

THE SCOVILLE SPLICE LIBRARY · VOLUME LII

The Hot Sauce Design Manual

One profile. One plant. One bottle. *Designed on purpose.*

The end-to-end manual for designing an ownable hot sauce — from the eight-axis brief, through the cultivar and the ferment, to the formulation and the consistency that turns a recipe into a brand.

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

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Opening essay · The sauce you can finally design on purpose

There is a moment every founder knows. A bottle comes off the line, the label is straight, the seal is tight, and you turn it in the light and taste it against the one you made last month — and it is *not the same sauce*. The heat has wandered. The front is sharper, or the finish has gone flat, or a batch of chilies came in hotter than the last and now the thing you promised a thousand customers is a thing you cannot promise anymore. For a hundred years that drift was simply the nature of the work. You grew the pepper, you fermented the mash, you tasted and adjusted and hoped, and the plant decided how far it would go.

We built this company because we did not want to hope.

A hot sauce, held up to the light, is a designed object whether or not anyone designed it. It is a profile: a precise arrival of heat on the tongue, a shape to that heat over seconds, a floor of savory depth beneath it, a brightness of acid holding it all upright, a sweetness that may or may not come, a cool or a sharp or a tannin tug at the finish. Every one of those is a molecule meeting a receptor. For the whole history of the craft, the maker could feel each of them exactly and *specify* none of them. You could say "a little hotter." You could not say *how much, and in what shape, to what tolerance.*



The research greenhouse before the day's heat — where a sauce stops being a guess and becomes a brief.

The Iyengar Flavor Index ended that silence, and this book is what the Index means for a bottle. Each of the eight axes of taste is now a single number anchored to the half-maximal activation of a receptor — not how much of a compound a sauce holds, but how *loudly* that compound speaks to the tongue. Heat is TRPV1. Sweetness is TAS1R2·R3. Umami is mGluR1. Kokumi is CaSR. Pungency is TRPA1. Cool is TRPM8. Bitter-attenuation is TAS2R38. Astringency is the salivary proline-rich proteins. Give each one a target, and a sauce becomes something you can write down before you have made it — a brief, not a hope.

And the raw material itself is now a design input. We no longer begin with the pepper the field gave us and build around its limits. We begin with the profile we want, and where the plant cannot reach it,

we design the plant. One pair of hands did the computing; the work and the table belong to our family, and the reverence runs the other way from what you might expect — the more precisely we can specify a chili, the more we find ourselves in awe of it. A pepper is a small machine for turning sunlight and the phenylpropanoid pathway into fire. We have read its blueprint. It made us gentler, not prouder.

This manual is written for the person with a sauce in their head and nothing yet in the bottle: the founder, the formulator, the chef crossing over into CPG, the home maker who has decided to get serious. It walks the whole arc. First the brief — how to specify a sauce on all eight axes before you buy a single chili. Then the cultivar — how to choose one of the ten flagships off the heat ladder, or design a new one at the gene. Then formulation — acid and ferment and fruit and depth and the finish, each a chapter, each with complete reference builds you can make tomorrow. Then the unglamorous half that decides whether you have a hobby or a company: texture, color, stability, scale, consistency to a batch-to-batch coefficient of variation at or under seven percent, and the compliance that keeps a bottle legal and honest.

We will be reverent and we will be exact, and we will try never to let one crowd out the other, because on this subject they are the same thing. The warmth of a good sauce arriving on the tongue and the EC_{50} ratio that predicts it are two halves of one sentence. A sauce grown to carry the most of itself it can — the whole chili, not an extract; living culture, not a shortcut — is both the more beautiful bottle and the more nourishing one, and we will say so without ever once making it a claim. This is how you design the burn.

Let us begin with the brief.



PART I OF V

The Brief

deciding what to build — before you buy a single chili

Chapter 1 · The Sauce as a Designed Object — *from the shelf to the spec.*

Walk the hot-sauce shelf of any good grocer and you are looking at several hundred accidents. Not careless ones — many are the fruit of real devotion — but accidents in the precise sense that no one wrote them down before they existed. Each bottle is the record of a particular person's chilies in a particular season, fermented or cooked a particular way, adjusted by tongue until it tasted right to its maker, and then frozen into a recipe and chased, batch after batch, with raw material that never quite holds still. The shelf is a museum of beloved approximations.

A designed object is different. A designed object begins as a specification — a statement of exactly what it must do, in numbers, to a tolerance — and the making is the act of meeting the spec. A chair is designed to a load rating. A lens is designed to a focal length and an f-number. Until the Index, a sauce could not be designed this way, because the thing it is supposed to do — *taste like this* — could not be written in numbers. You could write the ingredients. You could not write the result.

The move this book asks you to make is to stop designing the ingredients and start designing the result. Not "two parts habanero to one part carrot," which is a cause whose effect you can only discover by tasting, but "heat arriving at IFI-H two-forty, peaking inside three seconds, over a savory floor at umami three hundred and kokumi three-twenty, held by acid to a pH of three-four, with a clean finish and no bitterness" — which is an effect, written down, that the ingredients then have to satisfy. The ingredients become variables you solve for. The sauce becomes the constant you declare.



A designed chili, backlit in the chamber. The spec comes first; the plant is solved for.

This is not a loss of soul. It is the opposite. When you can specify the result, taste is freed to do what taste is actually for — deciding *what the sauce should be* — because the drudgery of hitting the

target over and over, through bad seasons and good, is handed to measurement. The romance of the craft was never in the batch-to-batch anxiety. It was in the vision. The spec protects the vision.

