signs, and Keeping a Log

Your senses catch some spoilage and miss other kinds. Mould, slime, gas and strong smells are warnings. But the organisms that cause the worst food poisoning often produce no smell or visible change, so “it smells fine” is not a safety test. The rule that follows through the course is: rely on the levers, not on your nose. When you run a home experiment, write down what you did and what you saw in a plain log. A simple template is below; later chapters add columns for salt weight and pH.

```
Experiment log (copy into a notebook or spreadsheet)
Date started : ________   Food : ________   Weight : ____ g
Levers used  : water activity [ ]  acid [ ]  temperature [ ]  oxygen [ ]
Storage      : ________ (where, how sealed, approx. temperature)
Day | Look | Smell | Texture | Notes / photo
  1 |      |       |         |
  2 |      |       |         |
  3 |      |       |         |
```

Do not

Do not taste food to find out whether it has spoiled; do not leave perishable food in the danger zone longer than two hours; do not assume a food is safe because it looks and smells normal; do not eat anything from the experiments below. Exercise 1 is an observation only, and everything you grow is thrown away unopened afterwards.

EXERCISE 1

A safe observation experiment (do not eat anything). Put one slice of plain bread in each of three zip bags: one left on a shelf, one in the fridge, one in the freezer, all sealed. Add a fourth slice, dried in a low oven first, in a sealed bag on the shelf. Use the log template to record each slice once a day for a week, then decide which levers each bag changed and in what order the slices spoiled. Bin the bags sealed.

View solution

EXERCISE 2

A calculation. A dish starts with 100 bacterial cells (assumed) and they double every 20 minutes. How long until there are one million cells? Compare your answer with the two-hour rule, then repeat the

calculation for an illustrative 5-hour doubling time and express both answers in hours.

View solution

EXERCISE 3

A diagnosis. For each of five foods or situations (a cut apple turning brown, a jar of jam with a mouldy surface, an opened bag of walnuts that tastes bitter, cooked rice left out overnight, a tomato that has gone soft in the fruit bowl) decide whether the cause is microbes, enzymes or oxidation, say which lever would have helped, and say whether the problem is one of safety or only of quality.

View solution

QUICK REFERENCE

- **Three causes of spoilage:** microbes (safety and quality), enzymes and oxidation (mostly quality)
- **Four levers:** water activity, acidity, temperature, oxygen
- **Danger zone:** 40 to 140 °F (about 4 to 60 °C); two hours at most for perishable food (one hour above 90 °F)
- **Doubling:** cells at time t = start × $2^{(t \,/\, \text{doubling time})}$; small differences in doubling time become huge differences in numbers
- **Hurdles:** the strongest preservation sets two or three levers at once
- **Rule:** trust the levers, not your nose

COMING NEXT

Fermentation and Food Preservation 2 is a short history of keeping food: drying, salting, smoking and pickling in early cultures, sea voyages and armies, Appert's canning and the arrival of the fridge, each read through the levers model from this chapter.

Fermentation and Food Preservation

Chapter 2 · Keeping Food Through History

Long before anyone had heard of bacteria, people kept food from spoiling, and they did it by trial and error. Looking back at their methods through the levers model from Fermentation and Food Preservation 1 is rewarding: nearly every traditional technique turns out to move one or two of the four levers (water activity, acidity, temperature, oxygen), whether or not the person doing it knew why. This chapter walks through the main inventions in rough order, shows which lever each one pulled, and asks what pushed people to invent them: seasons, travel and war. Only arithmetic and a calendar are needed.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: the French government offered a prize of 12,000 francs in 1795 for a way to preserve food for its armies; Nicolas Appert sealed food in glass jars and heated them in boiling water; he published his method in a book in 1810; and Peter Durand patented metal containers in 1810. **Sources disagreed** on whether Appert received the prize in 1809 or 1810, and on the date of his first factory, so this chapter gives no exact date for either. **Not verified by the search:** the dates and places given for ancient drying, salting, smoking and pickling, and for ice houses and mechanical refrigeration, are quoted from general history teaching and should be checked against a food-history reference. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed.

Why People Needed to Preserve

Preservation answers a timing problem. Harvests and hunts arrive all at once; hunger is spread across the year. A herd is slaughtered in autumn and must feed people through winter; a fishing fleet lands more than the town can eat in a week; an army marches far from any farm. Each pressure favoured a method that turned a short-lived surplus into a long-lived store, and the earliest methods are the ones that need no equipment at all.

The Oldest Methods: Drying, Salting, Smoking, Pickling

General history teaching places drying (sun, wind and later fire) among the oldest preservation methods, practised by many early cultures in warm or windy climates. Salt followed where it

could be mined or evaporated from seawater: salted fish and cured meat were staples of trade. Smoking combined drying with heat and chemicals from the smoke, and was practised over a fire already needed for warmth. Pickling in vinegar, or in brine that soured by itself, is also ancient. Using the levers model:

METHOD	MAIN LEVER	HOW IT WORKS	WEAK POINT
Drying	water activity	removes the water microbes need	rewetting restarts spoilage; moulds on damp stores
Salting	water activity	salt binds water and draws it out of the food	needs enough salt; salty foods can still mould
Smoking	water activity, with some oxygen and surface effects	dries the surface and deposits protective compounds	mainly protects the outside; usually combined with salt
Pickling	acidity	vinegar or fermentation lowers pH	needs enough acid and a clean seal

Notice that three of the four oldest methods work on water. That is no accident: water is the one lever you can pull with sun and wind, no fire or tools needed. Acid is harder to control by hand, which is why pickling became reliable mainly where a clean source of vinegar or a well-understood fermentation was available (Chapters 4 and 5 cover both).

Cold Before Machines

Cold storage is also old. Communities in cold climates stored food in snow, cellars, caves and ice houses cut from winter lakes. General history teaching describes ice being harvested and kept for use long into the warm months, and later traded by ship over long distances. Temperature was the lever, and the limit was supply: you needed winter ice or a cool cave. Mechanical refrigeration in the 19th century, and then the domestic fridge, turned that supply into something any household could keep running, and so made the temperature lever available everywhere (Chapter 9 covers the science).

Appert and the Jar

The most famous step in this story is deliberate invention. By 1795 the French government wanted a reliable way to feed its armies, and offered a prize of 12,000 francs for one (verified

above). Nicolas Appert worked out a process of filling glass jars with food, sealing them and heating them in boiling water, and published it in a book in 1810 (also verified). He did not know why it worked: the explanation, that heat killed the microbes responsible for spoilage, came decades later from Louis Pasteur's work. That fact is the best argument for the levers model in this chapter. Appert controlled temperature and oxygen, and the result worked a long time before anyone could explain it.

In the same year, 1810, Peter Durand patented metal containers, and tin-plated steel cans soon replaced glass as the easy, unbreakable choice for armies and sailors. Canned food made long journeys feasible. It also introduced a new lesson that Chapter 8 returns to: a sealed container with no air and some heat treatment is a very good home for the few dangerous microbes that need no oxygen, so the process had to be done correctly.

> Do not
> Do not copy an old method from a history book and assume it is safe today. Early canning, curing and pickling instructions were written before anyone understood the risks of low-acid foods in sealed containers. Use current, tested guidance from a national food-safety authority for anything you intend to eat; this chapter is history, not a recipe.

Which Lever, When?

A simple tally of the methods so far shows how the toolbox grew. The snippet below lists each method with the levers it uses (taken from the tables above, so the counts are of this chapter's list, not of history) and counts how many methods lean on each lever.

```
# Which levers do this chapter's methods use? (counts reflect this list only)
methods = [
    ("Sun drying", "water activity"),
    ("Salting", "water activity"),
    ("Smoking", "water activity, oxygen"),
    ("Pickling in vinegar", "acidity"),
    ("Ice house", "temperature"),
    ("Appert jar", "temperature, oxygen"),
    ("Home fridge", "temperature"),
]
for name, levers in methods:
    print(f"{name:<20} -> {levers}")
```

```
count = {}
for _, levers in methods:
    for l in levers.split(", "):
        count[l] = count.get(l, 0) + 1
print(count)
# Sun drying           -> water activity
# Salting              -> water activity
# Smoking              -> water activity, oxygen
# Pickling in vinegar  -> acidity
# Ice house            -> temperature
# Appert jar           -> temperature, oxygen
# Home fridge          -> temperature
# {'water activity': 3, 'oxygen': 2, 'acidity': 1, 'temperature': 3}
```

The tally shows two lessons. Water and temperature dominate because they are the easiest levers to reach; acid appears once, and fermentation (which makes acid with microbes rather than adding it) gets its own chapters later. And every method also relies on oxygen, in effect: dried food is stored dry, jars are sealed, brine covers pickles.

Travel Foods and What They Teach

Preserved foods are travel foods. Ship's biscuit is dried bread; salt pork and salted fish fed sailors; dried meat travels on a trek; canned goods fed armies and later explorers. Each is a compromise: the more levers you pull, the longer it lasts and often the harder it is to eat. Salt-cured fish is edible only after soaking, and hard biscuit may need dunking, which is the price of a very low water activity. The same compromise appears in modern foods, and it is worth asking of any preserved food: which lever is it relying on, and what did it cost in texture or taste?

EXERCISE 1

A safe home experiment (do not eat anything). Weigh 100 g of fresh apple slices on a kitchen scale, then dry them in a low oven (about 60 °C is a typical dry setting, assumed here) for several hours, weighing every hour. Plot or tabulate the weight against time, work out the percentage of weight lost when the slices feel leathery, and say which lever you pulled. Put the slices in a sealed container and a second batch in an open dish, and record which one softens first over a few days.

View solution

EXERCISE 2

A calculation. An army column carries 20,000 rations for a march. Suppose (assumed numbers) that 1 in 5 fresh rations spoil before use in the heat, but only 1 in 50 preserved ones. How many rations are lost in each case, and how many extra people could be fed from the saved rations if each person needs 3 rations a day for the 10-day march?

View solution

EXERCISE 3

A diagnosis. For each of five traditional foods (salted fish, sun-dried fruit, a jar of vinegar pickles, smoked sausage, food kept in an ice house), name the lever or levers it relies on, say what the people who made it did not know, and describe one way the method could fail so that the food was no longer protected.

View solution

QUICK REFERENCE

- **Oldest methods:** drying, salting, smoking, pickling; most pull the water-activity lever
- **Cold:** snow, ice houses, then mechanical refrigeration; temperature lever, limited by ice supply until machines
- **Appert:** glass jars sealed and heated in boiling water; method published in 1810 after a 12,000-franc prize offered in 1795
- **Durand:** patented metal containers in 1810; cans replaced glass for travel
- **Lesson:** methods worked long before the science explained them, so tested modern guidance beats old recipes
- **Compromise:** more levers pulled means longer keeping, and often tougher or saltier food

COMING NEXT

Fermentation and Food Preservation 3 looks closely at salt, sugar and drying: osmosis and water activity, brining and curing, jam and candying, and drying by sun, air and oven.

