

THE SCOVILLE SPLICE LIBRARY · VOLUME XLII

Engineered Sichuan

Two fires in one mouth — the tingle and the burn. *Málà, by the number.*

The cuisine of composed flavor, read on the Index at last. A receptor-level account of mála — the humming numbness of the peppercorn, the designed fire of the chili — and the flavor profiles a Sichuan cook has always built by hand, measured now against the eight axes.

SCOVILLE SPLICE · GROWN BY OUR FAMILY. ENGINEERED FROM SCRATCH.

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Opening essay · The two fires

There is a moment, a second or two after the first bite of real mápó dòufu, when the mouth stops telling the truth. The lips begin to hum — not burn, *hum*, a fine electric buzz as if a struck tuning fork had been laid against them — and only then, underneath the buzzing, does the heat arrive, a broad red warmth that spreads from the tongue to the back of the jaw. Two fires, lit a half-beat apart, in the same mouthful. The Sichuanese have a word for the pair that is older and more exact than anything we could invent: **málà** — 麻辣 — the numb and the hot, 麻 and 辣, spoken always in that order because that is the order the mouth receives them.

We first argued about málà at our own table, one night, over a batch of chili oil that had come out wrong — gorgeous and red and completely silent where the numbness should have been. One of us said the peppercorns were stale. One of us said the oil had been too hot and had burned the tingle out of them. Both were right, as it happened, and neither could prove it, because we had no number for the thing that was missing. We could taste the absence perfectly. We could describe it only as a hush.



Before the first number: the family in the research greenhouse, where every question in this library seems to begin.

This book is the number, and the cuisine that made us go looking for it. Sichuan cooking is, we have come to believe, the single most sophisticated act of flavor composition any human culture has ever performed without instruments — a thousand-year tradition of building sensation by addition and interference, of placing the numbing peppercorn against the hot chili against the sweet against the sour against the deep fermented savory, and tuning the whole chord by hand until it rings. There is a maxim in the Sichuan kitchen, repeated the way other trades repeat a prayer:

> 一菜一格，百菜百味 — *each dish its own form; a hundred dishes, a hundred flavors.*

A hundred flavors. Not a hundred ingredients — a hundred *composed sensations*, each one a named, repeatable target. Sichuan calls them 味型 (*wèixíng*), flavor-types, and counts something like two dozen of them as canon: fish-fragrant, strange-flavor, scorched-chili, lychee, home-style, red-oil, and on. Each is a recipe for the receptors, written long before anyone knew what a receptor was.

Sichuan — the great fertile basin in China's southwest, ringed by mountains, humid, misty, slow to see the sun — built this grammar out of necessity and then raised it to an art. The damp climate made warming, drying, appetite-waking food a kind of daily medicine; the terrain made preservation (the pickling, salting, and long fermentations of Chapter 7) a condition of survival; and the encircling mountains made the region a cul-de-sac where flavors could deepen in isolation. The cuisine we are about to read on the Index is, in its chili-forward form, surprisingly young — no older than the chili's own arrival in China, which came from the Americas by sea only in the late sixteenth century and did not fully remake Sichuan cooking until the Qing. For most of its long history this was a cuisine of má *without* là: the tingle standing nearly alone, braced by ginger and a native dogwood-pepper. The two fires have burned together, in the balance we now take for timeless, for only a few hundred years. Hold that in mind as we measure them — we are reading a living tradition at one moment in a very long composition, not a fixed and finished score.

The Iyengar Flavor Index is the other half of that sentence. Where Sichuan says *fish-fragrant*, the Index says: elevate umami to roughly 1,900, lift sweetness and a sour counter-tension into the 1,700s, hold heat moderate, carry pungency on the garlic and ginger, and let kokumi do the binding. Same target, two notations — one built from four hundred years of tongues, one from the half-maximal activation of eight receptors. This book sets them side by side and shows they are describing the same thing.

And we will be honest, from the first page, about the one fire we can measure but have not yet learned to *grow*. The chili we have rebuilt gene by gene; the engineered **Pepper** host alone backs **1,060 product SKUs**, and across the platform there are roughly **19,500** product SKUs — backed by approximately 225 distinct construct designs — tuned across **42 host organisms** and **8 sensory axes** at a batch-to-batch consistency of **≤7%**. The peppercorn, we still buy — from the mountains above Hanyuan, as cooks have for twelve centuries. Má, the tingle, sits just off the edge of our eight axes, in a family of channels the Index does not yet have a column for. That gap is not a weakness of the method. It is the most interesting thing in the book, and we have put it where it belongs: in the light.

What follows is built in four movements. **Part I** takes the two fires apart to the receptor — capsaicin on TRPV1, sanshool on the potassium channels — and shows that they are, improbably, the same kind of molecule doing opposite jobs. **Part II** walks the pantry: the chili we engineer for fragrance over fury, the peppercorn we still buy, the fermented dark of doubanjiang, and the red oil that carries

all of it. **Part III** is the cuisine itself — the *wèixíng*, the composed flavor-profiles, read as coordinates and cooked as recipes, each scored on the eight axes. **Part IV** looks over the edge, at the tingle we have not yet learned to grow and the nourishment that hums beneath the whole tradition. We write, throughout, as *we* — a family that reveres what it grows, setting the mathematics of flavor beside the oldest and most exacting flavor culture we know, to see what each can teach the other. The answer, it turns out, runs in both directions, and it is a great deal.



PART I OF IV

The Two Fires

là · TRPV1 · capsaicin — má · hydroxy-α-sanshool · the two-pore channels

Chapter 1 · Là — *the fire that is a lie.*

Begin with the one we understand. **Là** (辣) is the red fire, the heat, the burn — and the first thing to know about it is that it is not heat at all. No calorie of thermal energy enters the mouth when you eat a chili. The tissue does not warm. What happens is a deception, run at the molecular scale, and once you see the mechanism you cannot un-see how elegant the lie is.

Capsaicin, the active molecule of every chili on earth, binds **TRPV1** — the transient receptor potential vanilloid 1 channel, a non-selective cation channel studded along the trigeminal nerve endings of the tongue, lips, and palate. TRPV1 is, in its day job, a *thermometer*: it opens when the tissue around it climbs above roughly 43 °C, floods the neuron with calcium and sodium, and fires the signal the brain reads as *this is hot enough to damage you, pull away*. It also opens for protons — which is why acid stings a cut. Capsaicin does none of this by heating anything. It slips into a binding pocket on the channel and lowers the temperature at which TRPV1 will open. The threshold falls from 43 °C to somewhere near body temperature, and the receptor, now triggering at the mouth's own warmth, reports a fire that is not there. The brain cannot tell the difference between a genuine burn and a receptor lying about one. That is the whole trick, and it is why chili heat is real pain with no injury underneath it — a pleasure built, precisely, on a false alarm.

The receptor itself is one of the great stories in modern sensory biology. The channel was cloned and characterized in David Julius's laboratory in 1997, work that ran — by way of touch and temperature — to the 2021 Nobel Prize in Physiology or Medicine, shared with Ardem Patapoutian. We mention this not as trivia but because the same laboratory, as we will see in the next chapter, is the one that cracked how the *other* Sichuan fire works. Both of this cuisine's fires were, in a sense, read out of the same bench.

It matters, too, that neither fire is a *taste*. Taste proper — sweet, sour, salty, bitter, umami — is carried by dedicated receptor cells in the taste buds and runs to the brain along the gustatory nerves. Là and má travel a different wire entirely: the **trigeminal** nerve, the great sensory trunk of the face, which reports touch, temperature, and chemical irritation from the whole mouth. This is **chemesthesis** — chemical sensation on ordinary nerve endings — and it is why chili heat is felt not only on the tongue but on the lips, the gums, the inside of the cheek, places with no taste buds at all. It is also why the body answers heat the way it answers pain: with a wash of endorphins and a small adrenal lift, the mild, pleasant rush that chili-eaters chase and that the Sichuanese long ago folded, knowingly, into the pleasure of the table. The receptor keeps opening; the tissue is never harmed; the body, discovering the alarm was false, releases its own reward. *Benign masochism*, one psychologist

named it. We would call it the oldest free thrill in cooking — and the reason a cuisine could build its entire identity on a sensation that is, strictly speaking, a kind of pain.



A chili in cross-section — the pale placental tissue along the inner ribs, where the capsaicinoid glands sit, is the hottest real estate in the fruit.

On the Index, this axis is **IFI-H**, and like every axis it is anchored not to *how much* capsaicin a food contains but to how *loudly* that capsaicin speaks to the receptor:

$$\mathrm{IFI}(c) = 1000 \cdot \mathrm{EC}_{50}(\mathrm{ref}) \,/\, \mathrm{EC}_{50}(c)$$

EC_{50} is the concentration at which a stimulus drives its receptor to half of its full response. Capsaicin's EC_{50} at human TRPV1 sits in the sub-micromolar range — a few tenths of a millionth of a mole per litre is enough to half-open the channel — which is why a trace on the tongue reads as an inferno. Invert that against a fixed reference, scale by a thousand, and loudness becomes a single number a chili, a sauce, and a whole dish can be read against on one page.

The older number, the one most people know, measures something subtly different. In 1912 the pharmacist Wilbur Scoville devised a test in which an alcohol extract of a chili was diluted with sugar water until a panel of tasters could no longer detect the burn; the dilution factor at that vanishing point became the chili's rating in **Scoville Heat Units**. It was an ingenious assay for its day, and a deeply human one — the instrument was a tongue — but it measured *concentration by dilution*, not receptor loudness, and it drifted with every panel. Today the capsaicinoids are quantified by high-performance liquid chromatography and the SHU is back-calculated, so the figure is stable even if its meaning never changed: SHU counts molecules; IFI-H counts how hard those molecules push on TRPV1. For a single pure capsaicinoid the two track each other closely. For a blend — which every real chili is — they can diverge, because the capsaicinoids do not all speak to the receptor at the same volume.

CAPSAICINOID	TYPICAL SHARE	RELATIVE PUNGENCY	SHAPE OF THE BURN
Capsaicin	~69%	1.00	fast, bright, front of mouth
Dihydrocapsaicin	~22%	~1.00	slow, creeping, back of throat
Nordihydrocapsaicin	~7%	~0.57	gentle, fleeting, upper palate
Homocapsaicin	~1%	~0.50	faint, late
Homodihydrocapsaicin	~1%	~0.50	lingering, deep

The ratio of these five — and above all the balance of the first two — is what sets the *shape* of a chili's heat in time, whether it arrives like a slap and clears or creeps up the throat and stays. It is a trait we can design, because, as Chapter 3 will show, it is written by the fatty-acid half of the molecule, upstream of the forge.

Here is the first surprise this cuisine has for anyone who arrives expecting a Scoville arms race. **Sichuan is not about maximum heat.** The chiliheads' far horizon — the flagship superhots we engineered as a proof of what the method can reach — is a place Sichuan cooking almost never visits:

CULTIVAR · SKU	PREDICTED SHU	IFI-H	AXES
Ember · SS-0087	866K	1,570	2/8
Blaze · SS-0091	1.72M	2,630	4/8
Firestorm · SS-0094	2.47M	3,490	6/8
Phoenix · SS-0096	2.95M	4,200	8/8

A bowl of Chongqing noodles does not want 2.9 million Scoville. It wants a chili with the *fragrance* of toasted paprika, a clean moderate burn that blooms and recedes, and a red so deep it stains the oil. The Sichuan workhorse, the **èrjīngtiáo** (二荆条), is prized for exactly the trait a Scoville number cannot see: aroma. Its heat is genuine but polite — tens of thousands of units, not millions — and its glory is the warm, slightly sweet, sun-dried scent it gives to oil. We will spend a whole chapter (Chapter 5) on why engineering a chili *down* toward fragrant moderation, at tight consistency, is a harder and more useful problem than engineering one up toward the stratosphere. For now, hold the correction: in this cuisine, heat is a chord, not a competition.

Chapter 2 · Má — *the fire that hums.*

Now the fire we are only beginning to understand, and the reason this book exists.

Má (麻) is the numbness — though *numbness* is a poor translation, because the sensation is not a deadening but an *activity*, a bright buzzing paresthesia that the best eaters describe as the lips vibrating of their own accord. It is produced not by the chili but by the dried husk of a small reddish-brown berry, the **Sichuan peppercorn** — 花椒, *huājiāo*, literally "flower pepper" — which is not a pepper at all, nor related to the chili, nor to black pepper. It is the fruit husk of *Zanthoxylum*, a thorny shrub in the citrus family, and the kinship to citrus is written all over its aroma: a high, lemony, almost pine-resin brightness that lifts off the husk the moment it is warmed.

The molecule responsible is **hydroxy-α-sanshool** (and its siblings, hydroxy-β- and hydroxy-γ-sanshool), and its mechanism is genuinely strange. In 2008, the Julius laboratory — the TRPV1 lab again — showed that sanshool excites sensory neurons by a route no flavor molecule had been caught using before: it *inhibits* a family of two-pore-domain potassium channels, the **KCNK** channels, principally **KCNK3** (TASK-1), **KCNK9** (TASK-3), and **KCNK18** (TRESK). These channels are the neuron's pressure-relief valves; they leak potassium steadily to hold the cell quiet at rest. Block the leak and the cell can no longer keep still. It hovers at the edge of firing, and the lightest touch — the brush of your own lip against your teeth, the tremor of a pulse — tips it over. The tingle is not the peppercorn stimulating you. It is the peppercorn removing the brake, so that your own body's background noise becomes audible as a buzz.



We measure má in a vial because we cannot yet grow it. Hydroxy-α-sanshool, isolated — the one compound in this cuisine the Index must still bracket rather than score outright.

How fast is the buzz? Fast enough to measure. A 2013 study subjected volunteers to sanshool and then to mechanical vibration, and asked them to match the two; the tingling of the peppercorn proved perceptually equivalent to a physical vibration of **about fifty cycles a second** — roughly the flutter range of the skin's rapidly-adapting touch receptors. Má, in other words, is a *frequency*. The

peppercorn plays a fifty-hertz note on nerves that were built to feel texture, and the brain, having no category for "my lips are vibrating," files it under the uncanny.

Which nerves, exactly, is part of what makes má so strange. The fifty-hertz flutter lands in the response range of the skin's **rapidly-adapting mechanoreceptors** — the touch endings tuned to vibration and motion rather than to steady pressure — so the peppercorn is, quite literally, counterfeiting a tactile signal with a chemical. It co-opts the machinery of touch. This is the deep reason má feels categorically unlike heat: the burn is a false *temperature* played on pain fibers, while the tingle is a false *vibration* played on touch fibers, and the two are carried by different populations of neuron doing different jobs. Mála is not one fire turned up twice. It is two unrelated sensory systems, fired at once, by two molecules that happen to share a chemical strategy.