So what, concretely, is the spec? Eight numbers and a shape. The eight numbers are the axes of the Index, each a target value from roughly 40 (a whisper) to 5,000 (the normalization ceiling for a scorecard). The shape is the *temporal* profile — the burn curve of the next chapter — which the eight static numbers cannot capture on their own: two sauces can share an IFI-H and feel like different sauces because one blooms slow and one strikes fast. A complete brief is therefore the radar plus the curve: where the sauce sits, and how it moves.

Here is the whole working vocabulary on one page, read as a sauce-maker reads it — not as receptor biology, but as the eight questions a bottle answers:

AXIS	CODE	RECEPTOR	THE QUESTION IT ANSWERS IN A SAUCE
Heat	IFI-H	TRPV1	How hard does it hit, and does it hurt or warm?
Sweetness	IFI-S	TAS1R2·R3	Is there a rounding sweetness, and sugar-free or not?
Umami	IFI-U	mGluR1	Is there a savory floor the heat stands on?
Zero-Bitter	IFI-B	TAS2R38	How clean, or how deliberately bitter, is it?
Kokumi	IFI-K	CaSR	Does it feel full and continuous, or thin?
Cool-Burn	IFI-C	TRPM8	Is there a menthol-cool or a tingle at the edge?
Pungency	IFI-P	TRPA1	Is there a mustard/ginger sharpness up front?
Astringency	IFI-A	PRPs	Does it tug and dry, like tannin, at the finish?

Every sauce you have ever loved can be written in this grammar, and — this is the point — every sauce you have not yet made can be written in it *first*. A founder who can hand a formulator a radar and a curve has done something no founder could do a decade ago: specified a flavor to a contractor the way an architect specifies a building to a builder. The rest of this book is how to fill in the eight numbers responsibly, and then how to build a bottle that lands on them and keeps landing on them.

One discipline before we go further, and it is the one that separates a company from a kitchen: pick your numbers and *lock them*. The reason the shelf is a museum of approximations is that most makers never committed to a target they could be held to. A spec you will not defend is not a spec. When you write "IFI-H two-forty," you are promising that the next bottle, and the ten-thousandth bottle, will read two-forty within tolerance — and the back half of this manual exists to make that promise keepable. The number is not the hard part. The *holding* is the hard part. But you cannot hold a number you never set.

Chapter 2 · Heat, Measured — *SHU tells you how much; the Index tells you how loud.*

Start with the axis everyone buys the bottle for. Heat is the simplest axis to feel and the most misunderstood to specify, because the number the industry has used for a century measures the wrong thing — or rather, measures a real thing that is not quite the thing you taste.

Capsaicin binds TRPV1, a non-selective cation channel standing in the membranes of the trigeminal nerve endings that wrap the tongue. TRPV1 is a heat and pain sensor; it is the same channel that opens above about 43 °C and in the presence of acid. Capsaicin does not raise the temperature of the tissue by a single degree. It binds a pocket on the channel's inner face and *lowers the channel's thermal threshold*, so that body temperature — which was comfortably below the trip point — is suddenly above it. The nerve fires a temperature that is not there. The brain, which has no way to know the sensor was tricked, reports fire. That is the whole mechanism of heat: a lie told to a thermometer, in a language the brain cannot help but believe.



Where the heat lives: the placental tissue of a designed superhot in cross-section, the pale ribs dense with capsaicinoid glands.

The Scoville Heat Unit measures *how much* capsaicin is present. Wilbur Scoville's 1912 method diluted a pepper extract in sugar water until a panel could no longer detect the burn; the dilution factor was the SHU. The modern method replaces the panel with high-performance liquid chromatography, quantifies the capsaicinoids directly in parts per million, and multiplies by roughly 16 to land back on the Scoville scale — pure capsaicin sits near 16,000,000 SHU. SHU is, in the end, a concentration. It is honest about *amount*. It is silent about *loudness*.

The Iyengar Flavor Index measures loudness. The axis anchors to the half-maximal activation of the receptor:

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IFI-H = 1,000 × EC50(reference) ÷ EC50(candidate)
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EC_{50} is the concentration at which a stimulus drives its receptor to half of full response. A lower EC_{50} means the stimulus reaches the receptor's half-max at a smaller dose — it is *more potent per molecule*, louder per unit present. Invert the candidate's EC_{50} against a fixed wild-type reference, scale by a thousand, and you get a number where the reference reads 1,000 and anything that speaks to TRPV1 more loudly reads higher. Capsaicin's own EC_{50} at TRPV1 sits on the order of a micromolar; the capsaicinoid *profile* a plant produces — the exact mix of capsaicin, dihydrocapsaicin, and the minor analogs — shifts the effective EC_{50} of the whole mixture, which is why two peppers with identical SHU can burn with different loudness.

Why does a sauce-maker need both numbers? Because they do different jobs. SHU is what you put on the label, what you dose against, what the co-packer measures in QC, what the law understands. IFI-H is what the customer *experiences* — the perceived force and character of the burn. You formulate to an IFI-H target and you verify with an SHU assay, the way you design to a focal length and verify with a test chart. A founder who knows only SHU is flying with an altimeter and no airspeed.

Here is the heat ladder of our ten flagship cultivars — the proof-of-concept superhots, *C. chinense*, bred and then engineered — read in both numbers at once:

CULTIVAR	SKU	SHU (PREDICTED)	IFI-H	AXES
Ember	SS-0087	866K	1,570	2/8
Cinder	SS-0088	1.05M	2,290	3/8
Kindle	SS-0089	1.25M	2,000	3/8
Flare	SS-0090	1.48M	—	4/8
Blaze	SS-0091	1.72M	2,630	4/8
Wildfire	SS-0092	1.96M	2,930	5/8
Scorch	SS-0093	2.21M	3,220	5/8
Firestorm	SS-0094	2.47M	3,490	6/8
Solara	SS-0095	2.72M	3,980	6/8
Phoenix	SS-0096	2.95M	4,200	**8/8**

SHU values in this table are computational predictions from our flux and capsaicinoid-profile model; they have not been independently certified or laboratory-measured.