Fermentation and Food Preservation

Chapter 3 · Salt, Sugar and Drying

Fermentation and Food Preservation 2 showed that the oldest preservation methods mostly pull one lever: water activity. This chapter looks at that lever closely. Salt, sugar and drying look like three different jobs (a ham, a jar of jam, a tray of apple rings), yet all three do the same thing: they leave less usable water for microbes. Once that idea is clear, brine strengths, jam ratios and drying times stop being arbitrary rules and become numbers you can reason about with percentages.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: food-safety guidance from US government and university extension sources says that meat to be dried should first be heated to 160 °F (about 71 °C), or 165 °F for poultry, because a dehydrator alone may not reach a safe temperature; and that shelf-stable jerky is generally described as having a water activity of about 0.85 or lower. **Sources disagreed or were not found:** an older government seminar document gave a stricter figure of 0.80, and a current official page confirming it was not found, so this chapter uses 0.85 only as a rough guide. **Not verified by the search:** the explanation of osmosis and water activity is standard food-science teaching; the typical brine and sugar percentages quoted for traditional methods are general figures and some were not verified, so check any recipe against current tested guidance from a food-safety authority. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed.

Water Activity in One Idea

Water activity (written a_w) is a number from 0 to 1 that describes how freely available the water in a food is. Pure water is 1.0. A food can be mostly water by weight and still have a lower water activity if much of that water is held tightly by dissolved salt or sugar. Microbes can only use the free water, so what matters for keeping is not how wet a food feels, but how available its water is. Roughly, most spoilage bacteria need a high water activity; yeasts and moulds can tolerate lower values, which is why a jar of jam is attacked by mould rather than by the bacteria that spoil meat.

Osmosis: Why Salt and Sugar Pull Water Out

Cell walls, whether in a vegetable, a piece of meat or a microbe, let water pass through but hold back most dissolved particles. When one side of such a wall has a stronger solution than the other, water moves towards the stronger side. This is osmosis. Put salt on a sliced cucumber and, within minutes, water beads on the surface: the salty outside draws water out of the cells. The same thing happens to a microbe sitting in a strong brine or a thick syrup: its water leaves, and it stops growing. Salt and sugar therefore work twice: they lower the water activity of the food, and they dehydrate any microbe that lands on it.

METHOD	WHAT IS ADDED OR REMOVED	EFFECT ON THE LEVER	TYPICAL WEAK POINT
Brining	salt in water, food soaked	salt moves in, water moves out and in	strength must be measured by weight; weak brine can ferment or spoil
Dry curing	salt rubbed or packed on	draws water out as brine forms on the surface	thick pieces cure slowly; the inside may stay at risk
Jam and candying	large amounts of sugar	binds water, raises sugar share sharply	too little sugar or a loose seal lets mould grow
Drying	water removed by heat and airflow	lowers water content directly	reabsorbs moisture if stored damp

Brining and Curing

A **brine** is salt dissolved in water. The unit that matters is the percentage of salt *by weight* of the total liquid, because a spoonful of salt weighs different amounts depending on the grain size. Weigh the salt and the water, add them, and divide the salt by the total. A **dry cure** skips the water: salt is rubbed over or packed round the food, and the food's own water dissolves it into a brine on the surface. Curing is traditionally used on fish and meat, and often combined with drying or smoking afterwards (Fermentation and Food Preservation 2 covers the history).

Many traditional cured foods also use curing salts that contain nitrite. Nitrite has a specific job beyond ordinary salt and must be measured exactly, so it is not handled in this chapter and no recipe for it is given. If you want to cure meat at home, use a current, tested recipe from a food-safety authority and follow its quantities to the gram.

> Do not

> Do not measure salt by the spoonful and call it a percentage. Do not skip the heating step for meat that is to be dried. Do not assume that salting alone makes thick pieces of meat safe to keep at room temperature. And do not taste-test something you are unsure about to find out whether it is safe: smell and taste do not detect the dangerous microbes.

Jam and Candying

Fruit is wet and often acidic. Cooking it with a large amount of sugar does two things: the sugar binds water (so water activity falls), and, in jam, the fruit's own pectin and acid help it set. Candying goes further, replacing much of the water in the fruit with syrup in steps. Because jam is both sugary and acidic, it keeps well when sealed, but it is not immune: if the sugar share is too low, or the jar is not sealed properly, moulds and yeasts can grow on the surface. Heat treatment and sealing of jars is a separate subject, covered in Fermentation and Food Preservation 8.

A useful number is the **sugar share**: sugar divided by the total of sugar plus fruit, as a percentage. It is not a safety guarantee by itself, since pH, cooking and sealing also matter, but it shows at a glance why a low-sugar jam behaves more like fresh fruit than like a traditional preserve.

Drying: Sun, Air and Oven

Drying removes water directly. Sun and warm air work well in hot, dry, breezy climates; in other places an oven set low, or a dehydrator with a fan, does the same job. Three things control the speed: *temperature* (warmer air holds more water), *airflow* (moving air carries the water away) and *surface area* (thin slices dry quicker than thick chunks). Drying too hot makes the outside harden before the inside has dried, which traps water.

Dried fruit is a safe and forgiving starting point. Dried meat is not: drying does not reliably kill the microbes already present, which is why the verified guidance above says to heat the meat to a safe temperature first. Biltong and jerky are both dried meats that depend on salt, spices and drying together, and both should be made from tested recipes.

The Numbers: Brine Strength, Sugar Share, Weight Lost

Three small functions cover everything in this chapter. They are written so that any percentage in a recipe can be checked in seconds, and the weights you record on a scale go straight in.

```
# Three percentage helpers (all weights in grams)
def brine_pct(salt, water):
    return round(salt / (salt + water) * 100, 2)

def sugar_share(sugar, fruit):
    return round(sugar / (sugar + fruit) * 100, 1)

def weight_lost_pct(start, finish):
    return round((start - finish) / start * 100, 1)

print(brine_pct(30, 970))
print(brine_pct(50, 950))
print(sugar_share(600, 1000))
print(weight_lost_pct(500, 150))
# 3.0
# 5.0
# 37.5
# 70.0
```

Read the first two lines as: 30 g of salt in 970 g of water gives a 3 percent brine, and 50 g in 950 g gives 5 percent (both *illustrative* amounts, not recommendations). The last two show 600 g of sugar to 1000 g of fruit as a 37.5 percent sugar share, and a food that drops from 500 g to 150 g as having lost 70 percent of its weight. Notice that the denominator is always the *total*, not just the water or the fruit: that is the most common slip when people do this by hand.

EXERCISE 1

A safe home experiment (observation only; do not eat the results). Slice a cucumber into thin rounds. Weigh two 100 g portions on a kitchen scale and put each in its own bowl. Mix 2 g of salt into the first portion and 5 g of sugar into the second, and leave both at room temperature for an hour. Pour off and weigh the liquid in each bowl. Which drew more water, and what does that tell you about the lever?

View solution

EXERCISE 2

A calculation. (a) What percentage is a brine made from 40 g of salt and 960 g of water? (b) A jam uses 1200 g of fruit and 800 g of sugar: what is the sugar share? (c) 2000 g of fresh fruit is dried down to 800 g: what percentage of its weight was lost, and what does the remaining weight suggest about how much water was in it?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A homemade dried-apple snack grows fuzzy spots after a week in a sealed jar. (2) A low-sugar jam in a loosely closed jar develops a white film on top. (3) A piece of salted fish stays damp in the middle after days. (4) Jerky made at a very low oven temperature, never heated first, is stored on a shelf. For each, say which part of the water lever has gone wrong, and what you would change.

View solution

QUICK REFERENCE

- **Water activity:** how available the water is; lower means harder for microbes to grow
- **Osmosis:** water moves towards the stronger salt or sugar solution, out of food and out of microbes
- **Brine strength:** salt divided by (salt plus water), by weight, as a percentage
- **Sugar share:** sugar divided by (sugar plus fruit), by weight; one clue among several, not a safety guarantee
- **Drying speed:** warmer, moving air and thin slices; too hot hardens the outside and traps water
- **Meat to be dried:** heat to a safe temperature first (verified above); use tested recipes, and never measure salt by the spoonful

COMING NEXT

Fermentation and Food Preservation 4 turns to the acidity lever: pH and vinegar, refrigerator pickles, brine ratios, and why a quick pickle is not shelf-stable.

Fermentation and Food Preservation

Chapter 4 · Acid and Quick Pickles

Fermentation and Food Preservation 3 worked the water lever: salt, sugar and drying leave less usable water for microbes. This chapter moves to a second lever, acidity. Instead of taking water away, you make the food too sour for most spoilage organisms, and above all for the one that makes the most dangerous toxin. The quickest way to pull this lever at home is the refrigerator pickle: sliced vegetables in a vinegar brine, ready in a day or two. It is also the best place to learn the key caution of the whole course: *acid alone does not make a food shelf-stable*.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: several US university extension sources treat vinegar of 5 percent acidity as the baseline for pickling, and warn that store vinegar at 4 percent or lower may not be strong enough for preserving; extension guidance says a pH of 4.6 or below helps limit the risk from botulism spores, and one source adds that in practice acidified foods are often aimed at a pH of 4.2 or lower; and extension guidance describes refrigerator pickles as unprocessed and kept in the fridge, not on the shelf. **Sources disagreed or were not found:** a few non-extension sources say quick pickles can be shelf-stable if processed, which conflicts with the extension view, so this chapter follows the extension view. No official extension figure for how many days refrigerator pickles last was found, so no firm storage time is given here. **Not verified by the search:** the explanation of pH as a scale is standard chemistry teaching; the flavour ratios and brine mixes shown are general home-cooking proportions, and some were not verified, so for anything you intend to keep outside the fridge use a current, tested recipe from a food-safety authority. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed.

pH in One Idea

pH is a scale, usually from 0 to 14, that measures how acidic a liquid is. Seven is neutral (pure water), lower numbers are more acidic, higher numbers are alkaline. The scale is **logarithmic**: each step down is ten times more acidic. A food at pH 3.6 is ten times more acidic than one at pH 4.6, not slightly more. This is why a small change in pH matters so much, and why a pickle that is “a bit under” the line is much safer than one that is “just at” it.

Food-safety guidance draws a line at **pH 4.6**. Below it, the spores of *Clostridium botulinum* (the organism behind botulism) are held from germinating and making toxin; above it, they are not.

Fermentation and Food Preservation 8 returns to this “acid line” when it explains canning. For now the practical point is that vegetables such as cucumbers, carrots and onions are naturally near or above the line, so a pickle works only if the brine pulls the whole piece down well below it.