There is history folded into the tingle as well. Before the chili ever reached China, má was the dominant fire of this region. Classical Chinese cooking counted **three pungents** — huājiāo the peppercorn, ginger, and the native *zhūyú*, a wild dogwood-pepper kin of *Zanthoxylum* — and of the three the peppercorn was sovereign, prized for the warming, aromatic, appetite-waking food a damp climate wants. The chili, arriving from the Americas only in the late Ming, did not depose the peppercorn; it *married* it, and the marriage became málà. So when we taste the two fires in balance we are tasting a comparatively recent union laid over a very old foundation. The peppercorn was here first. The chili is the brilliant newcomer that learned to sing in harmony with it.

Here is where we must be rigorous and honest at once, because the temptation to over-claim is strong and the voice of this library does not permit it. **Má does not have a home among the eight axes.** The Index is anchored to a fixed set of receptors — TRPV1, the sweet and umami GPCRs, the bitter TAS2R family, the calcium-sensing CaSR, the cold TRPM8, the irritant TRPA1, the salivary proteins — and *none of them is a KCNK channel*. The true signal of the tingle sits off the map. What the Index can do — and this is the framing the cuisine itself hands us — is **bracket** it. Sanshool genuinely activates **TRPA1**, the sharp irritant channel, which gives má a real reading on **IFI-P** (pungency); and the cool, electric, almost-minty edge of a fresh green peppercorn reads partly on **IFI-C** (the thermomodulation axis, TRPM8/TRPV1). So mála, in this book's notation, is a composite coordinate — heat on **H**, the tingle's two visible faces on **C** and **P** — with the understanding, stated plainly, that its deepest component is a frequency we are measuring at the edge of what the eight axes can hear.

SENSATION	MOLECULE	TARGET	IFI READING
Là — burn	capsaicin	TRPV1 (opens)	**IFI-H**, direct
Má — tingle	hydroxy-α-sanshool	KCNK3/9/18 (inhibits)	*off-axis* — bracketed on **C**
Má — sharp onset	hydroxy-α-sanshool	TRPA1 (activates)	**IFI-P**, partial
Má — cool edge	sanshool + terpenes	TRPM8 (modest)	**IFI-C**, partial

Red huajiao (*Zanthoxylum bungeanum* — the famous 大红袍, "big red robe," cultivar) leans aromatic and warm; green huajiao (青花椒, *Z. armatum / schinifolium*) leans sharp, lemon-bright, and more intensely numbing, richer in hydroxy-β-sanshool. A Chongqing cook reaching for green and a Chengdu cook reaching for red are not making the same chord. They are choosing where, exactly, to place the fifty-hertz note.

The chemistry rewards a closer look. The husk carries not one tingling molecule but a small family — hydroxy-α-sanshool as the headline, with hydroxy-β-sanshool, hydroxy-γ-sanshool, and the non-hydroxylated sanshools and sanshoamides alongside — differing in the length and unsaturation of that polyene acyl chain, which tunes both the intensity of the buzz and the speed of its onset. Green huajiao's higher hydroxy-β-sanshool reads as a faster, sharper, more electric numbness; red huajiao's balance reads slower and rounder, wrapped in aromatic terpenes — limonene, linalool, the citrus-and-pine volatiles that give the husk its perfume. All of them are fragile. The sanshools oxidize and degrade with age, heat, and light, which is why a jar of peppercorns a year old has gone quiet, why the oil that opened this book had lost its tingle, and why — a point we return to with some feeling in Chapter 6 — cooking the husk too hard, or heat-treating it to clear customs, strips out the very molecule you bought it for. Má is a perishable thing. It is a fire with a shelf life, and the clock starts the moment the berry leaves the branch.

Chapter 3 · The amide strategy — *one bond, two fires.*

Set capsaicin and hydroxy-α-sanshool on the same page and something quietly astonishing appears: they are built the same way. Both are **acid amides** — a fatty, often polyunsaturated acyl chain condensed with an amine through a single nitrogen bond. Capsaicin is the amide of **vanillylamine** with an eight-carbon, methyl-branched fatty acid. Hydroxy-α-sanshool is the amide of a twelve-carbon polyene acid with a small hydroxylated **isobutylamine**. Black pepper's piperine is a third member of the family — an amide of piperidine. Three unrelated plants, on three different branches of the tree of life, all arrived at the same chemical idea: *to make a fatty acid speak to a nerve, hang it off an amine.* The amide bond is the loudspeaker. Change the acyl chain and the amine and you change which nerve hears, and how.

This is not a metaphor we have imposed. It is the design principle the whole platform runs on, read backwards out of the plants. If flavor at the sharp end of the tongue is a library of acid amides, then designing flavor is, in large part, designing *acyltransferases* — the enzymes that forge the amide bond — and the enzymes upstream that build the two halves to be joined.

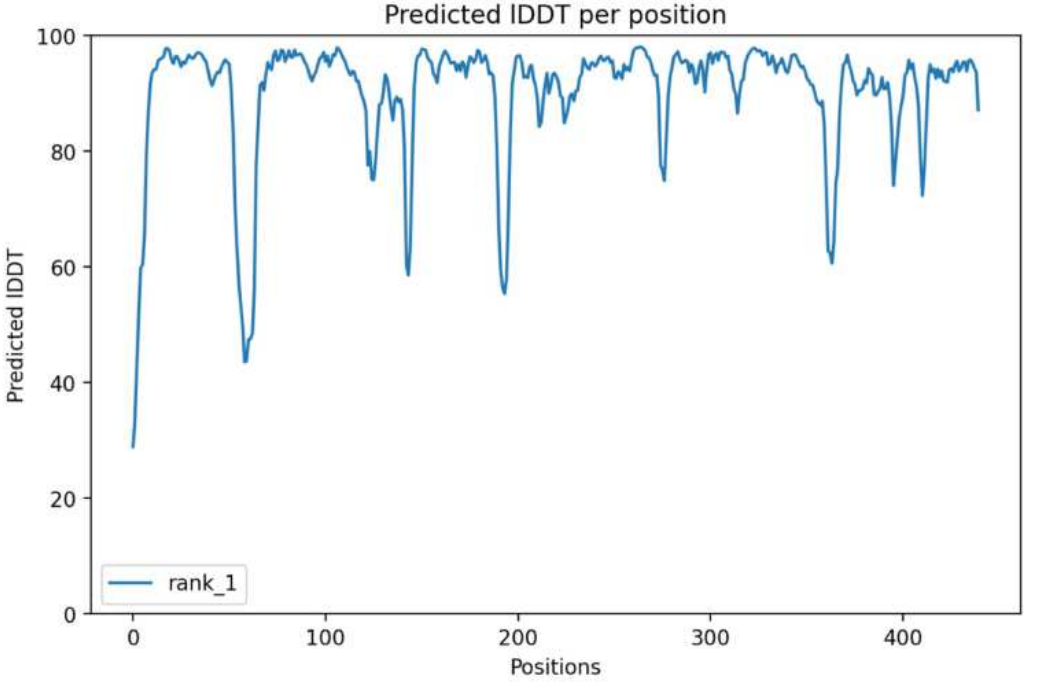


FIG. 1 — The capsaicin synthase, Pun1/AT3, coloured by pLDDT model confidence. The binding domain and the active-site cleft resolve at high confidence; this is the forge where vanillylamine and the branched-chain acyl-CoA are joined.

In the chili, the forge is **Pun1**, the gene encoding **capsaicin synthase** (an acyltransferase of the BAHD family, historically called AT3). Two streams feed it. The **phenylpropanoid** stream — the universal branch that runs in every vascular plant on earth — walks phenylalanine down a conserved staircase to vanillylamine. The

branched-chain fatty-acid stream builds the other half, the 8-methyl-6-nonenoyl group, out of the amino acid valine. Pun1 condenses the two, and the chili is hot.

STEP	ENZYME	TRANSFORMATION
1	**PAL**	phenylalanine → *trans*-cinnamic acid
2	**C4H**	cinnamic acid → *p*-coumaric acid
3	**4CL**	*p*-coumaric acid → *p*-coumaroyl-CoA
4	**HCT / C3′H**	→ caffeoyl ester → caffeic acid
5	**COMT**	caffeic acid → ferulic acid → vanillin
6	**pAMT**	vanillin → **vanillylamine** (transamination)
7	**BCAT → KAS**	valine → 8-methyl-6-nonenoyl-CoA
8	**Pun1 / CS**	vanillylamine + acyl-CoA → **capsaicin**

Steps 1 through 5 are not pepper genes. They are *everyone's* genes — PAL, C4H, 4CL, HCT, COMT run in a tomato, a grape, a stalk of rice. Only the last four terminal enzymes (**pAMT · Pun1/CS · KAS · BCAT**) are chili-specific. This is the single most consequential fact in the whole platform, and the thesis of the companion volume *Beyond Peppers*: the hard part of making heat already exists in every plant. To move a fire into a new organism you install four enzymes onto a staircase that was always there.

The forge itself deserves a closer description, because it is the part of the machine we most directly redesign. Pun1 belongs to the **BAHD** superfamily of acyltransferases — a large, ancient, promiscuous class of plant enzymes named for its first four members, the Swiss-army knives of plant specialized metabolism. A BAHD enzyme does one chemical thing, the transfer of an acyl group from a coenzyme-A thioester onto an acceptor molecule, and plants have tuned that single reaction thousands of ways to build everything from floral scents to defensive toxins. Capsaicin synthase is simply the version that accepts vanillylamine and a branched-chain acyl-CoA — which is why the *amide strategy* recurs across unrelated plants: the enzymatic toolkit for hanging a fatty acid off an amine is standard-issue, and evolution reaches for it again and again whenever a plant needs a small molecule that can talk to an animal's nerves.

What the amide bond itself does is serve as the molecule's **pharmacophore** — the rigid, hydrogen-bonding hinge that docks the long greasy tail into the receptor's pocket at exactly the right angle. Capsaicin's vanillyl head and amide hinge are what TRPV1 actually grips; the fatty tail is the lever that throws the switch. Change the head and you change which receptor listens; change the tail and you change how the burn unfolds in time. This is not a loose analogy. It is the literal reason we can design flavor at the sharp end of the tongue: these molecules are modular, and the modules are swappable by enzyme.

The second consequence is how we *tune* the forge. We do not breed-and-hope. Every possible single-residue substitution in Pun1 is scored by a 650-million-parameter protein language model for its predicted effect on catalytic efficiency and fold stability; a genome-scale flux-balance model locates where the true rate control sits in the pathway; and the winning edits are written in with CRISPR. Two substitutions, never found by any breeder because no breeder could

see them, are designed to stabilize the forge while holding the batch-to-batch coefficient of variation to **≤7%** against the 42% chaos of wild-type:

EDIT	EFFECT	ΔΔG (KCAL/MOL)
S39L	binding affinity ↑ (N-terminal)	−2.1
L345G	steric relief, active-site cleft	−1.8

A third structural annotation from our modelling, C175S (prevents disulfide misfold, ΔΔG −0.9), was not incorporated in the final shipped design.

These two edits were not found by growing ten thousand plants and tasting the survivors. A protein language model — trained, like the models behind every other part of this platform, on the raw text of evolution, the amino-acid sequences of millions of natural proteins — scored each of the thousands of possible single-residue substitutions in Pun1 for its predicted effect on catalytic efficiency and fold stability, and ranked them. A genome-scale **flux-balance** model, a stoichiometric account of every reaction in the plant's metabolism, then located the true rate control: our model predicts it sits upstream in the phenylpropanoid pathway — at **4CL** and **HCT/CCoAOMT** — not at the terminal Pun1/AT3 step. Pun1 is the final capsaicin synthase; it labels the product; the upstream steps govern the rate. The two Pun1 edits stabilize the enzyme's fold and active-site geometry for the precision the platform demands — holding batch-to-batch variation to ≤7% — rather than moving the rate limit itself. Only the edits that scored on both model counts were written in with CRISPR. This is the method behind the entire library: predict in silico, compute by flux, write with CRISPR, measure the real plant, repeat. It is how **42** host organisms now back roughly **19,500** product SKUs across **8** sensory axes; how **1,000** of those products are live and purchasable today; and how the work has produced **3** filed patents and **21** peer-reviewed papers, released open-access under CC BY 4.0. The chili was the proof of concept. Pun1 was the first forge we learned to re-tool. Everything else in this book — every recipe, every scorecard, every frontier we point at — stands on it.

Now hold that table against the peppercorn, and the frontier comes into focus. Sanshool is an amide too — which means, in principle, it is a problem of the same *shape*: build the polyene acid, build the hydroxy-isobutylamine, install an amide synthase to join them. But the sanshool route has never been fully drawn. The acyl chain is longer and more unsaturated than capsaicin's; the amide synthase has not been cleanly identified; and *Zanthoxylum* is not a validated host. So Chapter 3 ends where honesty requires: we can read the strategy, we can see that má is "merely" another amide, and we still cannot build it. The peppercorn keeps its secret, for now.

Chapter 4 · Mála as a coordinate — *the arithmetic of the chord.*

If là reads on H and má brackets onto C and P, then **málà is a point in a three-dimensional sensory space** — and that single reframing is what lets us do with a chili-oil what a sound engineer does with a chord: measure it, compare it, and design it on purpose.

Take the simplest case, a bare mouthful of red oil over blanched greens. Its position is a vector:

```
málà ≈ ( H, C, P ) = ( là-heat, tingle-cool, tingle-sharp )
```

A Chengdu-style oil, warm and aromatic, might sit near (1,400 · 300 · 600): heat forward, tingle present but gentle. A Chongqing hot-pot dip, built on green peppercorn, pushes the same vector toward (1,600 · 900 · 1,000): the tingle climbs, the cool-electric edge opens, and the whole sensation tilts from *warm* to *buzzing*. These are not the same flavor at different volumes. They are different *directions* in the space — and the eater feels the direction, not just the magnitude.

It is worth doing the arithmetic once, in full, because a number is only a form of respect for the reader if the reader can see where it comes from. Suppose a reference capsaicinoid half-activates TRPV1 at an EC_{50} of 0.70 µM, and a candidate oil's dominant capsaicinoid does the same at 0.50 µM — it binds a little tighter, speaks a little louder. Then:

```
IFI-H = 1000 × EC50(ref) ÷ EC50(cand) = 1000 × 0.70 ÷ 0.50 = 1,400
```

That is the 1,400 we assigned the warm Chengdu oil above — not a mood, a ratio. Every axis is built the same way against its own receptor and its own reference: sweetness against the TAS1R2·R3 dimer, umami against mGluR1, the tingle's bracket against TRPM8 and TRPA1. And every axis is clipped to a shared ceiling — the per-axis normalization maximum for a scorecard is **5,000** — so that no single sensation can run off the page and the eight numbers stay commensurable, readable together as one chord. That ceiling is why even Phoenix, engineered to the very top of the heat axis, is predicted to reach 4,200 and not forty thousand: the scale is built for the mouth's dynamic range, not the chemist's.