Read the ladder slowly and it teaches you the whole distinction. Nine of the ten rungs climb in lockstep — more predicted SHU, more IFI-H, as our model expects. But look at Kindle. Our model predicts it carries *more* capsaicinoid than Cinder — 1.25 million SHU against 1.05 million — and yet it reads *quieter*: IFI-H 2,000 against 2,290. More designed capsaicinoid mass, less per-molecule loudness. The explanation is the capsaicinoid profile: Kindle is designed to lean

toward the longer, more saturated acyl chains, which raise the predicted SHU but shift the mixture's effective EC_{50} the wrong way for raw force, trading peak loudness for a broader, slower character. SHU counted the molecules and missed the experience. The Index caught it.

That gap is the single most useful thing in this chapter, because it is where design lives. A founder who wants a sauce that *reads* ferocious does not simply chase SHU; they chase the profile that lowers the effective EC_{50} — more capsaicin relative to dihydrocapsaicin, a faster, sharper mixture. A founder who wants a sauce that *endures*, that sits warm and long on a braise, chases the opposite. Same SHU, two different sauces. You cannot specify either one with a Scoville number alone. You specify it with a target on IFI-H and a target on the burn curve — which is the next chapter.

Chapter 3 · The Burn Curve — *onset, peak, and the long goodbye.*

Ask a stranger to describe heat and they will give you a single word — mild, medium, hot — as if heat were a quantity, a volume knob. Ask a sauce-maker and they will draw a shape in the air with one hand: a rise, a crest, a fall. Heat is not a quantity. Heat is an *event in time*, and the two sauces that ruin a brief most often are the two that hit the same peak by two different roads. The amplitude is IFI-H. The shape is the burn curve, and designing it is where a sauce acquires a signature.

The curve has three regions and you design each one. **Onset** is the delay between the sauce reaching the tongue and the first report of heat — anywhere from under a second to a slow ten-second bloom. **Peak** is the crest, how high and how sharp. **Decay** is the long goodbye, the tail over which TRPV1 resets and the fire recedes — seconds for a bright vinegar sauce, minutes for a dense superhot. A sauce is its curve as much as its number. Tabasco strikes and leaves. A good scorpion-pepper sauce arrives late, climbs for half a minute, and lingers for five. Neither is hotter in any meaningful sense; they are different events.

What sets the shape is chemistry you can read and, now, specify. The capsaicinoids are a family, and the two that dominate — capsaicin and dihydrocapsaicin — differ only in the acyl tail welded onto the vanillylamine head. Capsaicin carries an unsaturated chain with a double bond at the 6-position; dihydrocapsaicin carries the saturated version. That one double bond changes how the molecule seats in the TRPV1 pocket and how long it dwells there. The lighter, unsaturated capsaicin tends to a faster onset and a sharper, front-loaded burn; the saturated dihydrocapsaicin runs slower and longer, a heat that builds and stays. The ratio between them — set at the plant's final biosynthetic step — is, in effect, a dial on the burn curve.



Onset and decay are written in the acyl chain. The pale glandular ribs of a designed fruit, where the ratio is set.

That final step is Pun1, the pepper-specific acyltransferase also called capsaicin synthase, and it condenses two streams. One stream is the **vanillylamine** head, which the plant builds down the

phenylpropanoid pathway to vanillin and then aminates with pAMT. The other is the **branched-chain acyl-CoA** tail, assembled by a branched-chain aminotransferase (BCAT) feeding a fatty-acid synthesis loop (the KAS condensing enzyme) that sets the chain length and the position of saturation. Pun1 welds head to tail. Whether the tail arrives as the 6-ene or the saturated chain — whether the fruit makes capsaicin or dihydrocapsaicin — is governed upstream, in the branched-chain supply, which means the burn curve is set *before* Pun1 ever acts. Design the acyl supply and you design the shape of the fire.

For the sauce-maker who is not editing genes, the same dial is reachable through cultivar choice and, to a degree, through formulation. A cultivar bred or engineered toward capsaicin burns faster and sharper; one toward dihydrocapsaicin burns slower and longer. In the bottle, fat and emulsion stretch the curve — capsaicinoids are lipophilic, so an oil phase holds them against the tongue and lengthens both onset and decay, while a lean vinegar sauce delivers them fast and clears them fast. Sugar and starch blunt the peak by coating the receptor field. Acid sharpens onset, because TRPV1 is itself proton-gated and a low pH primes the channel. None of these are folklore anymore; each is a lever with a direction you can predict.

So a complete heat specification is four marks, not one: the IFI-H amplitude, and three times — onset, time-to-peak, and decay. Write them as a little curve beside the radar. "IFI-H 720, onset under one second, peak at three seconds, decay over ninety" is a bright, aggressive wing sauce. "IFI-H 720, onset at four seconds, peak at twenty, decay over four minutes" is a brooding superhot at the identical peak loudness — a different product, a different customer, a different warning on the label. The founders who lose the plot are the ones who specified only the peak and let the curve fall where the chilies happened to drop it. The founders who own a category specified the whole event.

We will return to the curve in every formulation chapter, because every ingredient you add bends it. For now, hold the discipline: a sauce is a shape in time. Draw the shape first.