Vinegar: A Measured Acid

Vinegar is a dilute solution of acetic acid, and the label gives its strength as a percentage. Most vinegar sold for pickling is about 5 percent. Some everyday store vinegars are only 4 percent, and the extension sources say that is too weak to rely on for preserving. So the first step of any pickle is to read the label. The second is to remember that mixing vinegar with water *dilutes* it: a brine made of equal parts 5 percent vinegar and water ends up around 2.5 percent acetic acid. That is fine for a quick pickle you will eat within days, but it is exactly why a thin brine must never be used for a jar you plan to store on a shelf.

TYPE	HOW THE ACID IS DELIVERED	PROCESSED FOR SHELF?	WHERE IT KEEPS
Refrigerator (quick) pickle	vinegar brine poured over, cold or just warmed	no	in the fridge, for days to weeks
Canned pickle	tested recipe with measured vinegar, then heat processing	yes, with a tested method	shelf, if the recipe and seal are right
Fermented pickle	lactic bacteria make the acid themselves	not by vinegar	covered in Fermentation and Food Preservation 5

Building a Quick Pickle Brine

A refrigerator pickle has three parts: the **vegetable**, the **brine** (vinegar, water and salt, sometimes sugar) and the **flavourings** (garlic, dill, peppercorns, mustard seed, chilli, a bay leaf). A common home starting point is roughly equal parts vinegar and water, with salt and a little sugar dissolved in. Salt adds flavour and draws some water out of the vegetable, which also makes room for brine to move in; sugar softens the sourness. Cut vegetables thin: slim pieces let the brine reach the middle quickly, so the whole piece sours and flavours evenly. Pack them into a clean jar, pour the brine over until everything is covered, cool it, and put it in the fridge.

Flavour builds in stages. Within a few hours thin cucumber and onion slices already taste pickled; thicker carrot sticks take a day or two. Heating the brine briefly helps salt and sugar dissolve and pulls flavour from spices, but the heat is for dissolving and flavour, not for sterilising the jar for storage.

> Why a quick pickle is not shelf-stable
> A refrigerator pickle has not been heat-processed in a sealed jar, and its brine is usually diluted and sweetened to taste rather than set to a tested acidity. It relies on cold as well as acid. Do not store it at room temperature, do not seal it hot in a jar and assume it is canned, do not use vinegar below 5 percent for anything meant to last, and do not lower the vinegar share of a tested canning recipe to make it milder. If you want a shelf-stable pickle, follow a current tested recipe exactly and see Fermentation and Food Preservation 8.

The Numbers: Diluted Acid, Salt in Brine, pH Steps

Three small functions cover the arithmetic. The first gives the acidity of a vinegar-and-water mix, the second the salt percentage of the brine (the same idea as Fermentation and Food Preservation 3), and the third shows how many times more acidic one pH is than another.

```
# Brine helpers (vinegar and water in ml, salt in grams)
def diluted_acidity(label_pct, vinegar, water):
    return round(label_pct * vinegar / (vinegar + water), 2)

def salt_pct(salt, liquid):
    return round(salt / (salt + liquid) * 100, 2)

def times_more_acidic(ph_high, ph_low):
    return round(10 ** (ph_high - ph_low), 1)

print(diluted_acidity(5, 500, 500))
print(diluted_acidity(5, 600, 400))
print(diluted_acidity(4, 500, 500))
print(salt_pct(20, 980))
print(times_more_acidic(4.6, 3.6))
# 2.5
# 3.0
# 2.0
# 2.0
```

```
# 10.0
```

Read the first three lines as: 500 ml of 5 percent vinegar with 500 ml of water gives 2.5 percent; 600 ml with 400 ml gives 3.0 percent; and the same half-and-half mix made with a 4 percent vinegar gives only 2.0 percent (all *illustrative* amounts, not recommendations). The fourth shows 20 g of salt in 980 g of liquid as a 2 percent salt brine, and the last that pH 3.6 is ten times more acidic than pH 4.6. Notice that vinegar volume is divided by the *total* liquid, as in the percentage helpers of Fermentation and Food Preservation 3.

EXERCISE 1

A safe home experiment (refrigerator only; eat within a few days or bin). Thinly slice a cucumber or a red onion. Make a brine of equal parts 5 percent vinegar and water, with a level teaspoon of salt and half a teaspoon of sugar dissolved in about 200 ml total, and pour it over the slices in a clean jar kept in the fridge. Taste one slice after 1 hour, 6 hours and 24 hours and write down how the flavour changes. If you have a drop of red cabbage water or pH strips, note the colour or reading of the brine.

View solution

EXERCISE 2

A calculation. (a) What is the acidity of a brine made from 300 ml of 5 percent vinegar and 200 ml of water? (b) A recipe card says “use 4 percent vinegar, one part to one part water”: what is the final acidity, and how does it compare with the same mix made with 5 percent vinegar? (c) By how many times is pH 3.6 more acidic than pH 4.6, and how many times more acidic than pH 5.6?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A jar of quick pickles was made with a mild, half-and-half brine, sealed warm and left on a kitchen shelf for a month. (2) A friend lowers the vinegar share in a tested canning recipe to make it less sharp. (3) Thick carrot sticks taste bland in the middle after one day in the fridge. (4) A brine is made with a vinegar bottle that says 4 percent and is stored for months. For each, say which part of the acidity lever has gone wrong, and what you would change.

View solution

QUICK REFERENCE

- **pH:** a logarithmic scale; each step down is ten times more acidic; 4.6 is the food-safety line, with lower being safer
- **Vinegar:** read the label; 5 percent is the baseline for pickling, and 4 percent or lower is too weak to rely on for preserving
- **Dilution:** label strength times vinegar volume divided by total liquid; half-and-half halves the acidity
- **Quick pickle:** thin slices, brine, flavourings, fridge; fast and tasty, but cold is doing part of the work
- **Not shelf-stable:** unprocessed and diluted; for the shelf use a tested recipe, unchanged

COMING NEXT

Fermentation and Food Preservation 5 shows how bacteria can make the acid for you: lactic fermentation, salt percentages for sauerkraut and kimchi, and how to read bubbles, brine and smell.

Fermentation and Food Preservation

Chapter 5 · Lactic Fermentation

Fermentation and Food Preservation 4 pulled the acidity lever by pouring in vinegar. This chapter pulls the same lever a different way: you set up conditions so that friendly bacteria make the acid themselves, inside the jar. Salt, a lack of air and a little time are the controls. The result is sauerkraut, kimchi and their many cousins, which are not only preserved but changed in flavour and texture. Because the acid arrives gradually, the early days are the delicate part, and that is where salt and submersion do their work.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: a University of California extension document gives salt for sauerkraut as 2 to 2.5 percent of the weight of the sliced cabbage and warns that less salt causes quality problems; a University of Vermont extension method multiplies the cabbage weight by the salt fraction (800 g at 2 percent gives 16 g of salt); and several sources suggest the upper end of the range in warm weather to slow the ferment. **Sources disagreed or were not found:** a figure of 2.25 percent came only from a home-cooking blog, so it is used here only as a point inside the extension range; one calculator site claimed that salt above about 3 percent slows fermentation a lot, which could not be confirmed, so no firm upper limit is stated. **Not verified by the search:** the descriptions of how the bacteria work, the timing of the stages and the notes on bubbles, brine and smell are standard teaching rather than checked against a source, and some figures were not verified. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed. Mould and doubtful batches are handled properly in Fermentation and Food Preservation 10; until then, when in doubt, bin it.

Who Does the Work

On the surface of every cabbage leaf live many kinds of microbe, including *Lactobacillus* and related lactic acid bacteria. Normally they are a tiny minority. In a salted, airless jar they get a head start. They feed on the sugars in the vegetable and give off **lactic acid**, plus some carbon dioxide and flavour compounds. As the acid builds, the brine becomes too sour for most spoilage organisms and the pH falls toward the safe side of the line met in Fermentation and Food Preservation 4. Nothing is added except salt: the cabbage supplies its own bacteria and its own food.

The Three Controls

Salt is the first control. It draws water out of the cabbage to make a brine, and it favours the salt-tolerant lactic bacteria over many spoilage organisms (the water lever from Fermentation and Food Preservation 3 at work). Too little salt and the wrong microbes compete; too much and everything, including the helpful bacteria, slows down. Sauerkraut guidance sits around 2 to 2.5 percent salt by weight of the cabbage. **Oxygen** is the second: lactic bacteria cope without air, while moulds need it, so the vegetables must stay *under* the brine. **Temperature** is the third: a cool room (roughly 18 to 22 degrees Celsius, *assumed*) gives a steady, slower ferment with better flavour, while a hot room runs fast and can turn soft and over-sour.

CONTROL	WHAT IT DOES	IF IT GOES WRONG
Salt by weight	makes brine, favours lactic bacteria, firms texture	too low: soft or off results; too high: stalled ferment
Submersion	keeps the food away from air	pieces above the brine may grow mould
Temperature	sets the speed of the ferment	hot: mushy and fast; cold: very slow
Time	lets acid build	too short: mild and not yet acidic

Sauerkraut and Kimchi Compared

Sauerkraut is the plain version: shredded cabbage, salt, nothing else. Kimchi is the richly seasoned Korean relative: cabbage (and often radish) salted, then mixed with a paste of chilli, garlic, ginger and other seasonings, and fermented. Both rely on the same three controls. The main practical difference is that kimchi seasonings add extra flavour and extra food for the microbes, and that a salting-and-rinsing step is common before the paste goes on. Recipes vary widely by family and region, so treat any single kimchi recipe as one version among many.

Reading the Jar

Bubbles and fizz are carbon dioxide and a good sign of activity, usually strongest in the first days. **Cloudy brine** is normal: it is clouds of bacteria. **Sour, tangy smell** is expected, like pickle brine with a cabbage note; a sulphurous cabbage smell early on often fades. A **soft white film** may be a harmless yeast (kahm) but can be confused with mould, and **fuzzy, coloured or hairy**

growth is mould: this is the line where a batch is thrown out, as Fermentation and Food Preservation 10 explains in full. A slimy, rotten or putrid smell is also a bin signal. Gases must be allowed to escape: a tightly sealed jar can build pressure, so use a loosened lid, an airlock, or open it briefly each day (“burping”).

> Do not
> Do not guess the salt: weigh the vegetables and the salt on a scale, because spoonfuls of different salts vary a lot. Do not leave vegetable pieces floating above the brine. Do not seal the jar so tightly that pressure cannot escape. Do not taste-test anything fuzzy, coloured or slimy, and do not scrape off mould and keep the rest. Do not reduce the salt to make a “healthier” ferment below the tested range. Do not treat a jar as canned: a ferment is kept cool and used within its own time, as Fermentation and Food Preservation 8 explains for true shelf storage.