Composition is where it turns beautiful. A dish is not one stimulus but many, and the axes do not simply add. Two sub-threshold umami sources can sum to a supra-threshold whole; a sour counter-tension can suppress *perceived* sweetness without touching a grain of the sugar; and má, as we saw, lowers the felt persistence of là. We model these as cross-terms — small coupling coefficients between axes — and they are precisely what a Sichuan cook is adjusting when they add "just a little vinegar" to a dish that is not sour enough to taste as sour but tastes, suddenly, *balanced*. The multi-axis

libraries put figures on the strongest of these composites: a tuned **dual-axis** pairing can reach a composite index near **8,400**, a **triple-axis** one near **2,800** — numbers that only make sense because the axes are interfering, not merely stacking. Mála is this cuisine's native proof that flavor is additive in its molecules and *non-additive* in its sensations, and that the whole of the artistry lives in the gap between those two facts.

Walk it through on a real plate. Mápó dòufu, the dish of the next chapter, arrives at its coordinate from a stack of sources: the chili oil and dried flakes set the heat on **H**; the ground peppercorn, added raw at the end, drives the **C** bracket and part of **P**; the doubanjiang and douchi lay down a deep **U** and **K** floor; the tofu adds a soft, cooling **U** and a textural silence; a touch of sugar and the fermented tang nudge **S** and the sour counter-tension. Sum the loud axes, apply the má-on-là cross-term that shortens the burn's tail, clip each to the 5,000 ceiling, and the dish resolves near H 2,600 · C 1,800 · P 315 · U 2,400 · K 2,100 — the scorecard you will meet over the recipe. That profile is not a description written down after tasting. It is, increasingly, a *target* we can hand a formulator and hit, by choosing cultivars and ferments whose own profiles compose to it — the wèixíng turned from an inherited feel into an addressable coordinate, without the loss of a single degree of the warmth that made it worth addressing.

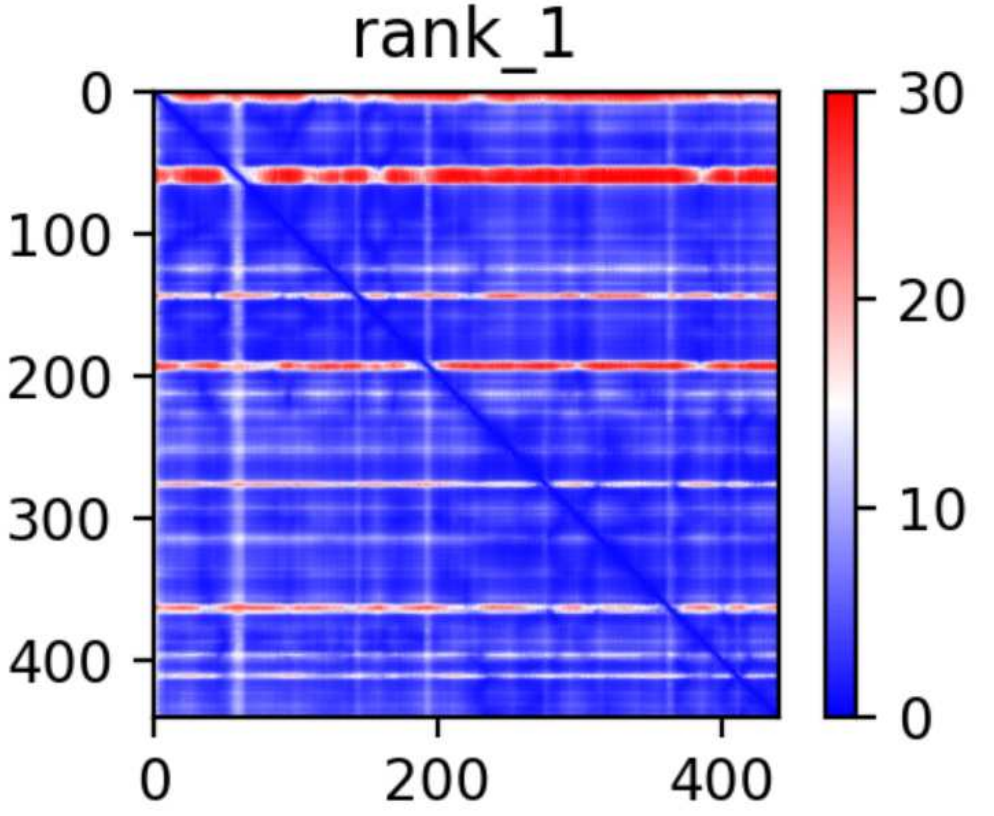


FIG. 2 — The predicted-aligned-error map of the same acyltransferase. The dark low-error blocks are the rigid, trustworthy core; the bright margins are where the model is least sure — a useful picture of exactly the humility the má axis demands.

The arithmetic has a second subtlety the cuisine knew before the receptors did: **the axes interfere.** Má does not merely sit beside là; it *changes how là is felt*. By holding the touch-and-cool neurons in a state of agitation, the peppercorn appears to raise the mouth's tolerance for the chili's burn and to shorten its tail — the heat arrives, crests, and clears faster than the same chili would alone.

This is why a dish can carry a startling quantity of chili and still read as *balanced* rather than punishing: the tingle is not an addition to the heat but a modulation of it. In Index terms we model this as a cross-term, a small negative coupling between the C bracket and the perceived persistence of H — the reason two dishes with identical IFI-H can feel a world apart depending on their C.

The composition then generalizes. A finished Sichuan dish is rarely a two-fire chord; it is a full eight-note one, because the oil and the tingle sit on top of fermented bean paste (umami, kokumi), sugar (sweetness), vinegar (a sour counter-tension the Index tracks through its effect on the other axes), garlic and ginger (pungency), and sesame (kokumi, a soft bitterness). The dish's IFI profile is the composed result, and the whole back half of this book is the catalogue of those compositions — the *wèixíng*, read as coordinates. The cook builds them by taste. We can now also build them by target, hand a formulator a vector and a tolerance, and grow the cultivars that hit it at **≤7%** variation batch to batch. Taste finds the point; the number lets you return to it, exactly, a thousand times.



PART II OF IV

The Pantry

the fragrant chili · the ungrown peppercorn · the fermented dark · red oil

Chapter 5 · The chili, redesigned for fragrance — *down is harder than up.*

Every other heat book in this library is, at some level, a story about climbing. This chapter is about the far more delicate engineering of coming *down* the mountain on purpose, and landing exactly where you meant to.

The Sichuan chili pantry is a set of specialists, and not one of them is chosen for raw Scoville. The **èrjīngtiáo** (二荆条) is the aromatic backbone — long, wrinkled, deep red, moderate in heat, extravagant in scent; it is the chili you toast for red oil and grind for the fragrant base of doubanjiang. The **cháotiānjiāo** (朝天椒, "facing-heaven") and the small **zǐdàntóu** ("bullet") bring the sharper heat and the handsome whole-pod drama of a plate of làzǐjī. The tiny **xiǎomǐlà** brings a bright, aggressive kick for those who want it. A real Sichuan oil is often a *blend* of two or three — one for color, one for fragrance, one for bite — because no single chili carries the whole chord.



The engineered Pepper host in the greenhouse: the trait we select for here is not peak burn but the warm, paprika-sweet aroma that makes an oil smell like Sichuan.

To design for this cuisine is therefore to optimize a *vector*, not a maximum — and three of the four targets have nothing to do with how hard the chili bites.

Color. The deep stain of good red oil is **capsanthin**, the red xanthophyll that accumulates as the chili ripens, with capsorubin alongside it. A Sichuan chili is selected to pack pigment, because the

eye eats first and because the pigment is lipophilic — it is what the oil actually extracts and carries. On the Index this is not a taste axis at all, but it is a design axis, and we track it.

The pigment has a pathway of its own, and it is one we can reach. Capsanthin and capsorubin are the red **xanthophylls** that bloom as a chili ripens, made at the very end of the universal carotenoid route by a single enzyme, **capsanthin-capsorubin synthase** (CCS), which rearranges the orange-yellow precursors — antheraxanthin and violaxanthin — into the deep reds unique to *Capsicum*. Tune CCS expression and the ripening fruit banks more red; a Sichuan-destined cultivar is selected to flood the placental and pericarp tissue with these xanthophylls, because the red that ends up in the oil is not a dye added later but the fruit's own carotenoid chemistry, extracted by fat. Color and heat ride the same lipophilic ticket into the oil — design one and you are obliged to mind the other.

Aroma. The toasted-paprika, sun-dried-fruit scent of èrjīngtiáo is a bouquet of volatiles — not capsaicinoids, which are nearly odorless, but the fruit's own esters and terpenes, lifted and transformed by gentle toasting. Breed or engineer the capsaicin up without minding the aroma genes and you get a hotter, duller chili. The whole art is to hold the fragrance while you move the heat.

The fragrance is a bouquet, not a single note, and most of it is not even present in the fresh fruit — it is *made* in the drying. A sun-dried èrjīngtiáo develops its toasted, raisined, faintly smoky scent through slow enzymatic and Maillard chemistry as the pod loses water on the rack: sugars and amino acids condense into roasted pyrazines and furans, carotenoids cleave into fruity apocarotenoids, and the sharp green volatiles of the fresh pod fade away. This is why *how* a chili is dried is as much a flavor decision as *which* chili it is, and why a kiln-dried pod and a sun-dried one from the same plant are not the same ingredient. We select our Sichuan-tuned Pepper lines for the *precursors* of that bouquet — the sugar and amino-acid load, the carotenoid content — so the drying has rich material to transform, and we hold the capsaicin in a fragrant middle band rather than chasing it up into the odorless superhot range where aroma goes to die.

Heat, placed — not maxed. The capsaicinoids concentrate in the pale placental tissue along the inner ribs, secreted by glands at the base of the seeds. A Sichuan-tuned cultivar wants a *clean, moderate, fast-clearing* burn — meaning a capsaicin-to-dihydrocapsaicin ratio weighted toward capsaicin (the quicker, brighter, more forward of the two), rather than the slow, creeping, back-of-throat dihydrocapsaicin that dominates the superhots. Recall from Chapter 3 that this ratio is set by the *acyl chain* Pun1 is handed: the length and saturation of the branched-chain fatty acid. Tune the upstream KAS/BCAT stream and you tune the *shape* of the burn, not merely its size.

Consistency. This is the one a condiment brand cares about most, and the one traditional agriculture cannot give. Wild-type chili heat varies batch to batch by around **42%** — a sauce that is mild in spring

and vicious in autumn. The engineered Pepper host delivers its target at **≤7%**. For a company that has to put the same product in a jar every week, that difference *is* the business.

ROLE	CHILI	HEAT BAND	SELECTED FOR
Fragrance / color	èrjīngtiáo (二荆条)	moderate	aroma, deep red, clean burn
Whole-pod heat	cháotiānjiāo (朝天椒)	medium-high	sharpness, visual drama
Bright kick	xiǎomǐlà (小米辣)	high	forward bite
Engineered base	**Pepper host** · 1,060 constructs	*to target*	color + aroma + placed heat at ≤7% CV

The flagship superhots of Chapter 1 are on the shelf above this one, and in Sichuan cooking we almost never take them down. They are the proof that the method reaches the ceiling. This cuisine is the proof that the method can hit a *window* — which, for a working kitchen, is the rarer and more valuable thing.

What does the window look like, in numbers? A Sichuan-tuned chili oil wants, roughly, an IFI-H in the **1,200–1,600** band — present, warming, never punishing — carried on a capsaicin-forward capsaicinoid ratio so the burn is bright and fast-clearing; a capsanthin load deep enough to stain the oil a translucent ruby; and a volatile profile weighted toward the toasted-fruit pyrazines rather than the green notes. Against that target the decisive specification is consistency. Wild-type chili heat varies batch to batch by around **42%** — the coefficient of variation, the standard deviation as a fraction of the mean — which for a sauce maker means a product mild in spring and vicious by autumn, the same label tasting like two different things across a year. The engineered Pepper host holds its target to **≤7%**. For a founder who must put the identical jar on the shelf every single week, that collapse in variance is not a refinement of the product. It is the difference between having a recipe and having a product.

Chapter 6 · The peppercorn we have not learned to grow — *an honest frontier.*

Here is the chapter other volumes in this library do not have to write, and we would not trade it. Everything else in the Sichuan pantry we can, in principle, design. The peppercorn, we source — and the reasons are worth laying out plainly, because they map the exact edge of what the platform can and cannot yet do.

The first reason is botanical. *Zanthoxylum* is a thorny, slow, woody shrub of the citrus family, not an annual you transform, grow out, and assay in a single season like a chili or a tomato. There is no validated **Zanthoxylum** host among our 42; it is a **concept organism**, a candidate on the Beyond-Peppers roadmap, not a shipping line. We will not give it an SKU it has not earned. When the frontier chapter (Chapter 17) imagines engineering the tingle, it imagines — it does not announce.

The second reason is the pathway, discussed in Chapter 3: the sanshool amide route is not fully drawn. We can see the strategy and still lack the parts list.



What is not yet grown: a young host in a transplant pot. The peppercorn remains, for now, a thing we buy from the mountains — not a thing we design.

The third reason is terroir, and it is the one the Sichuanese would insist on first. The world's most prized huājiāo comes from **Hànyuán** (汉源) county, high in the mountains south of Chengdu — the historic 贡椒, *gòngjiāo*, "tribute pepper," sent to the imperial court. Altitude, cool nights, and poor stony soil concentrate the sanshools and the aromatic terpenes in the husk; the berries are hand-picked, sun-dried, and winnowed from their shining black seeds, which carry little tingle and a faint bitterness. This is agriculture as a thousand-

year instrument, and we treat it the way we treat the vine in the wine book — with the respect owed to a thing humans have already optimized to a razor's edge by patience alone.

The grading is as exacting as any wine appellation. Prime huajiao is judged by the openness of the split husk — the best berries gape like tiny flowers, the *flower* in "flower pepper" — by the depth of color, by the oil you can feel when you crush one between finger and thumb, and above all by the *málì*, the numbing strength, tested by biting a single husk and counting how fast and how hard the lip begins to buzz. The seed, the shining black bead inside properly called *jiāomù*, is winnowed out and discarded for cooking, because it carries little sanshool and a muddy bitterness; a peppercorn sold heavy with seed is a peppercorn sold short. The crop is picked in high summer when the sanshools peak, and dried fast in the sun before oxidation can begin its quiet theft. None of this is folklore dressed up as craft. It is a community's accumulated empirical control over a perishable, fragile chemistry — the very thing we do with instruments, done instead with hands and a thousand years of attention.