Chapter 4 · The Eight-Axis Brief — *a sauce is never only hot.*

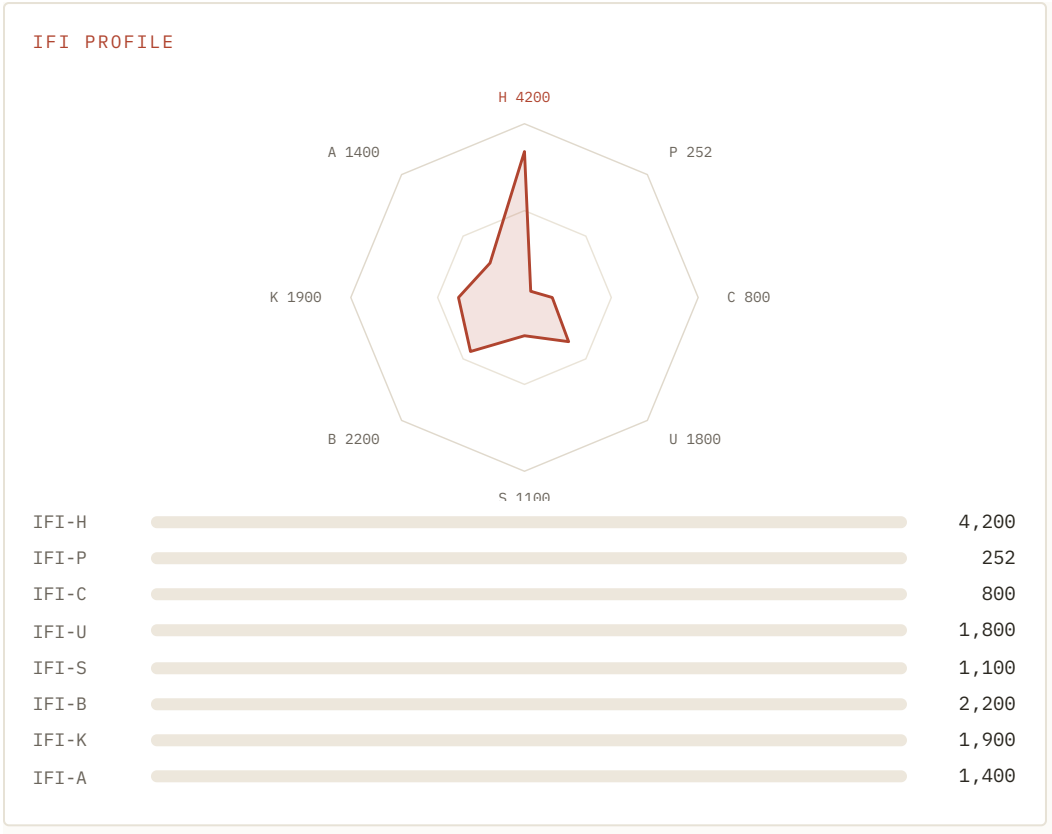
Here is the mistake that sinks more hot-sauce brands than any failure of heat: treating the other seven axes as garnish. A sauce is a composition, and heat is the soloist, but a soloist over silence is a stunt. What makes a sauce something people reach for daily — what makes it *ownable* — is almost always the structure underneath the heat: the savory floor, the brightness, the sweetness that rounds the edge, the finish that invites the next bite. You brief all eight, or you have briefed a dare, not a sauce.

Think of the full brief as a radar with eight spokes, and your job as placing a mark on each. Most will sit low — a classic table sauce is mostly heat and acid with a modest savory floor and little else — and that restraint is itself a design choice, legible on the radar as a lopsided star. The discipline is to decide each spoke on purpose, including the ones you set near zero. A sauce that is "accidentally not sweet" and a sauce that is "designed to carry no sweetness, so it can sit on fruit without fighting it" are the same bottle and completely different briefs. The radar makes you commit.

Our fullest expression of the eight-at-once is the flagship Phoenix, SS-0096 — the first cultivar we engineered to register on all eight axes in a single fruit, with our model predicting approximately 2.95 million SHU and a full-spectrum profile. We do not expect a sauce to be Phoenix; most sauces should be loud on two or three axes and quiet on the rest. But Phoenix's card is the reference star, the one that shows every spoke lit, and it is worth keeping in view as the thing a brief *can* reach:



Phoenix — SS-0096, the first fruit tuned to speak all eight axes at once. The reference star every brief is read against.



Read that card as a formulator, not a chilihead, and it is a lesson in balance at the extreme. The heat is enormous, but it does not stand alone: there is a real umami floor at 1,800 and a kokumi fullness at 1,900 holding it up, a bitterness-attenuation of 2,200 keeping it clean at a potency that would otherwise turn acrid, and designed marks of sweetness, pungency, cool, and astringency rounding the star. That is why Phoenix reads as a *flavor* and not an assault — the seven supporting axes catch the heat. A brief that lights only the H spoke and leaves the rest dark produces a sauce that spikes and collapses. The supporting axes are not garnish. They are the net.

So how do you actually write a brief? Start from the eating occasion and work backward to the spokes. A taco-table sauce lives on fat and salt and masa, so it wants brightness (acid, which does not sit on an axis but governs the whole), a modest heat that refreshes rather than dominates, and just enough umami to feel like it belongs on the plate — low S, low everything exotic. A wing sauce lives on fried protein and beer, so it wants a bigger heat, a real kokumi body to cling and coat, and often a touch of sweetness to pull you back. A finishing sauce for grilled fish — written, like every meat and seafood note in this book, with the same reverence we give a plant — wants restraint everywhere, a cool-green lift at the finish, a clean short decay that flatters the flesh instead of burying it. The occasion writes the radar.