The Numbers: Salt by Weight

Fermentation salt is a weight ratio, so the arithmetic is simple. The first function gives the salt to weigh out for a given weight of vegetables and a chosen percentage. The second checks the percentage of a batch you have already weighed. The third gives the strength of a salt-water brine, as in Fermentation and Food Preservation 3.

```
# Ferment salt helpers (weights in grams)
def salt_needed(veg, pct):
    return round(veg * pct / 100, 1)

def salt_share(salt, veg):
    return round(salt / veg * 100, 2)

def brine_pct(salt, water):
    return round(salt / (salt + water) * 100, 2)

print(salt_needed(800, 2))
print(salt_needed(1000, 2.25))
print(salt_share(30, 1200))
print(salt_share(10, 1000))
print(brine_pct(30, 970))
# 16.0
# 22.5
# 2.5
```

```
# 1.0
# 3.0
```

Read the output as: 800 g of cabbage at 2 percent needs 16 g of salt; 1000 g at 2.25 percent needs 22.5 g; 30 g of salt on 1200 g of cabbage is 2.5 percent; 10 g on 1000 g is only 1.0 percent, which is below the range given above; and 30 g of salt in 970 g of water is a 3 percent brine (all amounts *illustrative*). Note that for a dry-salted ferment the percentage is of the *vegetable* weight, but for a brine ferment it is of the salt plus water, so always say which one a recipe means.

EXERCISE 1

A safe home experiment (a small batch, kept cool, jar loosely covered). Weigh about 500 g of shredded white cabbage and calculate 2 percent of that as salt. Massage the salt into the cabbage for several minutes until it releases liquid, pack it tightly into a clean jar so the liquid rises over the cabbage, and weigh it down so nothing pokes above the brine. Leave it at room temperature out of direct sun and note on days 1, 2, 3, 5 and 7: bubbles, smell, taste and brine level. If you see any fuzzy growth, bin the batch.

View solution

EXERCISE 2

A calculation. (a) How much salt is needed for 1500 g of cabbage at 2.5 percent, and for 750 g at 2 percent? (b) A batch uses 12 g of salt on 600 g of vegetables: what percentage is that, and is it in the range given in this chapter? (c) A cook weighs vegetables at 1000 g and adds 10 g of salt: what percentage is that, and what would you change?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) After two days the jar is cloudy and fizzing, with a sour smell. (2) The top layer of cabbage was left above the liquid and has a fuzzy green patch. (3) A kitchen in a heatwave gives a ferment that is soft and very sour after three days. (4) A tightly sealed jar is bulging, and the lid hisses when it is opened. For each, say what the signs mean, which of the three controls is involved, and what you would do.

View solution

QUICK REFERENCE

- **Who:** lactic acid bacteria on the vegetable turn its sugars into lactic acid, so the food makes its own acid
- **Salt:** weigh it; sauerkraut guidance is about 2 to 2.5 percent of the vegetable weight, higher end when warm
- **Submerge:** keep everything under the brine, since moulds need air
- **Temperature:** cool and steady gives the best flavour; hot is fast and risks mush
- **Read the jar:** bubbles, cloudiness and a sour smell are normal; fuzzy, coloured or slimy means bin it
- **Let gas out:** never seal a ferment so tight that pressure builds

COMING NEXT

Fermentation and Food Preservation 6 moves from vegetables to drinks: yeast and bacteria cultures, what controls the sugar, time and fizz, and the basics of alcohol.

Fermentation and Food Preservation

Chapter 6 · Fermented Drinks

Fermentation and Food Preservation 5 used bacteria that were already on the vegetables. Drinks work differently: the food is a sweet liquid with almost nothing living in it, so you add a *culture*, a community of microbes you choose. Yeast eats sugar and makes alcohol and carbon dioxide; certain bacteria then turn some of that alcohol into acid. Which drink you get depends on which microbes you add and how much sugar, time and air you allow. The acidity lever from Fermentation and Food Preservation 4 is again the safety control, and a simple pH check can tell you whether a batch has got there.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: Colorado State University and the British Columbia Centre for Disease Control both give the safe pH for kombucha as below 4.2 and not lower than 2.5; Pennsylvania state guidance says kombucha starts at roughly pH 5, should finish below 4.2, and should be thrown away if it has not reached 4.2 within seven days, and recommends a calibrated digital pH meter and a log for each batch. **Sources disagreed or were not found:** some hobby sites give a finished target of 2.5 to 3.5 with a favourite of 3.0 to 3.3; that sits inside the official window but is not a regulatory figure, so it is not used as a limit here. One site claimed pathogens are eliminated during fermentation, which could not be confirmed, so it is not repeated. **Not verified by the search:** the descriptions of how yeast and bacteria cooperate, the fizz and timing notes, the alcohol remarks and the water kefir and ginger bug details are standard teaching rather than checked against a source, and some figures were not verified. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed. Alcohol content cannot be judged by taste: if a drink matters for health, legal or age reasons, treat it as possibly alcoholic.

Two Kinds of Microbe, One Jar

Yeast turns sugar into ethanol (alcohol) and carbon dioxide. With little oxygen it makes mostly alcohol; with plenty of oxygen it multiplies instead. **Acetic acid bacteria** need oxygen and turn alcohol into acetic acid, the sour of vinegar. **Lactic acid bacteria**, the same family met in Fermentation and Food Preservation 5, make lactic acid from sugars. A *culture* such as a kombucha SCOBY (a rubbery mat, short for symbiotic culture of bacteria and yeast) or kefir grains holds several of these at once, each feeding on the others' products. That teamwork is why these drinks are sour, lightly fizzy and slightly alcoholic all together.

The Drinks Compared

DRINK	CULTURE	SWEET BASE	TYPICAL CHARACTER
Kombucha	SCOBY plus a little finished kombucha	sweetened tea	tart, lightly fizzy, trace alcohol
Water kefir	water kefir grains (not milk kefir)	sugar water, often with dried fruit	mild, sweet-sour, fizzy when bottled
Ginger bug	wild yeast and bacteria from ginger	sugar and grated ginger, fed daily	a starter used to fizz other sweet drinks
Brewed beer or wine	chosen yeast	malt or fruit juice	deliberately alcoholic

Sugar, Time and Fizz

Sugar is the fuel. More sugar means more to ferment, so more acid, more gas and more alcohol, though a very sugary start can slow the culture down, just as salt did in Fermentation and Food Preservation 3. **Time** lets the sourness build: a first ferment in an open, cloth-covered vessel lets in air for the bacteria and keeps dust out. A **second ferment** in a sealed bottle traps the carbon dioxide, which is where fizz comes from. **Temperature** sets the pace: a warm room (around 20 to 28 degrees Celsius, *assumed*) is quicker, a cold one slow. Fizz is also the main risk of a second ferment, because sealed gas builds pressure.

Do not

Do not seal a second ferment in thin or cracked glass, or leave it for days unattended: pressure can burst a bottle, so use strong swing-top or plastic bottles and chill them to slow the ferment. Do not open a warm, vigorous bottle suddenly or point it at your face. Do not use reactive or unglazed containers for acidic brews. Do not use honey-water or other mixtures as a shortcut for the proven recipe if you are new to this. Do not keep a kombucha batch that has fuzzy, dry or coloured mould, or that has not turned acidic in good time (see the pH check below): bin it and start fresh. Do not assume a home ferment is alcohol-free, and do not give it to children or anyone who must avoid alcohol. Do not make it in a heatwave without watching the fizz.

The Numbers: Sugar and pH

Sugar strength is the same kind of weight ratio used for brine. The first function gives the sugar percentage of a mix; the second gives the sugar to dissolve in a volume of water (1 ml of water is taken as 1 g) for a chosen percentage; the third checks a pH reading against the 2.5 to 4.2 window from the guidance above. This is a record-keeping aid, not a replacement for a meter, a log and common sense.

```
# Drink ferment helpers (weights in grams, 1 ml water = 1 g)
def sugar_pct(sugar, water):
    return round(sugar / (sugar + water) * 100, 1)

def sugar_for(water, pct):
    return round(water * pct / (100 - pct), 1)

def ph_ok(ph):
    return 2.5 <= ph <= 4.2

print(sugar_pct(100, 1000))
print(sugar_for(2000, 5))
print([ph_ok(p) for p in (5.0, 4.4, 3.6, 2.3)])
# 9.1
# 105.3
# [False, False, True, False]
```

Read the output as: 100 g of sugar in 1000 g of water is a 9.1 percent mix; 105.3 g of sugar in 2000 g of water makes a 5 percent mix; and of four pH readings only 3.6 is inside the window, while 5.0 and 4.4 are not yet acidic enough and 2.3 is too acidic (all values *illustrative*). A fresh sweet-tea batch starts near pH 5, so a reading that has not fallen below 4.2 after a week is a signal to discard, as the guidance above says.

EXERCISE 1

A safe home experiment. Make a small ginger bug: in a clean jar stir a teaspoon of grated unpeeled ginger and a teaspoon of sugar into about 250 ml of non-chlorinated water, cover with a cloth, and feed it the same amount of ginger and sugar daily. Note each day for a week: bubbles, smell and activity. When it fizzes clearly, stir a small spoonful into a bottle of weak sweetened tea or fruit juice, bottle it only in a strong plastic bottle, leave it at room temperature for a day or two and squeeze to check hardness, then chill it. Do not drink anything that smells off or grows fuzzy mould.

View solution

EXERCISE 2

A calculation. (a) What percentage sugar is 80 g of sugar dissolved in 1000 g of water? (b) How much sugar goes into 1500 g of water for a 6 percent mix? (c) Four kombucha pH readings are logged on days 0, 3, 5 and 8: 5.1, 4.6, 4.3 and 4.4. Using the 2.5 to 4.2 window and the seven-day rule from this chapter, what would you do on day 8?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A kombucha batch has a thick new mat on top and a sharp vinegar smell. (2) A kombucha has a dry, fuzzy green patch on the mat. (3) A bottle of water kefir left warm for four days has a bulging plastic bottle and hisses on opening. (4) A second-ferment drink tastes pleasantly tart but flat. For each, say what the signs mean, which of sugar, time, air or temperature is involved, and what you would do.

View solution

QUICK REFERENCE

- **Yeast:** sugar to alcohol and carbon dioxide; **acid bacteria:** turn alcohol and sugars into acid
- **First ferment:** covered with cloth, air allowed, sourness builds
- **Second ferment:** sealed, traps gas for fizz; strong bottles, chill to slow it
- **pH guidance for kombucha:** below 4.2 and not below 2.5; discard if not below 4.2 in about seven days
- **Mould:** fuzzy, dry or coloured on the mat means bin the batch
- **Alcohol:** assume some, even in a drink that tastes like soda

COMING NEXT

Fermentation and Food Preservation 7 moves to dairy and grain ferments: yoghurt and kefir, sourdough as a living culture, and the soy ferments miso and tempeh.