HUAJIAO	SPECIES	REGION	CHARACTER
Red, *dàhóngpáo* (大红袍)	*Z. bungeanum*	Hanyuan, Gansu	deep, aromatic, warm numbing — the classic
Green, *qīng huājiāo* (青花椒)	*Z. armatum / schinifolium*	Chongqing, the south	sharp, lemony, intense fresh tingle
Tribute pepper, *gòngjiāo* (贡椒)	*Z. bungeanum*	Hanyuan (historic)	the graded best of the red, once sent to court

A Chengdu kitchen reaching for the aromatic red and a Chongqing kitchen reaching for the electric green are choosing two different points on the má axis, as deliberately as a cook chooses between two chilies. When we speak of "the peppercorn" as a single thing we are flattening a palette the cuisine treats with all the discrimination it brings to the chili — another reminder that what looks from outside like one ingredient is, from inside, a whole section of the orchestra.

There is, finally, a regulatory chapter to the peppercorn that reads like a parable about handling living flavor carelessly. From **1968 to 2005**, the import of Sichuan peppercorns into the United States was effectively banned — not for any danger to eaters, but because *Zanthoxylum*, as a citrus relative, can carry **citrus canker** (the bacterium *Xanthomonas*), and the agricultural authorities feared for the orange groves. When the ban was lifted, it came with a condition: imported peppercorns had to be **heat-treated to around 70 °C** to kill the pathogen. The treatment worked — and, predictably, it *dulled the tingle*, because the delicate sanshools and volatile terpenes are exactly the sort of molecules heat degrades. For years, American málà was a quieter fire than Sichuan's, by law. It is the cleanest illustration we know of a truth that runs under this whole library: flavor is a living, fragile chemistry, and how you grow, dry, and handle a thing is not separate from how it tastes. You cannot staple potency back onto a husk you have cooked the life out of. You have to grow it in.

That episode left a mark on the science, too. For the decades of the ban, and for years after under the heat-treatment rule, much of the má eaten outside China was a diminished thing, and a generation of cooks abroad learned málà with the numbing turned down by law. It is a small, strange case study in a principle this company takes seriously: that a rule written for one risk — here, a citrus bacterium with no interest in your dinner — can silently reshape a flavor, and that the honest answer is never to fake the lost potency with more of something else, but to restore the real molecule at its source. The peppercorn taught us, before we had the words for it, the thesis of the whole platform: you design flavor by designing the living thing, or you do not really design it at all.

Chapter 7 · Doubanjiang and the fermented dark — *the soul in the jar.*

If chili is the color of Sichuan and the peppercorn is its signature, **doubanjiang** (豆瓣酱) is its soul — and the cooks say so literally: 川菜之魂, *the soul of Sichuan cooking*. It is a thick, brick-red, deeply savory paste of fermented broad beans and chili, salt-cured and aged in open earthenware jars, and the best of it — from **Pixian** (郫县), outside Chengdu — is turned by hand and aged for one, three, even five years, sunned by day and dewed by night until it goes almost black and smells of the earth.



Soybean and its fermented kin stand behind nearly every savory note in this cuisine; proteolysis in the jar is where glutamate — and umami — are born.

What happens in that jar is a controlled demolition, and it builds flavor axes the raw bean cannot reach on its own. A mould — *Aspergillus* — is cultured first on the beans (and on wheat, in the related pastes), secreting proteases and amylases. Over months, the proteases take the bean's storage proteins apart into peptides and, finally, into free amino acids, chief among them **glutamate** — the molecule of umami, read by **mGluR1** and the TAS1R1·TAS1R3 heterodimer, scored on **IFI-U**. Lactic-acid bacteria and yeasts move in behind the mould, dropping the pH, generating esters and alcohols, and the long Maillard chemistry of the sun-aged paste builds the dark, roasted depth on top. The chili, fermenting alongside the beans, loses its raw sharpness and gains a rounded, lacquered heat.

The timeline of that demolition is worth laying out, because it is a succession as orderly as a forest growing back. First the mould: *Aspergillus* — the same genus behind soy sauce and miso — is cultured on the beans and wheat as **koji**, a living enzyme factory secreting the proteases and amylases that do the slow work. Then, as salt and time select the survivors, **lactic-acid bacteria** and salt-tolerant **yeasts** move in, dropping the pH and generating the esters, alcohols, and aromatic acids that give an aged paste its winey depth. Over months to years, in the open jar under sun and dew, the long **Maillard** chemistry lays the dark roasted top notes over everything beneath. The glutamate that is the engine of it all was first isolated,

as it happens, in 1908, when the chemist Kikunae Ikeda purified it from kombu and named the taste *umami*; crystallized monosodium glutamate followed within the year. Sichuan cooking uses MSG freely and without apology, and it also builds the very same glutamate the slow way, in the jar — which is the quiet argument this platform makes in another key: the molecule is the molecule, and the only real questions are how cleanly you can make it and how much else of value rides along beside it.

Those *else* molecules are where kokumi lives. The fermentation accumulates **γ-glutamyl peptides** — glutathione (γ-Glu-Cys-Gly) and short relatives such as γ-Glu-Val-Gly — which carry no taste of their own but bind the calcium-sensing receptor **CaSR** and amplify the sensation of body, continuity, and roundness. They are why a three-year Pixian paste does not merely taste saltier than a one-year paste but *deeper*, more whole, more lingering on the finish. On the Index this is IFI-K, the axis most invisible to the eye and most missed the moment it is gone.

Crucially, the jar also builds **kokumi** — the quiet axis, IFI-K, read by the calcium-sensing receptor **CaSR**, which responds to **γ-glutamyl peptides** (glutathione and its relatives) accumulated through fermentation. Kokumi carries no taste of its own; it is the sensation of *continuity and body*, the way a long-aged paste makes a sauce feel thick, round, and persistent even where the tongue can name nothing specific. It is the reason three-year Pixian doubanjiang tastes not merely saltier than one-year but *deeper*, more whole.

Doubanjiang does not stand alone in the fermented dark. **Douchi** (豆豉), fermented and salted black soybeans, bring a sharper, funkier glutamate hit — they are the pungent-savory studs in a mápó dòufu. **Yácài** (芽菜), the preserved mustard greens of Yibin, bring a sweet-savory, slightly sour depth to dry noodles. Each is a different fermentation drawing a different coordinate out of the same humble legume and brassica.

FERMENT	BASE	MICROBE-LED TRANSFORMATION	AXES IT BUILDS
Pixian doubanjiang (郫县豆瓣)	broad bean + chili	*Aspergillus* koji, long sun-aging (1–5 yr)	**U** · **K** · H
Douchi (豆豉)	black soybean	mould + salt, drier ferment	**U** · P
Yacai (芽菜)	mustard greens	salt ferment, sweet-savory	U · S
Zhacai (榨菜)	mustard stem	salt-press ferment, crisp, sour	U · (sour)
Soy sauce	soybean + wheat	koji + brine moromi	**U** · K

Read the right-hand column and the pantry resolves into a set of umami-and-kokumi instruments, each tuned a little differently — a savory section the chili and peppercorn play *over*. This is why Sichuan food tastes deep even when it is plain: the fermented base is already a composed chord before a single fresh ingredient is added to it. On the platform, we can engineer the **Soybean** host (360 constructs, U/K) toward umami and kokumi directly — but we say clearly that an engineered bean and a five-year Pixian jar are not the

same object, any more than a tuned grape is a vintage. One is a designed ingredient; the other is time, made edible. The honest cook uses both.

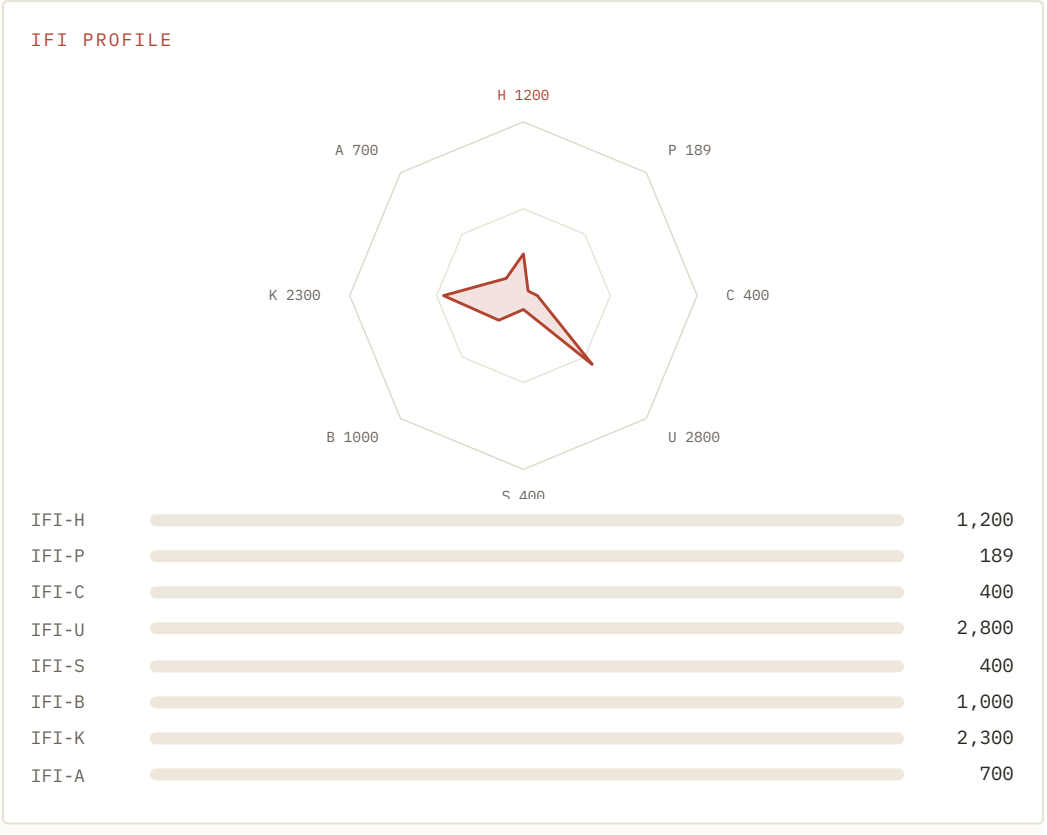
Recipe · A quick home doubanjiang-style chili-bean paste — *the three-month jar, in a week.*

Not a substitute for aged Pixian — a bridge, for when you want the lacquered depth and do not have three years. Use in any "home-style" (*jiāchán*g) dish below.

Dried èrjingtiao chilies, stemmed	60 g
Fermented broad beans (or douchi)	80 g, rinsed
Fermented chili paste (store, as base)	120 g
Garlic, minced	6 cloves
Ginger, minced	20 g
Shaoxing wine	2 tbsp
Neutral oil	120 ml
Sichuan chili flakes (coarse)	30 g
Salt	to taste

TIME · 40 min active · 5–7 days rest

1. Soak the dried chilies in hot water 20 minutes until soft, drain, and chop to a rough paste with the rinsed fermented beans.
2. Warm the oil to a gentle simmer (about 150 °C), add garlic and ginger, and fry 2 minutes until fragrant but not coloured.
3. Add the chili-bean paste and the store base. Cook low and patient, 15–20 minutes, stirring, until the oil runs red and the paste darkens and smells toasted.
4. Off the heat, stir in the wine and the coarse flakes; salt to taste.
5. Jar it, film the surface with a little oil, and rest at cool room temperature 5–7 days before first use. It deepens for a month.



Chapter 8 · Red oil — *hóngyóu, and the physics of the pour.*

Everything downstream begins here. **Hóngyóu** (红油), Sichuan red oil, is the medium that carries this cuisine's flavor — the lacquer on cold noodles, the slick on a wonton, the shining pool under mápó dòufu — and making it well is an exercise in applied physics as much as cooking, because the single variable that decides whether you get fragrance or acridity is **temperature**.

Capsaicin and capsanthin are both **lipophilic**: they dissolve into oil, not water, which is why red oil extracts the chili's heat and color so completely while a water broth barely touches them. But the chili's prized *aroma* volatiles are fragile, and so are the sanshools if peppercorn goes in. Pour oil that is too hot over the flakes and you scorch the sugars to bitterness and flash off the fragrance; pour it too cool and you fail to bloom the pigment and the aroma, leaving a dull, raw, under-extracted oil. The traditional solution is one of the quiet masterpieces of folk food science: **pour in stages, at descending temperatures**, so that each fraction of the flavor is extracted at the temperature that serves it.



Pigment and heat live in the chili's flesh and ribs; red oil is, at heart, a lipid extraction of exactly this cross-section.

POUR	OIL TEMP	WHAT IT EXTRACTS
First	~200 °C	deep color, a toasted edge; blooms the coarsest flakes
Second	~150 °C	the body of the heat and the paprika fragrance
Third	~120 °C	the delicate top-note aroma; the peppercorn's tingle, unscorched

Sidebar · Why oil, and not water

Red oil is a solvent choice as much as a recipe. Capsaicin, the capsanthin pigment, and the sanshools are all **lipophilic** — they dissolve into fat and barely at all into water — which is the single fact that organizes this cuisine's whole technique. It is why heat and color flood into oil and leave a water broth nearly untouched; why the fat base of a hot pot grows fiercer over an evening while the watery dipping-stock stays mild; why a thread of oil carries flavor across a dish that a spoon of stock cannot. It is also why water does so little to quench a chili burn, and why fat — or the casein in a glass of milk — actually helps: you are trying to dissolve the capsaicin and carry it away from the receptor, and only a solvent it likes will do the work. The staged pour above is simply this chemistry, managed: temperature deciding, fraction by fraction, which lipophilic molecule makes the jump into the oil, and in what order.

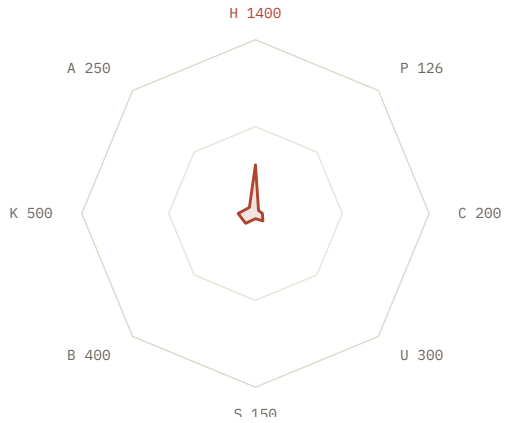
Recipe · Hóngyóu — *Sichuan red oil, three pours.*

Coarse Sichuan chili flakes (èrjingtiao)	80 g
Fine chili powder (for color)	20 g
Neutral oil (rapeseed, traditionally)	400 ml
Sichuan peppercorns (red, lightly crushed)	1 tbsp
Star anise	1
Bay leaf	1
Cassia bark	1 small piece
Ginger, sliced	20 g
Scallion, in lengths	2
White sesame seeds	1 tbsp
Salt	½ tsp

TIME · 30 min · rests overnight

1. Put the chili flakes, fine powder, sesame, and salt in a heatproof bowl.
2. Heat the oil with the peppercorns, anise, bay, cassia, ginger, and scallion until the aromatics are deeply fragrant and the ginger edges brown; fish out and discard the solids.
3. Let the oil fall to about 200 °C (a flake dropped in sizzles hard). Pour roughly a third over the chili, stirring — it will foam and smell toasted.
4. At about 150 °C, pour the second third, stirring.
5. At about 120 °C, pour the last third. Stir, cover, and rest overnight. The color deepens and the aroma rounds as it sits.