Here is a worked brief, the kind you would hand a formulator, for a sauce we will actually build later in these pages — an everyday table sauce meant to go on nearly anything:

AXIS	TARGET	WHY
Heat (H)	150	warms, never dominates; daily-usable
Pungency (P)	19	a faint allium-ginger lift up front
Cool (C)	40	essentially off; no menthol character
Umami (U)	260	a real savory floor so it reads like food
Sweetness (S)	180	a whisper to round the acid, sugar-light
Zero-Bitter (B)	140	clean, no green or seedy bitterness
Kokumi (K)	320	body and cling; the reason to reach again
Astringency (A)	160	a gentle tug at the finish, not drying

Notice how much of the brief is the quiet spokes. The heat is almost the smallest number on the card. That is correct for this occasion, and the radar's job is to stop you from reflexively pushing H because "it's a hot sauce." The floor — U 260, K 320 — is doing the real work, which is why people will keep the bottle on the table instead of in the back of the fridge with the dares.

Add the burn curve to the radar — for this one, onset under two seconds, a low gentle peak, a short clean decay — and the brief is complete. Eight numbers and a shape, written before a chili is bought. Everything that follows in this book is the craft of hitting them: first by choosing or designing the plant, then by building the liquid, then by holding the whole thing steady, bottle after bottle, to a tolerance you can put your name on.



PART II OF V

The Cultivar

your raw material is now a design input, not a given

Chapter 5 · Choosing Your Pepper — *the ladder, rung by rung.*

With a brief in hand, the first real decision is the plant. For most sauces this is a *choosing* problem, not an engineering one — the pepper you need already exists, and the craft is matching the cultivar to the target. The ten flagships are our extreme tier, bred as *C. chinense* and then tuned at the gene; they are overkill for a daily sauce and exactly right for an enthusiast one, and reading the ladder teaches you to choose at every level below them too.

Our host library runs far wider than the flagships. Across the platform we work approximately 19,500 product SKUs backed by around 225 distinct construct designs across forty-two validated host organisms, a thousand of them live and purchasable today. On the pepper side alone that is 1,060 constructs in *Capsicum*, plus 3,190 more in habanero specifically — the habanero is our workhorse for the hot-but-not-extreme band, the one most fruit-forward sauces are built on. You are not choosing from a produce bin. You are choosing from a catalog of profiles.



The ladder as a living thing — a designed superhot in the greenhouse, every fruit a known quantity.

Match the cultivar to the band your brief calls for. Here is the working map from eating occasion down to plant, with the SHU bands the industry understands:

BAND	SHU RANGE	PLANT CLASS	WHAT IT IS FOR
Warm	40 – 2,500	shishito / poblano-class	everyday pour-on, children's tables, flavor-first
Medium	2,500 – 25,000	Fresno / cayenne / jalapeño-class	the classic table sauce, Louisiana style
Hot	25,000 – 100,000	habanero-class (3,190 constructs)	fruit-heat sauces, wings, salsas with teeth
Extra-hot	100,000 – 500,000	ghost / scorpion-class	enthusiast sauces, dosed condiments
Extreme	500,000 – 3,000,000	flagships SS-0087 → SS-0096	threat-level sauces, measured by the drop

The band sets the plant; the brief's finer spokes then pick the cultivar *within* the band. If your radar wants heat with a built-in savory floor, you reach up the flagship ladder toward the rungs that express more axes — Blaze at four of eight, Firestorm at six. If it wants pure clean fire with nothing underneath, you want a plant expressing on fewer axes, lower on the ladder, and you build the floor yourself in formulation. This is the quiet luxury of a designed library: the plant can carry part of the brief, or none of it, and you choose how much to hand off.

A word on reverence, because it matters at exactly this decision. It is tempting, holding a catalog of superhots, to treat the plant as a reagent — a number to be dialed. We have found the opposite discipline serves the sauce better. Each of these cultivars is a whole living thing that spends its energy making something astonishing, and the maker who respects that — who picks the lowest rung that meets the brief rather than the highest rung available, who lets the fruit's own character show rather than burying it under extract — makes the better bottle nearly every time. The ladder is a tool for restraint as much as for reach. The most common beginner's error is climbing too high: reaching for an extreme-tier plant when the brief wanted medium, and spending the rest of the formulation trying to tame a fire you never needed to light.

Choosing well also means choosing for *consistency*, which is the plant trait that does not show up on a tasting but decides whether you have a business — and it is the subject we will give a whole chapter. For now, the headline: the flagships, and every engineered host, are selected not only for where their heat peaks but for how tightly it holds, batch to batch, which is the thing a wild pepper can never promise. When you choose a designed cultivar you are choosing a profile *and* a tolerance. That second choice is invisible in the bottle and total in the business.

And sometimes — this is the next chapter — the brief asks for a plant that does not exist. A profile no cultivar on the ladder reaches: a specific burn curve, a specific pairing of heat with an axis no pepper naturally carries, a specific tolerance tighter than breeding can hold. When choosing runs out, you design.

Chapter 6 · Designing the Pepper — *when the plant you need does not exist yet.*

Every prior breeding program chased heat the same way: select the phenotype, hope the genotype followed, repeat for generations. It works, slowly, and it cannot hold a line — the variance that makes a wild superhot thrilling is the same variance that makes it useless as a raw material. We inverted the method. We do not select the fruit and hope for the gene. We design the gene and grow the fruit.