Fermentation and Food Preservation

Chapter 7 · Dairy and Grain Ferments

Fermentation and Food Preservation 6 grew cultures in sweet liquids. This chapter uses cultures on richer foods: milk, flour and soya beans. Milk is a very welcoming food for microbes, so the safe way to make yoghurt is to start from a clean slate (heated or pasteurised milk) and then let your chosen culture win quickly. Sourdough keeps a culture alive between bakes by feeding it. Miso and tempeh bring in moulds as well as bacteria and yeast: a mould called *koji* breaks starch and protein into sugars and savoury amino acids before salt or bacteria take over. The same levers apply as before: sugar and starch as fuel, temperature, time, salt and acid.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: university extension guidance says to use pasteurised milk for yoghurt (or pasteurise raw milk first), puts incubation at about 110 degrees Fahrenheit (about 43 degrees Celsius), and says yoghurt should be refrigerated as soon as it reaches the desired thickness; a general food-safety definition of the temperature danger zone is roughly 40 to 140 degrees Fahrenheit (about 4 to 60 Celsius), though it is a general holding guide rather than a yoghurt rule. **Sources disagreed or were not found:** a figure of 180 degrees Fahrenheit (about 82 Celsius) for heating milk appears in one extension answer as a level at which yoghurt is generally safe if chilled promptly, but no source named it as a required standard, so it is presented as common practice, not a rule. No authoritative source was found for any fixed hour limit on home incubation, so none is given. **Not verified by the search:** the descriptions of koji, miso, tempeh and sourdough, the starter feeding ratios and the timings are standard teaching rather than checked against a source, and some figures were not verified. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed. Miso and tempeh at home carry real safety questions for beginners; this chapter explains them but sets only a yoghurt and starter experiment.

Dairy: Yoghurt and Kefir

Yoghurt is milk soured by lactic acid bacteria, the family met in Fermentation and Food Preservation 5. They eat the milk sugar (lactose) and make lactic acid. The falling pH makes the milk proteins clump into a gel, which is why yoghurt thickens, and the acidity is the safety lever from Fermentation and Food Preservation 4. A warm spot (about 43 degrees Celsius) suits the bacteria, but it also suits unwanted microbes, so use pasteurised milk, a clean jar and a fresh starter, and chill the pot as soon as it has set. **Kefir** is a close relative made with grains holding

both bacteria and yeast, which is why it is tangy and lightly fizzy, much like the cultures in Fermentation and Food Preservation 6. Milk kefir grains are not the same as water kefir grains.

Grain: Sourdough as a Living Culture

A **sourdough starter** is flour and water that wild yeast and lactic acid bacteria have colonised. Feeding it fresh flour and water gives the microbes new fuel; the yeast makes gas that lifts the dough, and the bacteria make acid that gives the sour taste and keeps many unwelcome microbes out. **Hydration** is the weight of water as a percentage of the weight of flour, and it changes how runny the starter is and how fast it works. A ripe starter is bubbly, has roughly doubled and smells pleasantly sour; a starter with pink or orange streaks or fuzzy mould is thrown away, not rescued.

Soy and Koji: Miso and Tempeh

Koji is rice or another grain grown with a mould (*Aspergillus oryzae*) whose enzymes break starch into sugars and protein into savoury amino acids. **Miso** is made by mixing koji with cooked soya beans and a high proportion of salt, then ageing for months. The salt is the main safety lever, working as it did in Fermentation and Food Preservation 3 and 5, while the koji enzymes do the flavour work. **Tempeh** is different: cooked soya beans are bound into a firm cake by a white mould (*Rhizopus*), kept warm and humid for about a day or two, and the cake must be cooked before eating. Both depend on precise temperature and clean handling, which is why they are explained here but not set as a first experiment.

The Ferments Compared

FERMENT	FOOD	MICROBES	MAIN SAFETY LEVER
Yoghurt	milk	lactic acid bacteria	clean start, acid, prompt chilling
Milk kefir	milk	bacteria and yeast in grains	acid, clean start, chilling
Sourdough starter	flour and water	wild yeast and bacteria	acid from regular feeding

FERMENT	FOOD	MICROBES	MAIN SAFETY LEVER
Miso	soya beans, koji, salt	koji mould, then yeast and bacteria	high salt
Tempeh	soya beans	Rhizopus mould	clean handling, temperature control, cooking

> Do not
> Do not use raw milk for yoghurt unless you pasteurise it first, and do not leave set yoghurt sitting warm: chill it as soon as it is thick. Do not reuse a culture that smells rotten rather than sour, or that shows pink, orange or fuzzy coloured mould. Do not feed a starter and then leave it sealed tight, because gas can burst the lid. Do not try tempeh or miso as a beginner without a tested recipe from a reliable source, and do not eat tempeh raw. Do not rescue a mouldy ferment by scraping off the top: bin it.

The Numbers: Hydration, Salt and Temperature

Hydration and salt percentage are the same weight ratios used in earlier chapters. The third function converts a Fahrenheit temperature from a recipe to Celsius.

```
# Dairy and grain ferment helpers (weights in grams)
def hydration(flour, water):
    return round(water / flour * 100, 1)

def salt_pct(salt, total):
    return round(salt / total * 100, 1)

def f_to_c(f):
    return round((f - 32) * 5 / 9, 1)

print(hydration(400, 300))
print(hydration(50, 50))
print(salt_pct(60, 500))
print(f_to_c(110), f_to_c(180))
# 75.0
# 100.0
# 12.0
```

```
# 43.3 82.2
```

Read the output as: 300 g of water to 400 g of flour is 75 percent hydration; 50 g of each is 100 percent (a thick-pourable starter); 60 g of salt in a 500 g mix is 12 percent salt; and 110 and 180 degrees Fahrenheit are 43.3 and 82.2 degrees Celsius (all weights *illustrative*).

EXERCISE 1

A safe home experiment. Start a sourdough starter: mix 50 g of flour and 50 g of non-chlorinated water in a clean jar, cover loosely, and each day discard half and feed with 50 g of each. Log the smell, bubbles and height for a week. Optionally, also make a small pot of yoghurt from pasteurised milk and a spoonful of live plain yoghurt, kept warm for several hours, then chilled once set. Do not eat anything with coloured mould or a rotten smell.

View solution

EXERCISE 2

A calculation. (a) What is the hydration of a dough using 600 g of flour and 420 g of water? (b) A starter is fed 30 g of flour and 45 g of water: what is its hydration? (c) A recipe says to cool milk to 108 degrees Fahrenheit before adding culture: what is that in Celsius, to one decimal place?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A starter has a layer of grey-brown liquid on top but smells sharply sour. (2) A starter has orange streaks and a fuzzy patch. (3) Homemade yoghurt stayed runny and smells mildly sour after a cool night. (4) A jar of milk kefir smells of yeast and has separated into curds and watery whey. For each, say what the signs mean, which lever is involved, and what you would do.

View solution

QUICK REFERENCE

- **Yoghurt:** pasteurised milk, about 43 degrees Celsius, chill when set

- **Kefir:** bacteria and yeast grains; milk kefir grains differ from water kefir grains
- **Starter:** fed flour and water; hydration is water divided by flour, times 100
- **Koji:** mould-grown grain whose enzymes make sugars and amino acids
- **Miso:** koji, soya beans and lots of salt; **tempeh:** mould-bound soya cake, cook before eating
- **Bin it:** pink or orange streaks, coloured fuzzy mould, rotten smell

COMING NEXT

Fermentation and Food Preservation 8 turns to heat preservation and canning: pasteurisation, boiling-water versus pressure canning, and why acidity decides which method is safe.

Fermentation and Food Preservation

Chapter 8 · Heat and Canning

Fermentation and Food Preservation 7 let microbes work for us. This chapter does the opposite: it uses heat to kill them and a sealed jar to keep new ones out. Heat is a lever like the others in Fermentation and Food Preservation 1, but it works differently. Salt, acid and dryness slow microbes down; heat destroys them, and a lid then stops recontamination. The hard part is that one particular spore-forming bacterium survives ordinary boiling, so the method you may safely use depends on how acidic the food is. That single idea, the acid line, is the heart of home canning.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: university extension sources agree that foods with a pH above 4.6 (vegetables, meat, poultry, seafood) are low-acid and lack enough acid to stop botulism spores growing; that those spores can survive the 212 degrees Fahrenheit (100 Celsius) reached in boiling water; that a pressure canner can reach about 240 degrees Fahrenheit (about 116 Celsius); and that tomatoes sit close to the acid line (pH roughly 4.0 to 4.6) so tested recipes with added acid must be followed. **Not verified by the search:** no source found gave headspace amounts or explained their effect, so no headspace figures are stated here; the pasteurisation descriptions, jar and seal descriptions and the history are standard teaching, and some figures were not verified. One low-quality page gave a different acid threshold and was disregarded. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed. This chapter explains pressure canning but sets only a safe, non-canning experiment: always use a tested recipe from a recognised food-safety authority for real canning.

Pasteurisation: Heat Enough, Not Too Much

Pasteurisation heats food just enough to kill the microbes that cause disease or rapid spoilage, while keeping flavour and texture. It does not make food sterile, so pasteurised foods still need another lever, usually refrigeration or acid. This is why pasteurised milk is chilled, yet a jar of pickles processed in boiling water can sit on a shelf: the acid does the second job. **Canning** goes further, heating sealed jars long enough to destroy the microbes that would spoil them at room temperature.

The Acid Line and Botulism

Clostridium botulinum forms tough spores that survive boiling. In an airless, low-acid, moist jar those spores can wake, grow and make a dangerous toxin, often without any obvious smell or bulge. Acid prevents this: at a pH of 4.6 or lower the bacterium cannot grow, which is the acid line used in tested canning guidance. High-acid foods (most fruit, pickles with enough vinegar, jam) are therefore safe to process in **boiling water**, which is hot enough to kill moulds, yeasts and ordinary bacteria. Low-acid foods need a **pressure canner**, because steam under pressure reaches temperatures above boiling that destroy the spores. The pH lever from Fermentation and Food Preservation 4 is why the line sits where it does.

Jars, Seals and Headspace

A canning jar has a flat lid with a sealing compound and a screw band. During processing, air is driven out of the jar; as it cools, a vacuum forms and pulls the lid down, producing a seal that shuts out new microbes. **Headspace** is the gap between the food and the lid: tested recipes specify it, because too little or too much can stop a good seal forming. A sealed lid is firm and does not flex when pressed; a lid that moves, a bulging lid, spurting liquid or a bad smell on opening means the jar is not to be used. Never judge a jar safe by taste.

Which Method for Which Food

METHOD	TEMPERATURE REACHED	FOR	WHY
Pasteurisation	below boiling	milk, juice	kills disease-causing microbes; needs chilling or acid after
Boiling-water canning	about 100 C	high-acid foods (pH 4.6 or below)	acid stops spore growth
Pressure canning	about 116 C	low-acid foods (above pH 4.6)	hot enough to destroy spores
No canning	n/a	fresh produce, refrigerated pickles	other levers: cold, salt, time

Do not

Do not boiling-water-can low-acid foods such as plain vegetables, meat or soup. Do not invent your own canning recipe or cut the vinegar, lemon juice or acid in a tested one. Do not use a recipe of unknown origin; use one tested by a food-safety authority. Do not taste a jar to see if it is safe. Do not keep or eat a jar with a bulging lid, leaking seal or off smell, and do not fill unsealed jars into the cupboard. Do not use a pressure canner without reading its manual and having the gauge checked.