IFI PROFILE



IFI-H	1,400
IFI-P	126
IFI-C	200
IFI-U	300
IFI-S	150
IFI-B	400
IFI-K	500
IFI-A	250

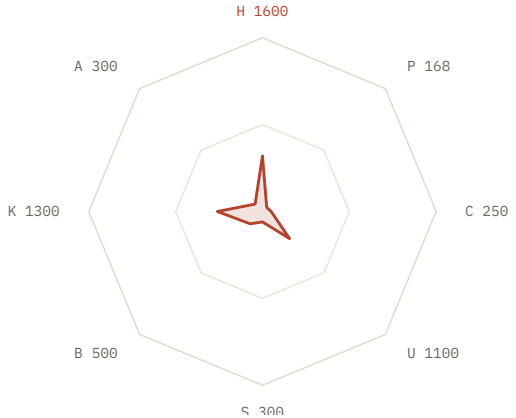
Recipe · Sichuan chili crisp — *the crunchy, savory cousin.*

Red oil's textured relative: the aromatics are kept in, fried to a crackle, and the jar is as much about crunch and umami as heat.

Neutral oil	350 ml
Shallots, thinly sliced	4
Garlic, thinly sliced	1 head
Coarse Sichuan chili flakes	60 g
Fermented black beans (douchi), chopped	2 tbsp
Sichuan peppercorns, crushed	1 tbsp
Roasted peanuts, crushed	3 tbsp
Sugar	1 tsp
Salt	1 tsp
Toasted sesame seeds	2 tbsp
TIME · 45 min	

1. Fry the shallots in the oil over medium-low until golden and crisp; lift out. Repeat with the garlic. Reserve both.
2. Let the oil cool to about 150 °C. Off heat, stir in the chili flakes, douchi, and peppercorns; the residual heat blooms them without scorching.
3. Return the crisp shallots and garlic; add peanuts, sugar, salt, and sesame.
4. Cool completely before jarring. Keeps weeks, refrigerated.

IFI PROFILE



IFI-H	1,600
IFI-P	168
IFI-C	250
IFI-U	1,100
IFI-S	300
IFI-B	500
IFI-K	1,300
IFI-A	300



PART III OF IV

A Hundred Dishes, A Hundred Flavors

the wèixíng, read as coordinates — málà · yúxiāng · gōngbǎo · guàiwèi · jiācháng

Chapter 9 · The twenty-three flavors — *wèixíng, as notation.*

This is the intellectual heart of the book, and the chapter we most wanted to write, because it is where the Sichuan tradition and the Iyengar Index turn out to be the same idea in two alphabets.

Sichuan cooking does not organize itself by ingredient or by technique the way most cuisines do. It organizes itself by **composed flavor** — the *wèixíng* (味型), the named, repeatable sensory target a cook aims a dish at. There are around two dozen in the classical canon, and a trained Sichuan chef can name the one a dish is in from a single taste, the way a musician names a chord.

The system is not loose folklore but codified craft, formalized and taught. Twentieth-century Sichuan culinary institutes fixed the canon at roughly two dozen named profiles and drilled apprentices in each — the exact ratios, the order of addition, the telltale by which you know a *yúxiāng* has tipped too far toward sweet or a *málà* has lost its numbing spine. A graduating cook could reproduce each wèixíng on demand and judge another cook's attempt against the standard. That is, precisely, a *specification regime*: a set of named targets, a training in hitting them, and a shared language for the misses. It is what an engineering discipline looks like when its only instrument is the human sensory system, refined across generations. We did not bring rigor to this cuisine. We brought a second instrument to a cuisine that had been rigorous for centuries — and found, to our delight, that its targets were already consistent enough to put numbers on. *Fish-fragrant*, *strange-flavor*, *scorched-chili*, *lychee*, *red-oil*, *home-style*, *peppercorn-numbing*, *mashed-garlic*, *aged-tangerine-peel* — these are not vague moods. They are specifications, handed down and held stable across generations of tongues.



The full-spectrum cultivar, Phoenix — eight axes lit at once. It is the engineered twin of what the Sichuan cook calls guàiwèi: every flavor present, in balance, on purpose.

What the Index adds is not a correction — the cooks were never wrong — but a *coordinate system*. Every wèixíng can be written as a position on the eight axes, which means it can be measured, reproduced to tolerance, and taught to someone who has never

stood in a Chengdu kitchen. Read the table below as a translation dictionary: the left column is how Sichuan names the chord; the right columns are how the receptors hear it.

WÈIXÍNG	GLOSS	DOMINANT AXES	SIGNATURE MOVE
麻辣 málà	numbing-hot	**H · C · P**	chili + peppercorn, the two fires
红油 hóngyóu	red-oil	H · K	chili oil over cold food, savory-sweet soy
糊辣 húlà	scorched-chili	H · P (+ roast)	chilies fried dark; pyrazine bitterness
椒麻 jiāomá	peppercorn-numb	**C · P** · U	green peppercorn + scallion, minimal chili
鱼香 yúxiāng	fish-fragrant	U · S · P	pickled chili, garlic, ginger, sweet-sour
荔枝 lìzhī	lychee	S · U	gentle sweet-sour tilt, heat low
糖醋 tángcù	sweet-sour	**S** · (sour)	sugar and vinegar in balance
宫保 gōngbǎo	kung-pao	H · S · P · C	lychee tilt + dried chili + peppercorn + peanut
家常 jiācháng	home-style	**U · K** · H	doubanjiang-built everyday savory
咸鲜 xiánxiān	salty-fresh	**U** · K	clean savory, umami foregrounded
蒜泥 suànní	mashed-garlic	**P** · K · H	raw garlic, red oil, soy
麻酱 májiàng	sesame	K · A	sesame paste body, soft astringency
陈皮 chénpí	tangerine-peel	B · H · A	dried citrus peel's bitter-aromatic edge
怪味 guàiwèi	strange-flavor	**all eight**	every axis present, none dominant

Run your eye down the right-hand columns and the cuisine's whole grammar appears as a pattern of emphasis. Málà drives H, C, P. The savory family — xiánxiān, jiācháng — drives U and K and leans on the fermented dark of Chapter 7. The bright family — yúxiāng, lìzhī, tángcù — lifts S and plays it against a sour counter-tension. And at the bottom sits **guàiwèi**, "strange flavor," which is strange only because it refuses to let any one axis win: it is the Sichuan name for *the full spectrum*, every receptor addressed at once, and it is the direct culinary cousin of the engineered full-spectrum cultivar, Phoenix, that lights all eight axes in a single fruit. We will give guàiwèi its own chapter. For now, note the astonishment of it: a folk tradition and a protein language model arrived, independently, at the same ambition — *address everything, balance everything* — and gave it almost the same meaning.

Recipe · Dàndàn miàn — *the demonstration dish.*

If one bowl proves that a wèixíng is a coordinate, it is this one — a composition in which no single element dominates and the whole thing lives or dies on balance. Vegetarian-first; the classic crowns it with crisp fried pork, and we honor that variation at the end.

Fresh thin wheat noodles	200 g
Sichuan preserved mustard (yacai)	3 tbsp, chopped
— The sauce, per bowl —	
Red oil (Ch. 8), with sediment	2 tbsp
Light soy sauce	1 tbsp
Chinkiang black vinegar	1 tsp
Sesame paste (or tahini), loosened	1 tbsp
Sugar	½ tsp
Ground roasted Sichuan peppercorn	¼ tsp
Garlic, grated	1 clove
Scallion + roasted peanuts	to finish
TIME · 25 min	

1. Dry-fry the yacai in a little oil until fragrant and slightly crisp; reserve.
2. Build the sauce in the serving bowl: soy, vinegar, loosened sesame paste, sugar, garlic, red oil, and the ground peppercorn.
3. Boil the noodles until just tender; lift them straight onto the sauce with a little starchy water to loosen.
4. Top with yacai, scallion, and crushed peanuts. Toss hard at the table so every strand is coated — the dish is *dry*, not soupy.
5. *Classic variation:* crown with 80 g pork minced and fried crisp with a splash of soy, treated with the same care as the vegetables it sits among.

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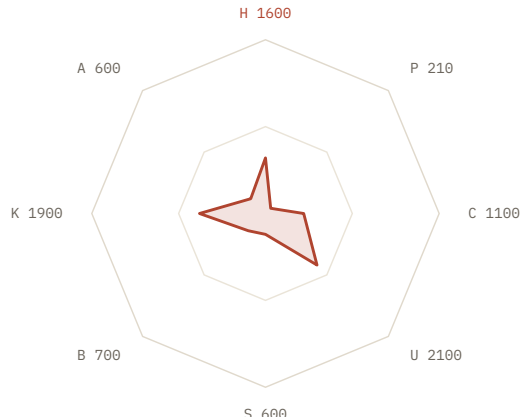

IFI-H	1,600
IFI-P	210
IFI-C	1,100
IFI-U	2,100
IFI-S	600
IFI-B	700
IFI-K	1,900
IFI-A	600

Chapter 10 · Málà — *the signature chord.*

Now the dish the whole book has been walking toward. **Mápó dòufu** (麻婆豆腐) is málà made legible: soft tofu in a brick-red sauce of doubanjiang and douchi, finished with a snowfall of ground peppercorn so the numbness lands last and lingers. It is said to have been cooked first in the 1860s by a pockmarked grandmother (*má pó*) near a bridge in Chengdu, who fed cart-drivers from a pot kept always on the fire. The name holds the two fires in it twice over — 麻 for her face and 麻 for the tingle.



Soft tofu is the quiet center of málà's loudest dish — a blank, cool, high-protein field for the two fires to play across.

Read as a coordinate, mápó dòufu is the clearest teaching example in the cuisine. Its heat (**H**) runs high but not punishing, because — recall Chapter 4 — the tingle modulates the burn's tail. Its má brackets strongly onto **C** and **P**. And underneath both fires sits a deep **U/K** foundation from the doubanjiang, the douchi, and the tofu itself — which is why the dish reads as *nourishing* and whole rather than merely hot. The tofu is not filler; it is the cool, pale, high-protein field across which the two fires are made visible, the silence that lets you hear the chord.

Sidebar · Why the má goes on last

There is a rule in this dish that reads like superstition and is in fact chemistry: the ground peppercorn is added *off the heat*, at the very end, and never cooked. Recall from Chapter 2 that the sanshools are fragile — they oxidize and volatilize with heat, and the fifty-hertz tingle is the first thing to go. Fry the powder into the simmering sauce and you brown its terpenes to a dull bitterness and flash the sanshool away; shower it on at the table and the buzz arrives intact and *first*, a half-beat ahead of the chili's burn — which is the entire sensory architecture of málà, 麻 before 辣, the numb before the hot, in that order because that is the order the recipe builds. The grandmother's sequence is a protocol for preserving a labile compound. She simply called it the right way to do it.

Recipe · Mápó dòufu — *the grandmother's fire.*

Soft (silken-ish) tofu, 2 cm cubes	450 g
Doubanjiang (Pixian, or Ch. 7 paste)	2 tbsp
Fermented black beans (douchi)	1 tbsp, chopped
Sichuan chili flakes	1 tbsp
Garlic + ginger, minced	2 cloves + 10 g
Scallion whites, sliced	2
Light soy sauce	1 tbsp
Vegetable stock	200 ml
Cornstarch slurry	1 tbsp in 2 tbsp water
Neutral oil	3 tbsp
Ground roasted Sichuan peppercorn	½ tsp, to finish
Scallion greens	to finish

TIME · 30 min

1. Slip the tofu cubes into barely-simmering salted water and hold them warm while you build the sauce; this firms them gently and keeps them intact.
2. Fry the doubanjiang and douchi in the oil over medium heat until the oil runs deep red, 2–3 minutes — this step *is* the dish; do not rush the color.
3. Add garlic, ginger, scallion whites, and chili flakes; 30 seconds to fragrance.
4. Pour in the stock and soy; slide in the drained tofu and simmer 3–4 minutes, nudging rather than stirring so the cubes stay whole.
5. Add the slurry in two additions until the sauce clings and glosses.
6. Off the heat, shower with the ground peppercorn and scallion greens. The má must go on *last*, and raw — cook it and you lose the fifty-hertz note.

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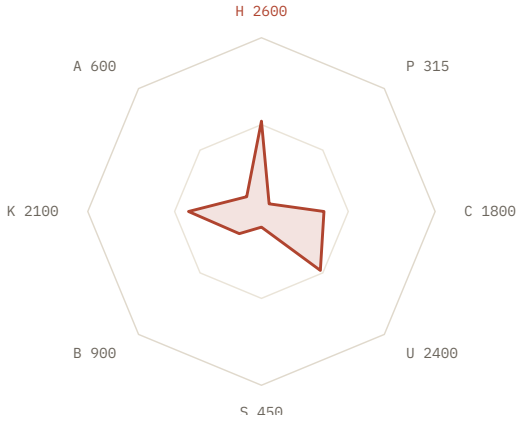

IFI-H	2,600
IFI-P	315
IFI-C	1,800
IFI-U	2,400
IFI-S	450
IFI-B	900
IFI-K	2,100
IFI-A	600

A note, in the first person, where the book otherwise speaks as we: the ground peppercorn at the end is the step everyone is tempted to skip or to stir in early, and it is the whole dish. Add it off the heat, let it sit thirty seconds, and taste the lips start to hum before the spoon is down. That hush we could not measure, the night this all began — it lives in that last spoonful of powder. — P.

Recipe · Shuǐzhǔ qīngcài — *water-boiled greens, the málà flood.*

"Water-boiled" (*shuǐzhǔ*) is one of the most dramatic málà forms: tender food poached in a savory broth, then drowned under a flood of hot oil poured over raw chili and peppercorn at the table, so it crackles. Classic with fish or beef, which we honor; here, vegetable-forward.

Napa cabbage + enoki + soft tofu	600 g total
Vegetable stock	500 ml
Doubanjiang	2 tbsp
— The flood —	
Dried chilies, halved	15
Sichuan peppercorns	1 tbsp
Garlic, sliced	6 cloves
Neutral oil	120 ml
TIME · 35 min	

1. Fry the doubanjiang in a little oil, add stock, and simmer to a savory red broth.
2. Poach the vegetables and tofu in the broth just until tender; transfer to a deep bowl, broth and all.
3. Scatter the dried chilies, peppercorns, and garlic over the top.
4. Heat the oil until shimmering (~200 °C) and pour it over the aromatics in one go — it will roar and release a cloud of fragrance. Serve at once, while it crackles.