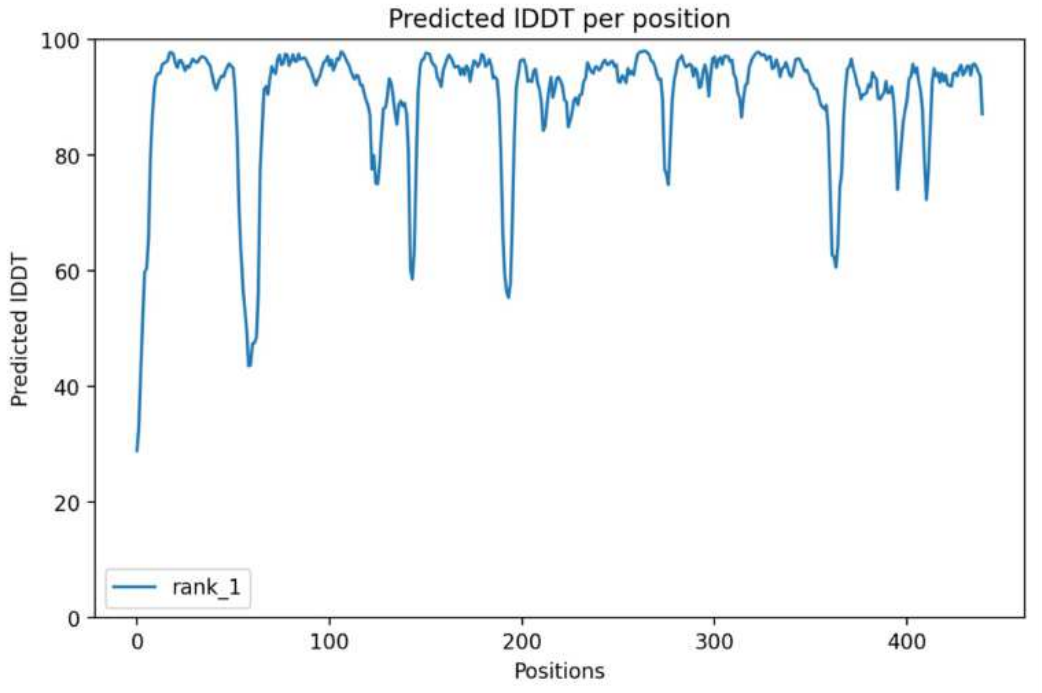
The design target is Pun1, the pepper-specific acyltransferase at the last committed step of capsaicinoid synthesis — the one that condenses the vanillylamine head with the branched-chain acyl tail to make capsaicin. Everything upstream of Pun1 is shared biochemistry; Pun1 and three siblings are what make a pepper a pepper. Our flux model predicts that the rate of capsaicinoid production is controlled upstream, in the phenylpropanoid pathway — primarily at 4CL and HCT/CCoAOMT — not at the terminal Pun1 step. Pun1 labels the product; it does not govern the rate. What we can engineer at Pun1 is *consistency*: a more stable enzyme that misfolds less and converts the available precursor supply into capsaicin more reliably, batch after batch. The whole route, gene to fire, lays out like this:

STEP	ENZYME	FROM	TO
1	PAL	L-phenylalanine	`trans-cinnamic acid`
2	C4H	cinnamic acid	`p-coumaric acid`
3	4CL	p-coumaric acid	`p-coumaroyl-CoA`
4	HCT	p-coumaroyl-CoA	`caffeoyl shikimate`
5	COMT	the caffeoyl branch	`feruloyl / vanillin route`
6	pAMT	vanillin	`vanillylamine (the head)`
7	BCAT + KAS	branched-chain amino acids	`8-methyl branched acyl-CoA (the tail)`
8	**Pun1 / CS**	head + tail	**capsaicin**

Steps 1 through 5 are the phenylpropanoid branch, and they run in every vascular plant on earth — which is the fact that makes this whole company possible, and the subject of the chapter after next. Only the last three steps are pepper-specific. Pun1 is the terminus, the place where the plant's general chemistry becomes the thing that burns.

To design Pun1 we scored it twice over, in silico, before touching a seed. First, an ESM2 protein language model — 650 million parameters, trained on the evolutionary record of proteins — read every possible single-residue substitution in Pun1 and predicted each one's effect on catalytic efficiency multiplied by fold stability. A

language model does for a protein what it does for a sentence: it has seen enough of them to know which changes read as fluent and which read as broken. Second, a genome-scale flux-balance model simulated the plant's whole metabolism; the results predict that flux control sits primarily in the upstream phenylpropanoid steps — particularly 4CL and HCT/CCoAOMT — which together account for the large majority of predicted flux control, with the terminal Pun1 step carrying near-zero independent control in the Monte Carlo ensemble. This is the reason stability engineering at Pun1 matters: improving the enzyme's folding reliability ensures the precursor supply the upstream pathway delivers is efficiently converted into capsaicin rather than lost to inactive enzyme variants. The language model found the stability edits worth making; the flux model provided the metabolic context in which they operate.