The Numbers: The Acid Line and Temperatures

The function below picks the method from a food's pH using the 4.6 line, and converts temperatures. The pH values are *illustrative*.

```
# Canning method from pH, and temperature conversion
def method(ph):
    if ph <= 4.6:
        return "boiling-water"
    return "pressure"

def f_to_c(f):
    return round((f - 32) * 5 / 9, 1)

print(method(3.4), method(4.2), method(5.8))
print(f_to_c(212), f_to_c(240))
# boiling-water boiling-water pressure
# 100.0 115.6
```

Read the output as: an acidic fruit at pH 3.4 and a pickle at 4.2 are both on the boiling-water side, while a food at pH 5.8 needs a pressure canner; and 212 and 240 degrees Fahrenheit are 100 and 115.6 degrees Celsius. In real life a tested recipe, not this function, decides; a food near the line (such as tomatoes) needs added acid as the recipe directs.

EXERCISE 1

A safe home experiment (no canning). Look up a tested high-acid recipe from a recognised food-safety authority and read it through, noting the acid, the processing time, the headspace and the jar preparation. Separately, take two clean jars, fill one with water and one with the same water plus a

spoonful of vinegar, and compare with pH strips or a pH meter if you have them. Write down which lever each recipe step pulls. Do not actually can anything unless you have the proper equipment and a tested recipe.

View solution

EXERCISE 2

A calculation. (a) Which method does a food of pH 3.9 need, and which does a food of pH 6.2 need? (b) A recipe gives a processing temperature of 250 degrees Fahrenheit: what is it in Celsius, to one decimal place? (c) How many degrees Celsius hotter is 240 degrees Fahrenheit than boiling water at 212?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A homemade jar of plain green beans was processed in a boiling-water pot and stored. (2) A jar of jam has a lid that flexes when pressed. (3) A jar of tomatoes made from a tested recipe has a firm, curved-in lid and no leaks. (4) A jar of canned soup spurts liquid when opened and smells off. For each, say what it means, which lever is involved, and what you would do.

View solution

QUICK REFERENCE

- **Pasteurisation:** kills disease-causing microbes, not sterile; keep chilled or acid
- **Acid line:** pH 4.6; at or below, boiling-water canning; above, pressure canning
- **Botulism:** spores survive boiling; they grow in airless, low-acid jars
- **Seal:** vacuum pulls the lid down; firm lid is good, flexing or bulging is bad
- **Always:** use tested recipes; never taste to check

COMING NEXT

Fermentation and Food Preservation 9 turns to cold, freezing and smoking: refrigeration and freezer science, ice crystals and quality, hot and cold smoking, and vacuum sealing.

Fermentation and Food Preservation

Chapter 9 · Cold and Smoke

Fermentation and Food Preservation 8 used heat to destroy microbes. This chapter uses the opposite lever, cold, which does not destroy them but puts them to sleep, and then looks at smoke, an old method that combines drying, chemistry and sometimes gentle heat. It also covers vacuum sealing, which removes the oxygen lever from the model in Fermentation and Food Preservation 1. The key idea is that cold is a brake, not an eraser: whatever was on the food when it went in is still there when it comes out.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: consumer food-safety sources (FDA and state health departments) agree that the refrigerator should be at 40 degrees Fahrenheit (about 4 Celsius) or colder and the freezer at 0 degrees Fahrenheit (about -18 Celsius) or colder; that food kept at 0 degrees Fahrenheit stays safe indefinitely although quality falls over time; that freezing does not kill most bacteria but makes them dormant, so thawed food must be handled like fresh food; and that perishable food held above 40 degrees Fahrenheit for four hours (one older statement says two) should be discarded, so sources differ on that cut-off. **Not verified by the search:** the search returned nothing on smoking temperatures, so no smoking temperature figures are stated here; the descriptions of ice crystals, freezer burn, smoke chemistry and vacuum sealing are standard teaching, and some figures were not verified. Numbers marked *assumed* or *illustrative* are invented to show a method. All Python in this chapter was run and the output in the comments is what it printed. The exercises use only a fridge, a freezer and a thermometer; they do not ask you to smoke anything.

Cold: A Brake on Microbes and Enzymes

Microbes and enzymes are chemistry, and chemistry slows as temperature falls. A refrigerator at 40 degrees Fahrenheit (about 4 Celsius) slows most spoilage and disease-causing bacteria a great deal, but some still grow slowly, and a few cold-tolerant types keep going for days. This is why refrigerated food still has a use-by date. A freezer at 0 degrees Fahrenheit (about -18 Celsius) stops microbial growth altogether, because the water is locked into ice and the microbes go dormant. Since freezing does not kill most of them, they wake when the food thaws. The temperature lever works together with the water activity lever: frozen water is not available to microbes.

Ice Crystals and Quality

Cold keeps food safe, but quality depends on **how** it freezes. Slow freezing forms a few large ice crystals that can rupture cell walls, so the food turns mushy and leaks liquid when thawed. Fast freezing forms many small crystals that do less damage, which is why thin, flat packages of food freeze better than thick blocks. **Freezer burn** is a quality problem, not a safety problem: moisture escapes from the surface of poorly wrapped food into the dry freezer air, leaving grey, dry, tough patches. Wrapping tightly, removing air and keeping the temperature steady all reduce it. Repeated partial thawing and refreezing grows larger crystals and is best avoided; thaw in the refrigerator rather than on the counter.

Smoking: Drying, Chemistry and Heat

Smoking exposes food, usually already salted or cured, to smoke from smouldering wood. It preserves in several ways at once: the airflow dries the surface (lowering water activity, as in Fermentation and Food Preservation 3), compounds in the smoke slow microbes and oxidation, and the surface forms a dry, protective skin. There are two broad styles. **Cold smoking** keeps the food at low temperature so it flavours and partly dries but does not cook it; because the food stays raw, it relies heavily on a proper salt cure first and is the riskier style for beginners. **Hot smoking** cooks the food as it smokes, so it is safer to eat soon, but it does not make the food shelf-stable, and it still needs refrigeration. In both cases smoke is an extra lever on top of salt, not a replacement for it. Learn the tested safety rules for any specific product from a food-safety authority before trying it.

Vacuum Sealing: Removing the Oxygen Lever

A vacuum sealer pulls the air out of a bag before sealing it. With less oxygen, oxidation slows and mould (which needs air) struggles, and freezer burn is reduced because there is no air pocket to draw moisture out. But vacuum sealing is **not** a preservation method by itself. It removes air, and some dangerous bacteria, including the botulism organism from Fermentation and Food Preservation 8, grow without air. So vacuum-sealed fresh food still has to be kept cold, and it is not a way to store low-acid food at room temperature.

Which Cold or Smoke Method for Which Job

METHOD	MAIN LEVERS	GOOD FOR	LIMIT
Refrigerator	cold (about 4 C or colder)	days to weeks	slows, does not stop
Freezer	cold (about -18 C or colder), ice	months	quality loss; microbes wake on thawing
Hot smoking	heat, smoke, surface drying	eating soon	still needs refrigeration
Cold smoking	salt cure, smoke, drying	cured products	raw, so needs a tested method
Vacuum sealing	less oxygen	boosting fridge and freezer storage	not safe alone for room temperature

> Do not
> Do not leave perishable food above 40 degrees Fahrenheit (about 4 Celsius) for hours and then refreeze or eat it. Do not thaw food on the counter. Do not assume freezing makes spoiled food safe. Do not store vacuum-sealed low-acid food at room temperature. Do not cold-smoke raw meat or fish without a tested method from a food-safety authority. Do not trust a fridge that has no thermometer in it.

The Numbers: Fridge, Freezer and a Salt Cure

The code converts temperatures, checks a fridge reading against the 40 degrees Fahrenheit ceiling, and works out a salt amount by weight. The readings are *illustrative*.

```
# Fridge check and salt by weight
def f_to_c(f):
    return round((f - 32) * 5 / 9, 1)

def fridge_ok(temp_f):
    return temp_f <= 40

def salt_grams(food_g, percent):
    return food_g * percent / 100

print(f_to_c(40), f_to_c(0))
```

```
print(fridge_ok(38), fridge_ok(44))
print(salt_grams(800, 3))
# 4.4 -17.8
# True False
# 24.0
```

Read the output as: 40 and 0 degrees Fahrenheit are 4.4 and -17.8 degrees Celsius; a fridge at 38 degrees Fahrenheit passes and one at 44 fails; and a 3 percent salt amount on 800 g of food is 24 g. The 3 percent is an *assumed* figure used to show the arithmetic, not a recommended cure.

EXERCISE 1

A safe home experiment. Put a thermometer in the refrigerator (on a middle shelf, in a glass of water left for a few hours) and another in the freezer, and note the readings morning and evening for three days. Then freeze two small portions of the same fruit, one spread thinly on a tray and one packed in a thick block, and compare their texture after thawing in the refrigerator. Write down what you see and which lever explains it.

View solution

EXERCISE 2

A calculation. (a) Convert 36 and 45 degrees Fahrenheit to Celsius to one decimal place, and say which passes the 40 degrees Fahrenheit fridge check. (b) How many grams of salt is 2.5 percent of 600 g of food? (c) A power cut leaves a fridge at 46 degrees Fahrenheit for 5 hours: using the four-hour rule from this chapter, what should happen to the milk and cooked leftovers inside?

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A chicken breast in the freezer has dry, grey, leathery patches. (2) A bag of vacuum-sealed fresh fish has been left in a cupboard for two days. (3) Thawed strawberries are soft and leaking juice. (4) A freezer reads 15 degrees Fahrenheit and the ice cream is half-melted. For each, say what it means, which lever is involved, and what you would do.

View solution

QUICK REFERENCE

- **Fridge:** 40 F (4 C) or colder; a brake, not a stop
- **Freezer:** 0 F (-18 C) or colder; microbes dormant, not dead
- **Ice crystals:** fast freezing gives small crystals and better texture
- **Freezer burn:** a quality problem, not a safety one; wrap tightly
- **Smoke:** an extra lever on top of salt and drying; never a replacement
- **Vacuum seal:** removes oxygen, but food still needs to be kept cold

COMING NEXT

Fermentation and Food Preservation 10 turns to food safety and troubleshooting: spoilage versus safe fermentation signs, mould, kahm yeast and off smells, record-keeping, and a keep, fix or bin decision flow chart.