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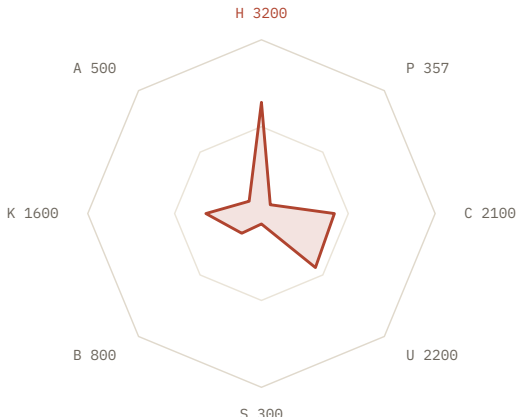

IFI-H	3,200
IFI-P	357
IFI-C	2,100
IFI-U	2,200
IFI-S	300
IFI-B	800
IFI-K	1,600
IFI-A	500

Chapter 11 · Yúxiāng — *fish-fragrant, and there is no fish.*

Of all the wèixíng, **yúxiāng** (鱼香) — "fish-fragrant" — is the one that most delights and confounds newcomers, because the dish contains no fish and tastes of none. The name points to a *flavor memory*: the seasoning paste traditionally used to cook freshwater fish in Sichuan homes — **pickled chili** (泡椒, *pàojiāo*), garlic, ginger, scallion, sugar, and vinegar — turned out to be so complete, so delicious, that cooks began applying it to everything else, and the flavor kept the name of the fish it had left behind. It is one of the most elegant arguments in all of cooking that *a flavor is a composition, not an ingredient* — which is, of course, this entire library's thesis, arrived at by a Sichuan grandmother centuries early.



Eggplant is yúxiāng's perfect vehicle: its collapsing, custardy flesh drinks the sweet-sour-savory paste the way nothing else can.

As a coordinate, yúxiāng is a study in brightness held in tension. Pickled chili and a little sugar lift the dish toward **S**; a measured pour of vinegar sets a sour counter-tension against the sweet; garlic and ginger carry **P**; and the whole thing rests on a savory **U**/**K** base. The heat is deliberately moderate — yúxiāng is not a málà dish; its drama is the sweet-sour-pungent-savory braid, not the burn. On the Index it reads nothing like mápó dòufu, and that is the point of putting them in consecutive chapters: same cuisine, same pantry, two completely different regions of the eight-axis space, each hit on purpose.

Sidebar · The pickled chili, and a flavor that outlived its fish

Yúxiāng's secret is **pàojiāo** (泡椒), chilies lacto-fermented in brine until their raw heat softens into something sour, funky, and complex — a different instrument from the dried chili of red oil, contributing acidity and depth as much as warmth. The sweet-and-sour braid laid over it is a study in the cross-terms of Chapter 4: the sugar and the vinegar are tuned not to be *tasted* outright as sweet or sour but to hold each other in tension, each suppressing the other's edge, so that what the mouth reads is roundness and lift. It is the same trick as the lychee tilt of gōngbǎo, run a little louder. And the dish is proof, served nightly across Sichuan, of this library's founding claim: a flavor is a *composition* — portable, nameable, able to outlive the

very ingredient it was named for. The fish is four hundred years gone from the recipe. The fragrance it left behind is on the table tonight.

A word on the eggplant itself, because the vegetable is doing real physical work. Its flesh is a sponge — an open, air-filled parenchyma that, raw, floats and resists — and the first heat collapses that structure, driving out the air and opening the tissue to drink fat and sauce into the space where the air had been. This is why fried eggplant turns from squeaky and pale to silken and glossy, and why the yúxiāng sauce penetrates it so completely rather than sliding off: the cooking literally remakes the vegetable into a vessel for the composed flavor. Choose a slender Asian eggplant, thinner-skinned and with fewer seeds, and the transformation is cleaner still. It is a small instance of something this library keeps rediscovering — that texture and structure are not separate from flavor but part of how a flavor is delivered to the mouth at all.

Recipe · Yúxiāng qiézi — *fish-fragrant eggplant.*

Chinese eggplant, in batons	500 g
Pickled red chilies (paojiao), minced (or doubanjiang + extra sugar)	2 tbsp
Garlic, minced	4 cloves
Ginger, minced	15 g
Scallions, sliced (whites/greens apart)	3
— The yuxiang sauce —	
Light soy sauce	1 tbsp
Chinkiang vinegar	1½ tbsp
Sugar	1½ tbsp
Cornstarch	1 tsp
Water	3 tbsp
Neutral oil	for frying

TIME · 30 min

1. Fry the eggplant batons in a generous slick of oil until collapsing and golden — eggplant wants fat and patience; drain.
2. Stir the sauce ingredients together until the sugar dissolves.
3. In a little oil, fry the pickled chili, garlic, ginger, and scallion whites until intensely fragrant, about 1 minute.
4. Return the eggplant; pour in the sauce and toss until it thickens to a gloss and clings, 1–2 minutes.
5. Finish with scallion greens. The dish should taste sweet, then sour, then savory, then warm — in that order, each clearly.

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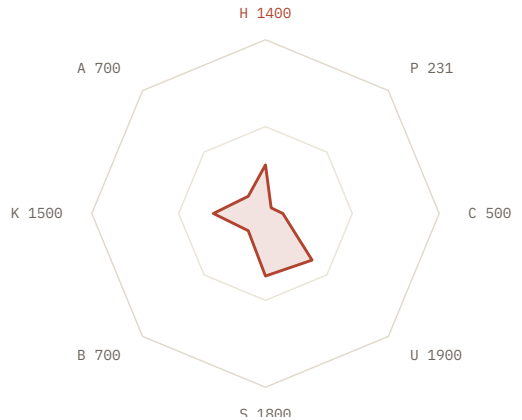

IFI-H		1,400
IFI-P		231
IFI-C		500
IFI-U		1,900
IFI-S		1,800
IFI-B		700
IFI-K		1,500
IFI-A		700

Chapter 12 · Gōngbǎo — *the lychee tilt.*

Gōngbǎo（宫保）— known in the West, through a long game of telephone, as "kung pao" — is named for a Qing-dynasty governor of Sichuan, Ding Baozhen, whose honorific title was *Gōngbǎo*. The dish that carries his name is a masterclass in restraint: a tangle of diced protein, dried chilies, peppercorn, and peanuts, bound in a sauce tuned to the **lìzhī**（荔枝, "lychee") tilt — a gentle sweet-sourness, named for the fruit, that should be *sensed* rather than tasted, a lean toward sweet-and-sour that never tips over into either.



Peanuts are not a garnish in gōngbǎo but a structural voice — the crunch, the fat, the soft sweetness that answers the dried chili's bite.

The technique that defines gōngbǎo is **húlà** — the "scorched-chili" move. The dried chilies are fried in hot oil until they darken almost to black just before they would burn, which transforms them: the Maillard and pyrolysis chemistry generates roasted, nutty **pyrazines** and a faint, pleasant bitterness, so the chili contributes *aroma and depth* more than raw heat. It is the same principle as the staged pour in red oil — heat as a tool for shaping the chili's flavor, used here at the aggressive end. As a coordinate, gōngbǎo is busy and balanced: **H** and **P** from the scorched chili and peppercorn, **C** from the má, **S** from the lychee tilt, **U/K** from the savory base, and a real textural axis — crunch — that the Index does not score but the mouth never forgets.

Sidebar · Scorched, not burned — the húlà line

The whole dish depends on a window of a few seconds. Fry a dried chili and it moves through stages: first it softens and reddens, then it darkens and throws off toasted, nutty **pyrazines** as Maillard chemistry runs in the pod's residual sugars and amino acids, then — one beat later — it tips into acrid carbon and is ruined. *Húlà*, scorched-chili flavor, lives on the near side of that line, where the chili has traded raw heat for roasted aroma and a pleasant whisper of bitterness but has not yet burned. It is the same temperature logic as the staged pour of red oil in Chapter 8, run at the aggressive end: heat used as a tool to *reshape* the chili's flavor rather than merely to

extract it. Miss the window by five seconds and the wok must be washed and the chilies begun again. Every Sichuan cook has done it. It is how you learn where the line is.

Note, too, what all those dried chilies are *for*. A plate of gōngbǎo may be built with a dozen or more whole pods, and a newcomer braces for an inferno that never arrives — because the chilies are left whole, scorched for aroma, and largely not eaten; their work is to perfume the oil and the dish, not to flood it with heat. It is the whole cuisine in miniature: heat deployed for fragrance and shape rather than brute magnitude, the coordinate placed with care. The peanut answers the chili across the plate — its fat, its gentle sweetness, and above all its crunch are a structural voice, the cool solid counterweight to the scorched pods and the slick sauce. Take the peanuts away and the dish does not merely lose a garnish; it loses an axis the Index cannot score and the mouth will not forgive.

Recipe · Gōngbǎo with mushrooms and peanuts — *the lychee tilt, vegetable-forward.*

Classic gōngbǎo is chicken, and it is wonderful; king oyster mushroom, cut in cubes and seared hard, gives the same meaty bite and we make no apology for it.

King oyster mushrooms, 2 cm cubes	400 g
Roasted peanuts	80 g
Dried chilies, halved, seeds shaken out	12
Sichuan peppercorns	1 tsp
Garlic + ginger, sliced	3 cloves + 10 g
Scallion whites, in 2 cm lengths	3
— The lychee-tilt sauce —	
Light soy sauce	1 tbsp
Chinkiang vinegar	1 tbsp
Sugar	2 tsp
Shaoxing wine	1 tbsp
Cornstarch	1 tsp
Water	2 tbsp
Neutral oil	2 tbsp
TIME · 25 min	

1. Sear the mushroom cubes in a hot, dry wok first to drive off water and concentrate them, then add oil and brown; set aside.
2. Stir the sauce until smooth. Taste it raw — the sweet and sour should be nearly equal, a *tilt*, not a hit.
3. In fresh oil over medium heat, fry the dried chilies and peppercorns until the chilies darken and smell toasted — húlà — about 45 seconds; do not let them turn to ash.
4. Add garlic, ginger, scallion whites; 20 seconds. Return the mushrooms.
5. Pour in the sauce; toss until it glazes, 1 minute. Fold in peanuts off the heat so they stay crisp.

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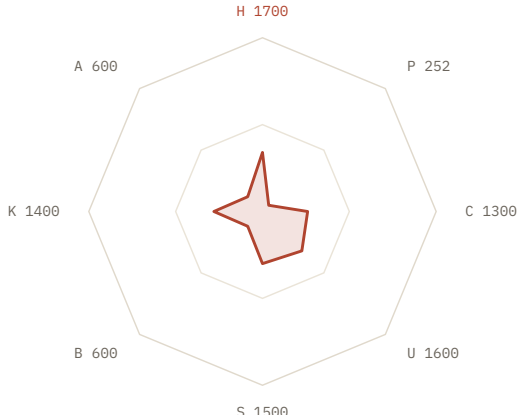


IFI-H	1,700
IFI-P	252
IFI-C	1,300
IFI-U	1,600
IFI-S	1,500
IFI-B	600
IFI-K	1,400
IFI-A	600

Chapter 13 · Guàiwèi — *the strange flavor, or: the full spectrum on a plate.*

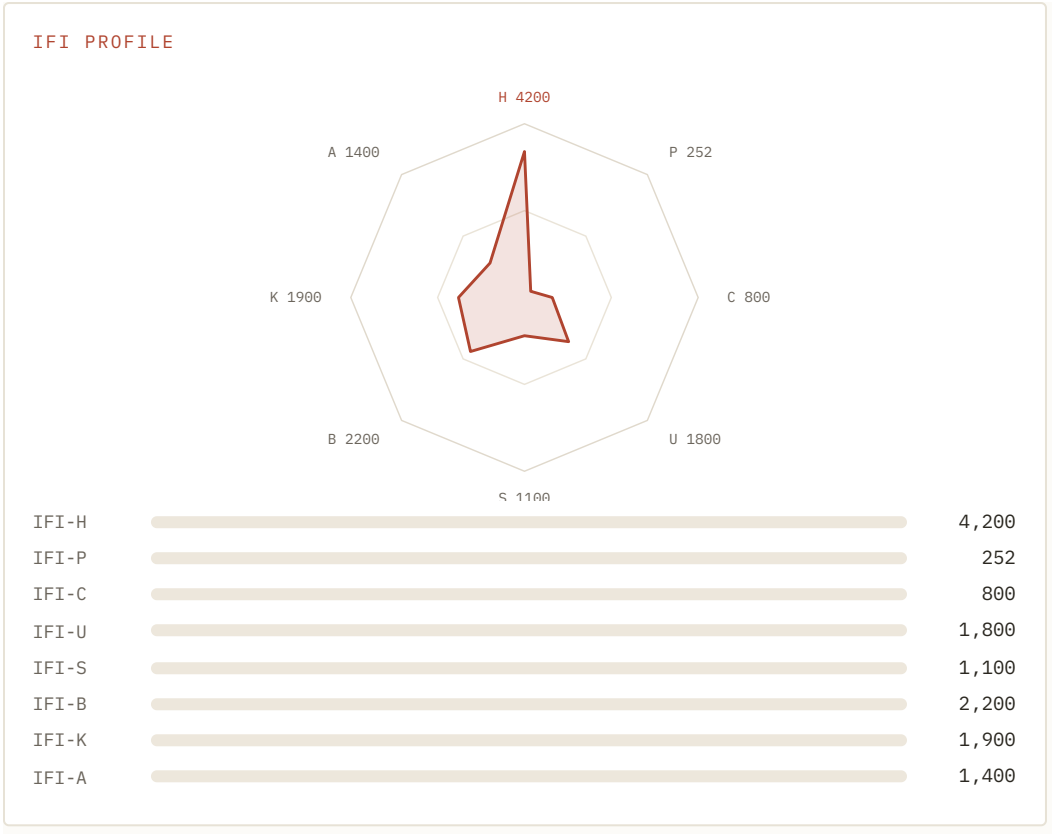
We have saved the strangest and most beautiful of the wèixíng for its own chapter, because it is the one that stopped us in our tracks when we first mapped the cuisine onto the Index.

Guàiwèi (怪味) translates, flatly, as "strange flavor" or "weird flavor" — and it is strange only in the way a white light is strange to someone who has only ever seen single colors. A guàiwèi sauce is salty, sweet, sour, numbing, hot, savory, nutty, and aromatic *all at once*, with no single sensation permitted to win. Done right, you cannot name what you are tasting, because you are tasting everything; the tongue reports a shimmering balance it has no word for, and the cook's whole skill is in the equilibrium — one element too loud and the spell breaks into mere sweet-and-spicy. The Sichuanese named this centuries ago and built it into the canon: a flavor whose entire identity is *total balance across every axis.*



This is guàiwèi, engineered: Phoenix, the only cultivar to register on all eight axes at once. The dish and the fruit are the same ambition — address everything, let nothing dominate.