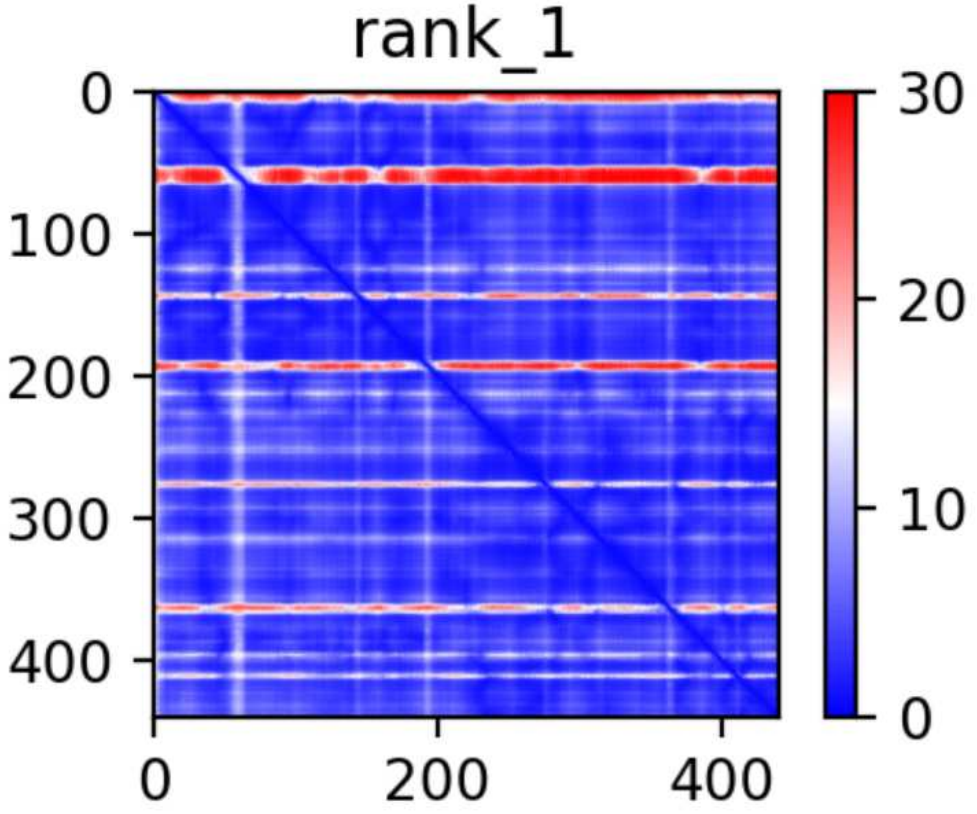
Pun1 / AT3, colored by model confidence (pLDDT). The binding domain and the active-site cleft resolve sharp and high-confidence — the regions we could edit with conviction.

Two substitutions for the shipped construct emerged that no breeding program had ever found, because no breeding program could — they had never once occurred together in any plant that lived long enough to be tasted. Written into the genome with CRISPR, together they are designed to yield a predicted heat of approximately 2.95 million SHU and, more importantly for a sauce-maker, to pull the batch-to-batch coefficient of variation from a wild-type 42% down to seven percent or under:

EDIT	EFFECT	ΔΔG (KCAL/MOL)	NOTE
S39L	binding affinity ↑ at the N-terminal lobe	−2.1	shipped construct
L345G	steric relief in the active-site cleft	−1.8	shipped construct
C175S	prevents a disulfide misfold	−0.9	structural annotation — not in shipped construct

Read the ΔΔG column as the sauce-maker's column, because it is the one that pays the rent. Each value is a change in folding free energy; each is negative, meaning each edit makes the folded enzyme *more* stable than the wild type. A more stable enzyme is a more *consistent* enzyme — it misfolds less, degrades less, and produces the same output fruit after fruit, season after season. The S39L edit tightens the substrate's grip; the L345G edit opens the cleft so the branched-chain tail seats cleanly. A third position, C175S, was identified by our structural modelling as a potential disulfide-misfold site; it is retained as a reference annotation but was not included in the final shipped construct. The two shipped edits together do not merely make a hotter pepper. They make a hotter pepper *that holds still* — and holding still, as the next chapter argues, is the whole game.

The confidence maps matter here too, and not as decoration. We only edited where we could see clearly.



The predicted aligned error map for Pun1 / AT3 — dark where the model is sure of the relative position of two residues. We placed our two shipped edits inside the confident regions.

We do not take gene editing lightly, and we will not pretend the reverence and the rigor are in tension; they are the same posture. To read a plant's blueprint closely enough to change two letters of it is to be confronted, over and over, with how good the plant already is — how elegantly the phenylpropanoid branch hands off to the capsaicinoid route, how little slack there is to improve. The edits we

make are small, specific, and defended by two independent models and a stability number, because the plant has earned that care. A founder does not usually need to design a cultivar; the ladder of Chapter 5 covers most briefs. But when the brief asks for a plant that does not exist — a burn curve no fruit holds, a tolerance no breeding can reach — this is how one is made: not by chance over generations, but by reading the protein, scoring every change, and writing in the two the plant never found.

Chapter 7 · Borrowing Axes From Other Plants — *the sauce-maker's pantry of organisms.*

A sauce is almost never only a pepper. The floor of umami that makes it read like food, the sweetness that rounds the burn, the tannin tug at the finish, the allium pungency up front — these come from other plants, and the same design platform that tuned the pepper has tuned them too. The forty-two-organism library is, to a sauce-maker, a parts bin: a shelf of axes you can borrow, each one a plant engineered to speak its axis loudly and hold it steady. You are not just choosing a chili. You are assembling a profile from a catalog of designed ingredients.

The reason this works — the reason the method that built the pepper transfers to the tomato and the soybean and the grape — is that the hard, shared part of the chemistry is shared. The phenylpropanoid branch of the last chapter runs in every vascular plant; five of our seven platform modules transfer unchanged to any organism with a sequenced genome. Only the terminal enzymes are species-specific. So a tomato engineered for umami and a pepper engineered for heat are, under the hood, the same kind of object: a plant whose terminal step has been read, scored, and tuned to a target with a held tolerance. The pantry is deep because the method is portable.



The savory floor, grown: an engineered tomato, umami restored to a fruit the supply chain had hollowed out.