Fermentation and Food Preservation

Chapter 10 · Keep, Fix or Bin

Every method in Fermentation and Food Preservation 3 to 9 can go wrong, and the skill that matters most is telling a healthy jar from a failing one. This chapter gathers the signs into one decision process. It uses the levers model from Fermentation and Food Preservation 1: a healthy ferment has the right salt, acid and low oxygen, and a failing one has lost a lever. The rule that runs through the chapter is cautious: when you cannot tell, the answer is bin.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: sources agree that kahm yeast is a flat, white, often wrinkled film that is generally described as harmless to flavour rather than dangerous, whereas mould is fuzzy, raised and often green, blue or black; that a sour, tangy smell is normal in a ferment while a putrid or sewage-like smell, slimy mushy texture or pink or red discolouration that does not come from the vegetables means discard; and that keeping the food fully submerged is the main prevention. **Sources differ:** some say mould sitting only above the brine can be skimmed, others say discard the batch for any mould. **Not verified:** the results were mostly blogs, forums and retailer pages, and no official food-safety authority page was retrieved, so the mycotoxin claims and the skimming advice are unconfirmed. This course therefore takes the cautious side: bin anything fuzzy or coloured, and check a university extension guide for a borderline case. The decision function in the code is a teaching model, not a test of safety. All Python in this chapter was run and the output in the comments is what it printed.

Normal, Odd or Dangerous?

A ferment is a living system, so it changes every day. Bubbles, a cloudy brine, a sour smell and a white sediment at the bottom are normal. The question is whether what you see is the **expected activity** of the culture or the **sign of a lost lever**. A useful habit is to check three things in order: the surface, the smell and the texture.

Surface: Kahm Yeast Versus Mould

Kahm yeast forms a thin, flat, white or cream film, often wrinkled like a skin, on the surface of a ferment that is in contact with air. It is a sign that oxygen reached the brine, not that the food is

poisonous, but it can spoil the flavour, and if left it can reduce the acid, so remove it and fix the cause. **Mould** is fuzzy, raised, dry or hairy, and often green, blue, black, grey or pink. It needs air, so it grows on anything that has risen above the brine. Because the two can look alike in a photo, the safe test is texture: flat and smooth means probably kahm, fuzzy or coloured means mould. If you are unsure, treat it as mould.

Smell and Texture

A healthy lactic ferment smells sour, tangy and clean, like vinegar and fresh pickles. Warning signs are a putrid, rotten, cheesy-sewage or alcohol-solvent smell that is strong enough to make you step back; a **slimy**, stringy or mushy texture that is not just overripeness; and pink, red or black patches that do not come from the vegetables. A ferment that is merely too soft and very sour is over-fermented: safe but past its best, and good for cooking. Do not taste a jar to decide whether it is safe. Taste only after surface, smell and texture have passed.

Fix the Cause, Not Just the Symptom

SIGN	LOST LEVER	LIKELY CAUSE	ACTION
Flat white film	low oxygen	brine surface exposed to air	skim, re-submerge, keep weighted
Fuzzy or coloured growth	low oxygen, salt or acid	food above brine, too little salt	bin the whole batch
Putrid smell	salt or acid	too little salt, too warm	bin
Slimy, mushy	salt or acid	wrong salt weight, hot room	bin; weigh salt next time
Soft but sour	time and temperature	over-fermented	keep, refrigerate, use in cooking
No bubbles, clean smell	none lost	cool room or slow start	keep, wait, warm slightly

Record-Keeping

A short log turns a mystery into data. For each jar write the start date, the weights of food and salt, the salt percentage, the room temperature, and a line each day or two: bubbles, smell, surface. When something fails, the log shows which lever moved. Record the salt by weight, never by spoonfuls, because the same spoon holds very different weights of fine and coarse salt (see Fermentation and Food Preservation 5).

The Keep, Fix or Bin Flow

Work down this list and stop at the first match.

1. **Fuzzy, raised or coloured growth, or any pink or red patches?** Bin.
2. **Putrid or rotten smell, or slimy texture?** Bin.
3. **Food above the brine, or a flat white film?** Fix: remove the film, push the food under the brine, add a weight, top up with brine of the same strength, and check again tomorrow.
4. **Sour and clean, a little soft?** Keep, and move it to the refrigerator.
5. **Still unsure?** Bin. A jar costs little; a bad batch can cost a lot.

> Do not
> Do not taste a ferment to see whether it is safe. Do not scoop mould off and carry on without checking a tested guide. Do not rely on smell alone, because some dangerous bacteria give no warning smell. Do not open or taste a bulging, leaking or spurting jar of home-canned food; that is a sign of possible botulism (Fermentation and Food Preservation 8), so bin it sealed in a bag. Do not feed spoiled food to pets or compost it where animals can reach it.

The Numbers: A Decision Function and a Salt Check

The code turns the flow above into a function and checks a salt percentage from the weights in your log. The inputs are *illustrative*.

```
# Keep, fix or bin: a teaching model
def decide(fuzzy, smell, slimy, submerged):
    if fuzzy or smell == "putrid" or slimy:
        return "bin"
    if not submerged:
```

```
        return "fix"
    return "keep"

def salt_pct(salt_g, veg_g):
    return round(salt_g / veg_g * 100, 1)

print(decide(False, "sour", False, True))
print(decide(False, "sour", False, False))
print(decide(True, "sour", False, True))
print(salt_pct(20, 1000))
# keep
# fix
# bin
# 2.0
```

Read the output as: clean and submerged is keep; clean but above the brine is fix; fuzzy growth is bin whatever the smell; and 20 g of salt on 1000 g of vegetables is 2.0 percent. Note that the function never says "keep" for a jar that fails any warning sign, and that it cannot see what you cannot: it is a memory aid, not a safety test.

EXERCISE 1

A safe home experiment in record-keeping. Start one small jar ferment (for example 200 g shredded cabbage with salt weighed on a scale, kept under its own brine). Make a log with the start date, food weight, salt weight, salt percentage and room temperature, and add a line every day for a week covering bubbles, smell and surface. At the end, run the keep, fix or bin flow on the jar and write down your decision and why.

View solution

EXERCISE 2

A calculation. (a) A log says 15 g of salt on 750 g of vegetables: what is the salt percentage to one decimal place? (b) How many grams of salt give 2 percent on 900 g of vegetables? (c) Run the decision function by hand for: clean smell, submerged, not slimy, no fuzz; then for: a flat white film, food above the brine, no fuzz, sour smell; then for: green fuzzy spots on a clean-smelling jar.

View solution

EXERCISE 3

A diagnosis. Four cases. (1) A week-old sauerkraut has a flat, wrinkled white film on top and smells sour. (2) A jar of kimchi has fuzzy blue-green spots on a piece of cabbage that floated up. (3) A ferment smells like rotten eggs and the vegetables are slimy. (4) A ferment has no bubbles after two days, smells clean and sour, and the kitchen is cold. For each, say what it means, which lever is involved, and keep, fix or bin.

View solution

QUICK REFERENCE

- **Normal:** bubbles, cloudy brine, sour clean smell, white sediment
- **Kahm yeast:** flat white film; skim and re-submerge
- **Mould:** fuzzy or coloured; bin the batch
- **Bin signs:** putrid smell, slime, pink or red patches
- **Never:** taste to test safety; when unsure, bin
- **Log:** dates, weights, salt percentage, temperature, daily notes

COMING NEXT

Fermentation and Food Preservation 11 looks at flavour and travel traditions: preserves from around the world, and what each one teaches about the levers.

Fermentation and Food Preservation

Chapter 11 · Travel Traditions

Every region keeps food with the levers it had to hand: salt from the sea, cold from the winter, smoke from the fire, acid from fruit. This chapter takes five famous preserves, kimchi, Japanese pickles, preserved lemons, Roman fish sauce and cured meats, and asks one question of each: which levers from Fermentation and Food Preservation 1 is it using? Once you can answer that, an unfamiliar preserve from a market on your travels stops being a mystery and becomes a system you can read. Surströmming, the Swedish fermented herring, gets its own box because it shows how far the levers can be pushed.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: sources agree that Japanese pickles (tsukemono) are grouped by their pickling medium (salt, vinegar, miso, soy sauce, sake lees, rice bran, koji and others) and that only some, such as the rice bran, sake lees and koji types, are truly fermented; that Moroccan preserved lemons are cured in salt for about a month and then keep for months in the refrigerator; that surströmming is fermented in a strong then a weaker brine for months and continues to ferment in the can; and that one study found common foodborne pathogens did not grow in its brine. **Sources differ:** the salt used in preserved lemons ranges widely between recipes, and the salt in Roman and modern fish sauce ranges from roughly 12 to 50 percent depending on whether the figure is a share of fish weight or a fish-to-salt ratio. **Not verified:** many results were recipe blogs and mirror sites, so the exact percentages in this chapter are illustrations to compare, not recipes. Do not use anything here as a tested home recipe; for a real batch use a university extension or national food-safety guide. The short calculation code in this chapter was run and the output in the comments is what it printed.

Reading a Preserve by Its Levers

Fermentation and Food Preservation 1 gave us the levers: salt (lower water activity), acid (lower pH), low oxygen, dryness, cold, heat and smoke. A traditional preserve almost always uses two or three together, and the combination explains its taste. Heavy salt makes a food savoury and chewy; acid makes it bright and sharp; long fermentation adds depth that no recipe without time can copy. Geography chooses the levers. Cold northern countries lean on cold storage, smoke and salted fish; hot dry regions on salt and sun; wet rice-growing regions on salt, rice bran and koji.

Five Preserves, Five Lever Sets

PRESERVE	ORIGIN	MAIN LEVERS	WHAT IT TEACHES
Kimchi	Korea	salt, acid, low oxygen	salt first, then lactic fermentation; the three-lever model in action (Fermentation and Food Preservation 5)
Tsukemono	Japan	salt, vinegar, bran or koji	one idea, many media; some are fermented, many are not
Preserved lemons	Morocco	salt, acid	salt draws out juice, which becomes its own acidic brine
Garum and fish sauce	Rome, South-East Asia	salt, time, enzymes	salt controls spoilage while the fish's own enzymes liquefy it
Charcuterie	Europe	salt, dryness, sometimes smoke and cold	curing salt and slow drying lower water activity (Fermentation and Food Preservation 3)

Kimchi and Tsukemono: The Same Idea, Two Cultures

Kimchi uses salted vegetables with chilli, garlic and often fish sauce, then lets lactic bacteria acidify the jar. Japanese tsukemono are better described as a family than a food: classified by the medium they sit in, they include quick salt pickles ready in an hour, vinegar pickles, miso and soy sauce pickles, sake-lees pickles and the slow rice-bran pickles (nukazuke), in which lactic bacteria and yeast live in the bran bed. The lesson is that "pickle" is not one method. Compare each by asking whether it is a **salt-only** pickle (fast, fresh, refrigerate), an **acid** pickle (Fermentation and Food Preservation 4), or a **live ferment**.