Set that beside the Index and the recognition is total. **Guàiwèi is the folk name for the full spectrum — IFI-F**, the composite axis, all eight receptors addressed in balance. And the engineered twin of guàiwèi already exists in this library: **Phoenix** (SS-0096), the flagship cultivar built gene by gene to be the first organism to light every axis at once, carrying the two AI-designed Pun1 edits of Chapter 3. Its profile is the eight-axis balance made botanical:



A Sichuan cook composing guàiwèi in a bowl, by taste, and a protein language model composing Phoenix in a genome, by prediction, were chasing the identical ideal — *every flavor present, none dominant* — four hundred years and a world apart. We find this not merely satisfying but instructive. It suggests that "balance across the whole sensory field" is not an arbitrary cultural preference but something close to an attractor, a place the art of flavor keeps independently arriving at. The Index did not invent the full spectrum. It gave a number to an ideal Sichuan had already named.

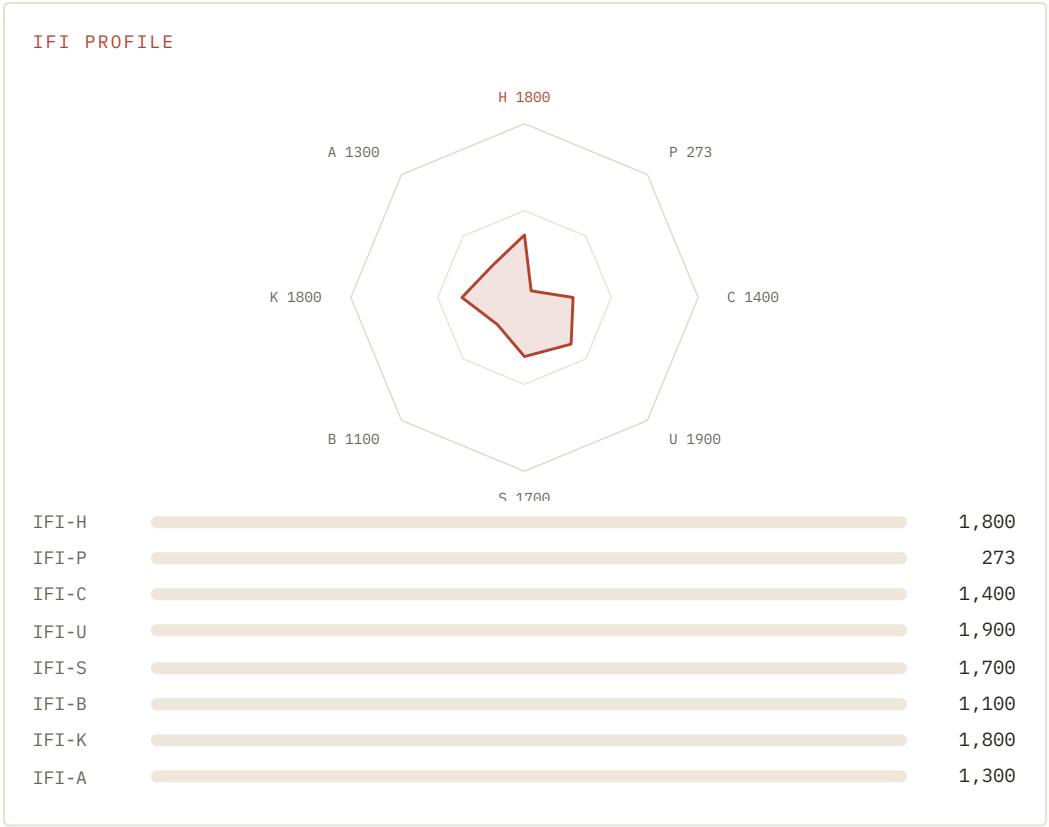
Recipe · Guàiwèi huāshēng — *strange-flavor peanuts.*

The simplest way to taste the full spectrum: a cold sauce that hits all eight, poured over crisp peanuts. Pay attention as you eat — see how long it takes to name a single flavor. You will not.

Roasted peanuts, skins on	200 g
— The guaiwei sauce —	
Sesame paste (or tahini)	2 tbsp
Light soy sauce	1 tbsp
Chinkiang vinegar	2 tsp
Sugar	2 tsp
Red oil (Ch. 8), with sediment	2 tbsp
Ground roasted Sichuan peppercorn	½ tsp
Garlic, grated	1 clove
Toasted sesame seeds + scallion	to finish
Salt	to balance

TIME · 10 min

1. Loosen the sesame paste with the soy and vinegar to a pourable cream.
2. Whisk in sugar, red oil, peppercorn, garlic, and a pinch of salt. Taste and adjust until *no single element wins* — chase the balance; that is the whole dish.
3. Fold through the peanuts just before serving, or spoon the sauce over so they stay crisp. Finish with sesame and scallion.



Note how level the readout is — no axis below 1,100, none above 1,900. That flatness *is* guàiwèi. Where mápó dòufu spikes on H and U, the strange flavor refuses every spike. It is the one dish in the cuisine whose IFI signature is legible at a glance: the plateau.

Sidebar · Balance is the hardest target

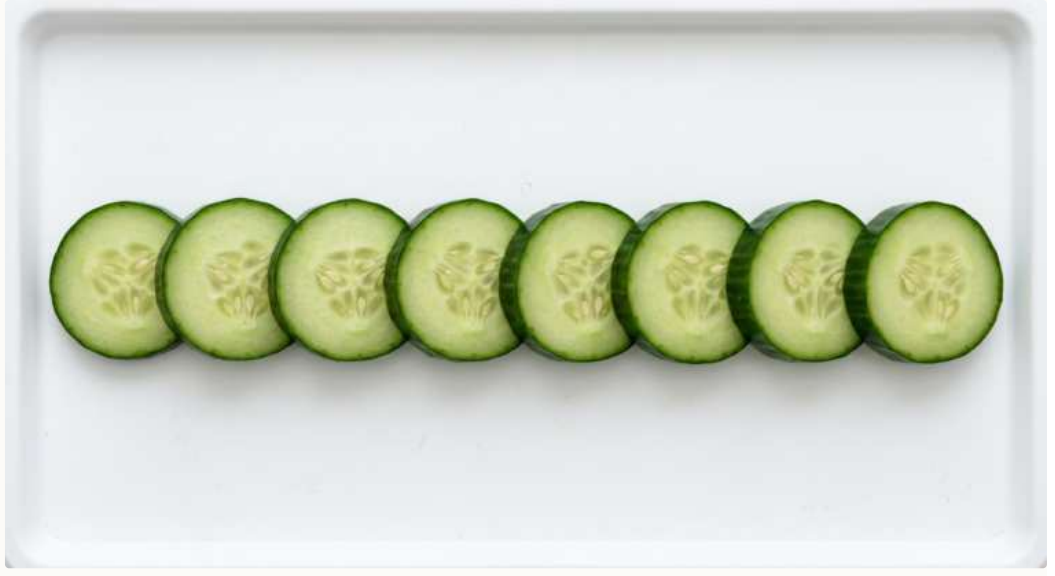
It is tempting to think a flat, all-axes-lit profile is the *easy* one — just add a little of everything. The opposite is true, and both the cook and the engineer know it. A spike is forgiving: overshoot the heat and you still have a hot dish. A plateau is unforgiving, because it is defined entirely by its *ratios*, and every element you add shifts all the others at once; one axis half a step too loud and the shimmer collapses into ordinary sweet-and-spicy. This is exactly why Phoenix was the hardest cultivar in the whole library to build and the last of the ten flagships to arrive: lighting one axis is a push, but lighting all eight *in balance* is a constrained optimization, every edit rippling through the entire metabolism, the flux model earning its keep. Guàiwèi is the grandmother's version of the same impossible problem, solved with a spoon and a lifetime's calibration. Both are balance held against the tendency of everything to tip.

Chapter 14 · The cold table — *liáng cài, and the cool edge.*

Sichuan meals open, almost always, with cold dishes — *liáng cài* (凉菜) — and they are not an afterthought but a deliberate tuning of the whole arc of the meal. Cold food reads differently on the axes than hot: the chili's volatile aroma is quieter, the fermented depth more forward, and the **C** axis — the cool, electric edge — comes into its own, because a cold red-oil sauce lets the peppercorn's TRPM8-adjacent brightness and the sauce's own temperature work together. The cold table is where má is at its most crystalline.

Sidebar · Cold changes the coordinate

Temperature is not neutral to flavor; it moves the axes. Chill a dish and the chili's volatile aroma quiets — fewer molecules take flight from a cold surface — the perception of sweetness dips, and the fermented savory depth and the sour notes come forward, which is why a cold red-oil sauce is built differently from a hot one, tuned sweeter and more pungent to compensate for what the cold will mute. The tingle, meanwhile, reads *cleaner* cold, its cool-electric **C**-axis edge no longer competing with the rising warmth of a hot dish. A Sichuan cook laying out the cold table is, in Index terms, recomposing every profile for a palate held at a lower temperature. The meal's opening act is a different set of coordinates from its main course, on purpose.



Smashed, not sliced: tearing the cucumber opens ragged faces that drink the garlic-and-oil dressing far better than a clean knife cut ever could.

Recipe · Pāi huángguā — *smashed cucumber.*

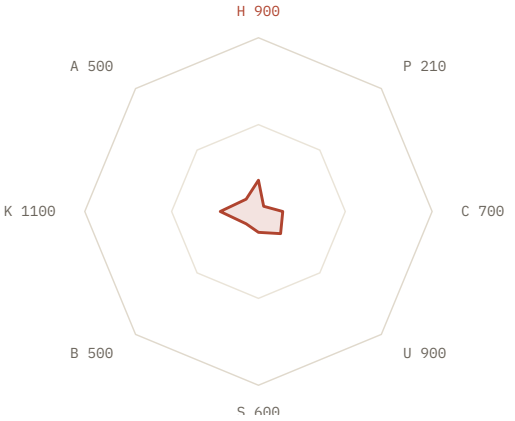
The most-ordered cold dish in Sichuan, and a lesson in how physical structure is a flavor variable: the cucumber is *smashed* with the flat of a cleaver so it fractures into craggy, thirsty pieces.

Cucumbers	2 (about 400 g)
Garlic, grated	3 cloves
Light soy sauce	1 tbsp
Chinkiang vinegar	1 tbsp
Red oil (Ch. 8)	1 tbsp
Sugar	½ tsp
Salt	½ tsp
Toasted sesame oil	½ tsp

TIME · 15 min + 15 min salting

1. Smash the cucumbers with the flat of a knife until they split, then tear into bite pieces.
2. Salt them and leave 15 minutes; drain off the water that beads out — this is what keeps the dish crisp, not watery.
3. Toss with garlic, soy, vinegar, red oil, sugar, and sesame oil just before serving, so the cucumber stays bright and snapping.

IFI PROFILE



IFI-H	900
IFI-P	210
IFI-C	700
IFI-U	900
IFI-S	600
IFI-B	500
IFI-K	1,100
IFI-A	500

Recipe · Kǒushuǐ jī — *mouthwatering chicken.*

Named, without euphemism, for what it does — 口水, "saliva" — this cold chicken under a red-oil guàiwèi-leaning sauce is one of Sichuan's great dishes, and we cook it here with the full respect the bird deserves, not as a lesser version of anything.

Whole chicken legs or a poached half	600 g
— poach with ginger, scallion, wine —	
— The sauce —	
Red oil (Ch. 8), generous	3 tbsp
Light soy sauce	2 tbsp
Chinkiang vinegar	1 tbsp
Sugar	2 tsp
Sesame paste	1 tbsp
Garlic, grated	2 cloves
Ground roasted Sichuan peppercorn	½ tsp
Crushed peanuts + scallion + sesame	to finish

TIME · 45 min + cooling

1. Poach the chicken gently with ginger, scallion, and a splash of wine until just done; cool in the liquid to stay succulent, then chill and chop through the bone, Sichuan-style, or pull.
2. Whisk the sauce smooth, chasing the guàiwèi balance — rich, sweet-sour, numbing, savory.
3. Lay the cold chicken out, flood with the sauce, and finish with peanuts, scallion, and sesame. Serve cold; the fat of the bird and the cool numbing sauce are the entire point.

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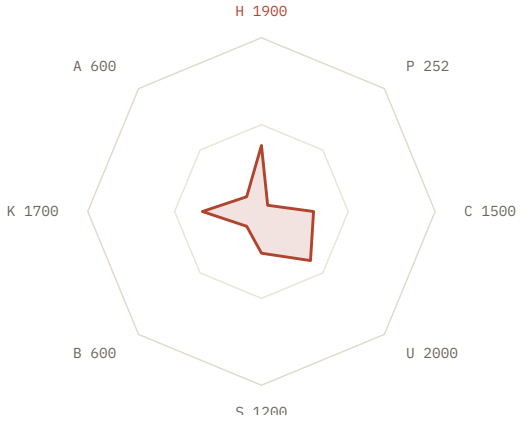

IFI-H	1,900
IFI-P	252
IFI-C	1,500
IFI-U	2,000
IFI-S	1,200
IFI-B	600
IFI-K	1,700
IFI-A	600

Chapter 15 · The home wok — *jiācháng, the everyday fire.*

Restaurants gave Sichuan its legend, but the cuisine lives in the **jiācháng** (家常) register — "home-style," the everyday cooking built on a jar of doubanjiang, a wok, and whatever the market had. Jiācháng flavor leans hard on **U** and **K**, the fermented savory and the kokumi body, with heat as a warm given rather than a headline. It is, quietly, the most *nourishing* corner of the cuisine — vegetable-dense, protein-smart, flavor-complete — and the place where the clean-living ethos that runs under this whole library needs no announcing, because it is simply how people here have always eaten well on little.

Sidebar · The economy of depth

The genius of jiācháng cooking is how much flavor it draws from how little. A spoonful of doubanjiang, a handful of aromatics, a vegetable, and a modest amount of meat used for seasoning rather than bulk — and the result tastes complete, satisfying, worth looking forward to. This is not austerity; it is efficiency of pleasure, and it rests on the fermented base doing the heavy lifting that an extravagance of meat does in other cuisines. We find in it a plain version of something this library argues at length: that flavor built from plants and ferments, designed to its fullest, can carry a meal all the way home. Sichuan's home cooks proved the point generations ago, out of necessity, and made it delicious enough that no one ever had to frame it as sacrifice.



Sweet-potato starch noodles — the slippery "vermicelli" of ants-climbing-a-tree — drink savory sauce and hold the minced aromatics like branches holding ants.