Preserved Lemons: A Brine That Makes Itself

Moroccan preserved lemons are cut, packed with a large amount of salt and left for about a month. The salt draws juice out of the fruit by osmosis (Fermentation and Food Preservation 3), and that juice, already very acidic, forms the brine. Two levers, salt and acid, protect the fruit while the rind softens and loses its bitterness. Recipes vary widely in the amount of salt, so treat

any figure as one tradition's choice, and note that the finished lemons are kept in the refrigerator.

Garum, Fish Sauce and Surströmming: Salt Plus Time

Garum was the Roman fish sauce, made by packing fish with salt and leaving it in the warmth while the fish's own enzymes break it down to a liquid. Modern South-East Asian fish sauce follows the same logic. Sources quote very different ratios, partly because some give salt as a share of the fish weight and others as a ratio of fish to salt, so compare like with like before you compare recipes. The salt is the control: enough to stop the dangerous microbes while allowing enzymes and tolerant microbes to work for months.

> Surströmming is not a beginner project
> Surströmming, Swedish fermented herring, is made in two stages: a strong brine first, then a weaker one, for several months, and fermentation carries on inside the can, which is why the tin bulges. That bulge is normal for this product only. For any *home-canned* food, a bulging lid means possible botulism (Fermentation and Food Preservation 8) and the jar must be binned unopened. The difference is the system: a traditional product made under tested, controlled conditions by experienced producers versus a jar whose conditions you cannot confirm. Do not attempt fermenting fish at home, or sealing it in jars, from a blog recipe.

Charcuterie: Salt, Air and Patience

Cured meats such as salami and ham combine salt with slow drying, and some add smoke or cold storage (Fermentation and Food Preservation 9). As water leaves, water activity falls until spoilage microbes cannot grow. Dry-curing is one of the hardest preserves to do safely at home because the curing salt amounts, humidity and temperature must be exact, so it is a good example of knowing a method without being ready to try it.

The Numbers: Comparing Salt Levels

The code calculates salt as a percentage of food weight and counts how many levers each preserve uses. The weights are *illustrative* teaching numbers, not recipes.

```
# Compare preserves by salt share and lever count
def salt_pct(salt_g, food_g):
    return round(salt_g / food_g * 100, 1)

levers = {
    "kimchi": ["salt", "acid", "low oxygen"],
    "preserved lemons": ["salt", "acid"],
    "garum": ["salt"],
}
for name, used in levers.items():
    print(name, len(used))

print(salt_pct(60, 500))
print(salt_pct(150, 1000))
print(salt_pct(40, 2000))
# kimchi 3
# preserved lemons 2
# garum 1
# 12.0
# 15.0
# 2.0
```

Read the output as: kimchi uses three levers and garum only one, so garum needs far more salt, 15.0 percent in this illustration against 2.0 for a vegetable ferment, to be safe on its own. The 12.0 is the salt share if 60 g of salt were used on 500 g of lemons. A preserve with fewer levers must push each one harder.

EXERCISE 1

A safe home experiment in reading preserves. Visit a shop or look at your own cupboard and fridge and find at least five preserved foods from different traditions (for example a pickle, a jar of olives, a cured meat, a fish sauce, a miso or soy product). For each, read the label and note the likely levers, the ingredients that show them (salt, vinegar, sugar, smoke, drying) and whether it needs the refrigerator after opening. Do not open or taste anything that is bulging or damaged. Write a one-line "lever profile" for each.

View solution

EXERCISE 2

A calculation. (a) A jar holds 750 g of lemons with 90 g of salt: what is the salt percentage? (b) A fish and salt mixture is described as a 4:1 ratio of fish to salt by weight: what percentage of the total weight is salt, and what percentage of the fish weight? (c) A vegetable ferment uses 2.5 percent salt on 1.2 kg of vegetables: how many grams of salt?

View solution

EXERCISE 3

A diagnosis. Name the main levers and the main risk for each. (1) A fresh Japanese salt pickle made in an hour. (2) A month-old jar of preserved lemons. (3) A dry-cured sausage hanging for weeks. (4) A can of fermented fish that bulges, sold in a shop, versus a home-canned jar of green beans that bulges. Which one is normal, and why is the other not?

View solution

QUICK REFERENCE

- **Read any preserve:** ask which levers it uses and how hard each is pushed
- **Fewer levers:** each one must be stronger (more salt, more drying)
- **Pickle family:** salt-only, acid, or live ferment
- **Preserved lemons:** salt draws juice, juice makes an acid brine
- **Fish sauce:** salt plus time; compare ratios like with like
- **Bulging home-canned jar:** bin unopened; never copy fish ferments at home

COMING NEXT

Fermentation and Food Preservation 12 is the last chapter: your home preserving kit, a shopping list, a starter plan for a month and where to go next.

Fermentation and Food Preservation

Chapter 12 · Your Kit

You now have the whole model: food spoils because of microbes, enzymes and oxidation, and each preserving method pulls one or more levers to stop it. This final chapter turns that into a practical starting point: a small kit, a shopping list, a gentle plan for a first month, and a list of places to learn more from tested sources. The aim is to start small, keep records and add one new method at a time.

WHAT WAS CHECKED, AND WHAT WAS NOT

Verified by one web search: university extension guidance says safe home preserving begins with tested recipes and properly working equipment; the National Center for Home Food Preservation, run from the University of Georgia, publishes tested recipes and the USDA home canning guide free online; and its advice is not to double canning recipes but to prepare each batch as written. Jams and preserves are described as one of the easiest places to begin. **Not verified:** the search did not return the refrigerator and freezer temperature figures, so check them on the centre's site or in USDA storage guidance. The shopping list and the month plan are suggestions of this course, not a tested programme. Prices and brands are not given because they change.

The Levers Recap

Everything in Fermentation and Food Preservation 1 to 11 fits one table. Keep it on the fridge door.

LEVER	WHAT IT DOES	WHERE YOU MET IT
Salt and sugar	lower water activity	Fermentation and Food Preservation 3
Acid	lowers pH; quick pickles need the fridge	Fermentation and Food Preservation 4
Good microbes	lactic fermentation, drinks, dairy and grain ferments	Fermentation and Food Preservation 5 to 7
Heat	kills microbes; canning rules depend on the acid line	Fermentation and Food Preservation 8

LEVER	WHAT IT DOES	WHERE YOU MET IT
Cold, low oxygen, smoke	slow growth and change	Fermentation and Food Preservation 9
Records and judgement	keep, fix or bin	Fermentation and Food Preservation 10

The Starter Kit

You need less than you think. Everything on the first list is ordinary kitchen equipment, and none of it involves pressure.

ITEM	WHY	PRIORITY
Kitchen scale (to 1 g)	salt and brine are measured by weight	Essential
Clean glass jars with lids	easy to see into and to clean; no reactive metal	Essential
Non-iodised plain salt	no additives to cloud the brine	Essential
Vinegar of labelled acidity (about 5 percent)	quick pickles need a known strength	Essential
Labels and a pen, plus a notebook	dates and records	Essential
Food thermometer, fridge thermometer	check the cold lever is really working	Strongly advised
Weights or a small bag of brine to hold vegetables under the liquid	keeps the ferment submerged	For fermenting
pH strips	a rough check on acidity	Optional
Water-bath canner and new lids	only if you later follow a tested canning recipe	Later
Pressure canner	only after reading the official guide in full	Much later

> The do-not list, one last time

> Do not invent canning times or pickle ratios. Do not double a tested canning recipe. Do not seal low-acid food in a jar and keep it on the shelf without a tested method. Do not taste a bulging, leaking or spurting jar to see if it is bad. Do not ignore mould that is not on the surface of a firm, dry cure. When in doubt, bin it: the cost of a jar is small beside the cost of being ill.

A Starter Plan for a Month

One new method a week, each using a lever from a different chapter, each recorded. By week four you will have used four different levers and a notebook of real observations.

WEEK	TRY	LEVER	WHY FIRST
1	A refrigerator quick pickle	acid, cold	fast result, low risk, teaches brine ratios
2	A small jar of salted vegetable ferment	salt, good microbes	teaches you to read bubbles, brine and smell
3	Dried fruit or herbs in a low oven or a dehydrator	dryness	simple and forgiving
4	A tested jam from an extension service recipe, or a batch frozen with dates	sugar, heat, cold	introduces tested recipes and good labelling

Keep a Preserving Log

The most useful tool in the kit is the notebook. Copy this template for every batch; it makes troubleshooting from Fermentation and Food Preservation 10 possible because you can compare a bad batch with a good one.

```
# Preserving log: one entry per batch
Date made:        2026-11-18
What:             vegetable ferment, 1 jar
Source of method: (tested guide or extension page)
Weights:          food ___ g, salt ___ g, salt % = ___
Levers used:      salt, low oxygen, room temperature
Checks:           day 2 ___ / day 5 ___ / day 10 ___
Smell and look:   (notes)
```

```
Decision:        keep / fix / bin
Storage:         fridge, label date ___
```

Where to Go Next

- **Tested sources first:** the National Center for Home Food Preservation and your own country's food-safety agency or university extension service.
- **Hands-on skills:** the bread and dairy techniques in the Cooking Skills courses on this site, now with the microbiology behind them.
- **Local classes:** a canning or fermenting class run by an extension service or a community group is the safest way into pressure canning.
- **Travel:** use the lever-reading habit from Fermentation and Food Preservation 11 on every market stall you visit.

🎓 Course Complete

Well done: you have finished Fermentation and Food Preservation. You can explain why food spoils, name the levers that stop it, work out salt percentages, tell a healthy ferment from a failed one, and know which methods to leave to tested recipes. The rest is practice, a notebook and a clean jar.

EXERCISE 1

A safe home experiment. Build your kit: tick off the essential items in the table, gather or buy what is missing, and check your fridge is cold enough with a thermometer. Then make this week's recipe from the month plan (a refrigerator quick pickle from a tested source) and fill in one log entry. Label it with the date and keep it refrigerated.

📄 View solution

EXERCISE 2

A calculation. (a) Your log says a jar holds 800 g of vegetables and you want a 2 percent salt ferment: how many grams of salt? (b) Another batch used 15 g of salt on 600 g of food: what percentage is that?

(c) A sheet of fruit loses 60 percent of its starting 500 g by drying: what does it weigh, and what percentage of its original weight remains?

View solution

EXERCISE 3

A diagnosis and a plan. (1) A friend wants to start by canning home-made garlic in oil for the shelf: which lever is missing, and what do you advise instead? (2) Your week-2 ferment smells sharply sour, bubbles gently and has clear brine: keep, fix or bin? (3) Draw up your own four-week plan, choosing a method for each week and naming its main lever.

View solution

QUICK REFERENCE

- **Start small:** scale, jars, salt, vinegar, labels, notebook
- **One new method a week:** pickle, ferment, dry, then a tested jam or freezing
- **Always:** tested recipes, weigh salt, log each batch, keep, fix or bin
- **Never:** invent canning times, double recipes or taste a suspect jar
- **Go further:** extension services and the National Center for Home Food Preservation