Recipe · Huíguōròu — *twice-cooked pork.*

The emblem of jiācháng, and often called the national dish of Sichuan. Pork belly is first simmered, then sliced and *returned to the wok* (hence "twice-cooked") to crisp in doubanjiang with leek or garlic sprouts. Meat, written with the same care as every vegetable in this book.

Pork belly, in one piece	400 g
Leek or garlic sprouts, angled cut	200 g
Doubanjiang (Pixian)	1½ tbsp
Fermented black beans (douchi)	1 tsp
Sweet wheat paste (tianmianjiang)	1 tsp
Shaoxing wine	1 tbsp
Sugar	½ tsp
Ginger + garlic	to taste
Neutral oil	1 tbsp

TIME · 50 min

1. Simmer the pork belly with ginger and scallion 25 minutes until just cooked; cool, then slice as thin as you can.
2. In a little oil, fry the pork slices until their edges curl and render and the fat turns glassy — this is the second cook, and the texture it builds is the dish.
3. Push the pork aside; fry the doubanjiang and douchi in the rendered fat until red and fragrant. Add the sweet paste, wine, and sugar.
4. Toss in the leek or garlic sprouts and stir-fry just until crisp-tender. The vegetable should keep its snap against the rich pork.

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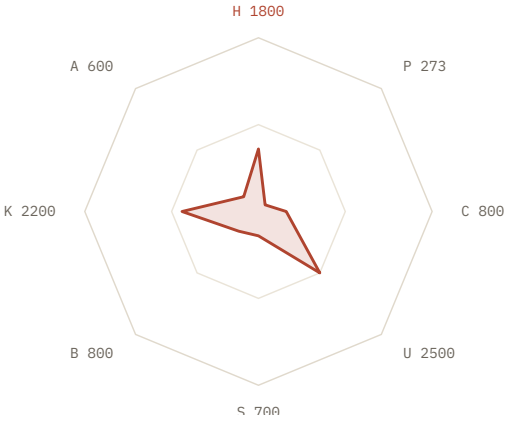

IFI-H	1,800
IFI-P	273
IFI-C	800
IFI-U	2,500
IFI-S	700
IFI-B	800
IFI-K	2,200
IFI-A	600

Recipe · Mǎyǐ shàng shù — *ants climbing a tree.*

One of the great poetic names in all of cooking: slippery sweet-potato noodles ("the branches") studded with minced savory bits ("the ants"). Traditionally pork; here, finely minced mushroom and fermented bean do the same work.

Sweet-potato (or mung bean) starch noodles	150 g
Shiitake or king oyster, finely minced	200 g
Doubanjiang	1 tbsp
Light soy sauce	1 tbsp
Garlic + ginger, minced	2 cloves + 10 g
Scallion	2
Vegetable stock	250 ml
Neutral oil	2 tbsp

TIME · 25 min

1. Soak the noodles in warm water until pliable; drain.
2. Fry the minced mushroom hard until browned and "meaty"; add doubanjiang, garlic, and ginger and fry to fragrance.
3. Add stock and soy, then the noodles; simmer, tossing, until the noodles turn translucent and drink nearly all the liquid, so the "ants" cling to the "branches."
4. Finish with scallion. The dish should be glossy and barely saucy, each strand coated and clinging.

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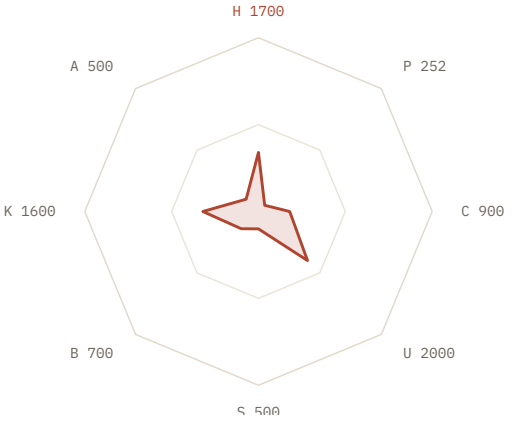


IFI-H	1,700
IFI-P	252
IFI-C	900
IFI-U	2,000
IFI-S	500
IFI-B	700
IFI-K	1,600
IFI-A	500

Chapter 16 · Hot pot — *the communal cauldron.*

No book on Sichuan could close its kitchen without **huǒguō** (火锅) — hot pot — which is less a dish than a social machine for applying málà to everything, together, for hours. A cauldron of fierce red broth simmers at the center of the table; everyone cooks their own morsels in it; and the broth itself is the most concentrated expression of málà in the cuisine, a rolling extraction of chili, peppercorn, doubanjiang, and aromatics in a deep base of fat.



The hot-pot spread is the cuisine laid bare: a field of raw ingredients and one roaring red coordinate to cook them in.

The physics of the pot is worth a moment. The traditional Chongqing base is built on **beef tallow** (or, in vegetarian pots, a generous neutral or plant fat), and the fat is not incidental — it is the solvent. As the pot simmers, the lipophilic capsaicin and capsanthin and the fat-soluble sanshools migrate steadily *into the fat*, so the broth grows hotter and more numbing as the meal goes on, and every piece of food cooked in it is lacquered with the accumulated two fires. The eater's job is to manage the coordinate: a quick dip reads milder, a long simmer reads fierce, and the little dish of sesame oil and garlic at each place is a *cooling counter-sauce*, a way to dial the málà down by a few hundred points on the tongue between bites. Hot pot is málà made adjustable, in real time, by hand — the whole book's argument, turned into an evening.

Sidebar · The pot as a living extraction

A málà pot is a chemistry demonstration that happens to seat eight people. The fat base is a solvent reservoir; over an evening it steadily pulls the lipophilic capsaicin, capsanthin, and sanshools out of the chilies and peppercorns suspended in it, so its coordinate *climbs* as the meal goes on — the last dip genuinely hotter and more numbing than the first. Every diner manages their own exposure in real time: a quick swish reads mild, a long simmer reads fierce, and the little dish of sesame oil and raw garlic at each place is a cooling counter-sauce, a few hundred points of IFI-H lifted off the tongue between bites. Nowhere else does a cuisine hand each eater the live controls of the composition and trust them to tune it. Hot pot is málà

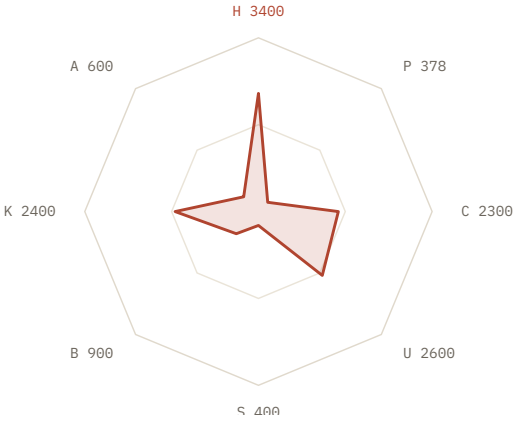
as a participatory instrument — and, not incidentally, as an argument that the best way to eat the two fires is together, slowly, for hours, with people you love.

Recipe · Málà hot pot broth — *the roaring base.*

Neutral oil or plant fat (or beef tallow)	150 ml
Doubanjiang (Pixian)	4 tbsp
Dried chilies, halved	40 g
Sichuan peppercorns (red + green)	3 tbsp
Garlic	1 head, smashed
Ginger	40 g, sliced
Rock sugar	1 tbsp
Fermented black beans	1 tbsp
Whole spices (star anise, cassia, bay, fennel, clove, black cardamom)	a small handful
Vegetable or bone stock	2 L
TIME · 1 hr + a long simmer	

1. Warm the fat and fry the doubanjiang low and slow until the oil runs deep red and the raw edge is gone, 8–10 minutes — patience here sets the whole pot.
2. Add garlic, ginger, whole spices, douchi, and about half the chilies and peppercorns; fry to deep fragrance.
3. Pour in the stock, add the rock sugar, and simmer 30–45 minutes to marry.
4. Just before serving, scatter in the reserved chilies and peppercorns for a fresh top-note of fragrance and tingle, and bring the pot bubbling to the table. Cook everything in it; dip in sesame oil and garlic to taste.

IFI PROFILE



IFI-H	3,400
IFI-P	378
IFI-C	2,300
IFI-U	2,600
IFI-S	400
IFI-B	900
IFI-K	2,400
IFI-A	600



PART IV OF IV

The Frontier

engineering the tingle · nourishment · the chord we have not yet written

Chapter 17 · Engineering the tingle — *what it would take to grow má.*

We return, at the end, to the gap we opened at the beginning: the one fire in this cuisine we can measure but cannot grow. This chapter is written in the conditional, deliberately and without apology, because the discipline of this library is to be exact about the line between what is built and what is imagined. Everything below is *what could be built* — roadmap, not catalogue. There is no engineered **Zanthoxylum** today. There is a problem, well-posed, and a method that has solved problems of its shape before.



The sequencer bench — where a frontier organism's genome would be read before a single edit is designed. The tingle is a build we can scope, not yet a build we have shipped.

Recall the three obstacles from Chapter 6, and take them in turn as an engineer would.

The pathway. Má is an amide (Chapter 3), which means the strategy is known even where the parts are not. To write sanshool into a host we would need to reconstruct its biosynthesis: build the twelve-carbon polyene acyl chain through a tailored set of **fatty-acid desaturases**, build the hydroxylated **isobutylamine** head from valine, and — the missing keystone — identify or design the **amide synthase** that joins them. This is precisely the kind of enzyme-discovery problem the platform's protein language model and flux-balance stack were built for: score candidate acyltransferases by predicted catalytic efficiency and fold stability, let the flux model locate the true rate control, and write the winners in with CRISPR, exactly as we did for the two Pun1 edits in the shipped construct. The amide forge is familiar machinery pointed at an unfamiliar amide.

The target that is not an axis. This is the deeper challenge, and the more interesting one. Má's true receptor is the **KCNK** two-pore channel family — a target the eight-axis Index does not score, because má is a *frequency*, a fifty-hertz paresthesia, not a classical taste. To design má rationally, the platform would need a ninth measurement: an assay anchored not to an EC_{50} of activation but to the *degree of KCNK inhibition*, and a normalization that turns "how hard the leak is blocked" into a number that sits beside H and C and P. We do not have that column yet. Writing it — defining an **IFI-M̄** for the tingle, anchoring it to KCNK3/9/18 inhibition — is, we think, the

single most scientifically valuable thing this cuisine is asking of the Index. Sichuan has handed us a sensation our instrument cannot fully read, and the honest response is to build a better instrument, not to pretend the old one hears it.

The host and the humility. Even granting the pathway and the assay, *Zanthoxylum* itself is a slow woody perennial, a frontier host on the order of our hardest roadmap organisms — years, not seasons, to engineer and grow out. And beyond the biology sits the regulatory frontier: a plant engineered to produce a novel paresthetic compound, or a purified designed sanshool, would enter as a **novel food ingredient** — a GRAS determination or food-additive petition in the United States, a Novel Food authorization in the European Union — with the full safety dossier that status demands. We flag this not as a barrier but as part of an honest scope. Designing the tingle is a real program with a real pathway, a missing axis, a hard host, and a regulatory road. It is a thing that *could* be built. We have not built it, and we will tell you on the day we do — not before.

There is one more honest thing to say about the ninth axis, and it points past this book. If we did define an **IFI tingle-axis** — anchor it to KCNK inhibition, calibrate it against the peppercorn's own fifty-hertz standard — it would not only let us design má. It would let us *read* every food for a sensation the Index is currently deaf to, and we suspect má is not the only one hiding in the gap. The carbonation bite of a sparkling drink; the fatty mouth-coating some researchers argue is a taste in its own right; the metallic, the starchy, the whole quiet orchestra of mouthfeel — the sensory world is almost certainly wider than eight receptors. Sichuan, by handing us one sensation our instrument cannot fully hear, has done us the favor of showing us the edge of the map. Several of the next volumes in this library are, in part, about walking past it.

Chapter 18 · Nourishment and the numb mouth — *why the fire is kind.*

We began at our own table, over a silent chili oil, and we end there too, because the last thing this cuisine has to teach is not about heat at all. It is about why heat, done this way, feels like care.



Where the book began and ends: the family, at the edge of the greenhouse, at the hour when the questions come.

Strip away the legend of the superhots and look at what a Sichuan household actually eats, night after night, and you find something the Scoville number entirely misses: a cuisine that is overwhelmingly **vegetable-forward**, built on tofu and beans and leafy greens and mushrooms, seasoned to completeness by fermented plants, and using meat — when it uses meat — in small, respected measures that flavor a dish rather than dominate it. Mápó dòufu is tofu. Yúxiāng qiézi is eggplant. Ants-climbing-a-tree is noodles and mushroom. The two fires are not an assault laid over this food; they are what make an everyday bowl of beans and greens into something you *look forward to*, something that satisfies deeply enough that you need little else. That is the quiet genius of málà: it is a technology of pleasure that happens to make plants irresistible.

Look harder at the everyday table and the pattern sharpens. The dishes in this book that a Sichuan family actually eats most nights — the tofu, the eggplant, the smashed cucumber, the noodles and greens — are plant-forward by default, dense with legume and vegetable, and seasoned to a completeness that makes them genuinely crave-worthy rather than dutiful. The two fires are the reason a bowl of beans and greens becomes a thing you *want*, not merely a thing you should eat; and the fermented base means the savory depth that other cuisines buy with meat is here grown in the jar. We say this as attribute, never as prescription — we make no promise about what any of it does inside a body. We only observe what a well-built málà dish does to a *meal*: it makes plants the thing you reach for first, which is, quietly, the whole direction this family and this company are pointed.

There is a thread of real biology under this, and we will state it the way the guardrails of this library require — as attribute and observation, never as a claim on your health. Capsaicin's receptor,

TRPV1, is not only on the tongue; the burn is part of a whole-body signal, and cultures built around chili have long paired it with a sense of warmth, appetite, and satisfaction. The peppercorn's tingle slows the meal, makes each bite deliberate, turns eating into attention. We make no promise about what spice does to a body. We only notice what a well-composed málà dish does to a *meal*: it makes it an event, a thing you give yourself with intention, built from plants grown — in the version of this we are reaching toward — to hold the most nourishment they can carry.

That is where the family voice and the eight-axis Index finally meet. We measure flavor because you cannot design what you cannot measure — and we design flavor because we believe that food meant to nourish you should also be food you cannot wait to eat. These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory. Sichuan figured out the second half of that sentence four hundred years before we arrived with the number for the first. A hundred dishes, a hundred flavors; and under every one of them, the same intention — to feed the body right, and to make the fire a kindness.

The oil, that first night, had gone silent because the peppercorns were stale and the pour had been too hot. We know that now, in numbers. But the thing we were really chasing — the hum beneath the heat, the fifty-hertz note that tells you someone built this chord on purpose — that is still, and we hope always, a little ahead of the instrument. It is why we keep cooking. It is why there is a next book.