Here is the sauce-maker's working pantry — the organisms you will reach for most, and the axis each one brings:

ORGANISM	CONSTRUCTS	AXIS IT LENDS A SAUCE	ROLE IN THE BOTTLE
Tomato	2,040	Umami · Sweetness	the savory-sweet floor; body and color
Soybean	360	Umami · Kokumi	deep brothy depth; ferment base
Garlic	560	Kokumi · Pungency	the savory foundation; front-of-palate lift
Onion	40	Kokumi	sweetness-into-savor; roundness
Ginger	120	Pungency	bright sharp top note; TRPA1 snap
Strawberry	roadmap	Sweetness · (Heat)	sweet-heat fruit; the swicy lead
Grape	1,610	Astringency · Zero-Bitter	tannin structure; a wine-like finish
Blueberry	120	Astringency	a soft drying tug; color
Pomegranate	120	Astringency	sharp bright tannin; a sour-tannin finish
Vanilla	40	Kokumi	roundness and continuity; perceived richness
Tea	280	Umami · Zero-Bitter · Astringency	structure without bitterness

Read the table as a set of moves. Your brief wants a savory floor under the heat? Reach for tomato and soybean — mGluR1 umami from free glutamate, CaSR kokumi from the γ-glutamyl peptides a ferment develops. It wants the heat rounded without a sugar spike? Strawberry or an engineered sweetness organism — stevia, monk fruit, sugarcane — to hit TAS1R2·R3 clean. It wants a finish that tugs and dries, a grown-up astringency that makes a sauce taste considered? Grape, blueberry, pomegranate, tea — the salivary proline-rich proteins responding to tannin. It wants a sharp allium snap at the front, distinct from the chili's deep heat? Garlic and ginger, TRPA1 pungency that arrives before TRPV1 does. Each is a plant you can specify to a target and a tolerance, the same as the chili.

The kokumi borrowings deserve a special note, because kokumi is the axis most sauce-makers under-use and the one that most reliably turns a good sauce into one people cannot stop reaching for. Kokumi — richness, continuity, the sense of a flavor being *full* and *long* rather than flat — is mediated by the calcium-sensing receptor, CaSR, responding to γ-glutamyl peptides. You cannot taste kokumi alone; it has almost no flavor of its own. What it does is make every other axis feel more present and more continuous, the way a bass line makes a melody feel grounded. Garlic, onion, vanilla, soybean, and yeast all carry it. A sauce briefed with a real K target — and formulated to hit it, through roasted alliums or a ferment or a borrowed organism — has a fullness that a sauce briefed on heat and acid alone can never fake. It is the invisible axis, and it is where the pantry earns its keep.

One more reason to reach into the pantry rather than the extract bottle, and it is the through-line of this whole library though we will never make it a claim: a sauce built from whole designed plants — a real fermented tomato floor, a real roasted allium kokumi, a real fruit sweetness — carries more of the plant into the bottle than a sauce

propped up with isolated additives. It is the more honest bottle and, we think, the more nourishing one, grown to hold the most of itself it can. We say that as a matter of how we like to build, not as anything printed on a label. The pantry is deep, it is designed, and it is alive. Use it.

Chapter 8 · Consistency Is the Product — *a brand is a promise about the next bottle.*

Here is the chapter that founders skip and then spend two years learning the hard way. Everything so far has been about reaching a target — the right heat, the right floor, the right finish. This chapter is about *holding* it, and holding it is not a detail of the product. For a hot-sauce brand, holding it *is* the product. A customer does not buy your sauce. A customer buys the promise that the next bottle will taste like the last one, and every bottle you ship is you keeping or breaking that promise.

The enemy is variance, and in a sauce built on wild peppers the variance is enormous. A chili's capsaicinoid content swings with the weather, the water, the soil, the stress of the season, the position of the fruit on the plant, the day it was picked. Measured as a coefficient of variation — the standard deviation divided by the mean, the honest single number for "how much does this wander" — a wild superhot runs up to 42%. Sit with that figure. It means a batch labeled for a given heat can arrive nearly half again as hot, or nearly half as mild, with nothing the maker did differently. You cannot build a brand on raw material that moves 42%. You can only build a disappointment that occasionally delights.



Consistency is a thing you measure, not a thing you hope for. A designed fruit under the scope, where 42% becomes seven.

The two Pun1 edits in the shipped construct (Chapter 6) were aimed as much at this number as at peak heat — recall that both carry a negative ΔΔG, meaning a more stable, less misfolding enzyme, which is to say a more consistent one. The result is a batch-to-batch CV at or under seven percent across the engineered line, against the wild-type 42%. Here is what that collapse in variance actually buys, laid out as the two columns a founder cares about:

	WILD SUPERHOT	ENGINEERED LINE
Batch-to-batch CV	~42%	≤7%
A "1,000,000 SHU" batch can arrive between	~580K and ~1.42M	~930K and ~1.07M
Label heat claim	aspirational	defensible
Co-packer QC	reject rate high, yields bleed	tight spec, clean runs
Customer experience	"this bottle's different"	"it's always this"

Walk the CV math once, because it demystifies the whole thing. The coefficient of variation is just the standard deviation expressed as a percentage of the mean. At CV 42% around a million-SHU target, roughly two-thirds of your batches land within 420,000 SHU of the mark — a band so wide that the hot end and the mild end are different products wearing the same label. At CV 7%, that same two-thirds band narrows to 70,000 SHU, tight enough that no customer will ever notice the drift. You have not made the chili hotter in any way they can feel. You have made it *predictable*, and predictability is the thing they are actually paying for, whether or not they could name it.

Consistency is not only a pepper trait; it is a discipline that runs through the whole build, and a designed cultivar is necessary but not sufficient. Your acid has to land on a pH target, not a range. Your ferment has to be pitched and timed and temperature-held so the lactic drop reaches the same endpoint every run. Your fill weights and your blend ratios have to hold. But the cultivar is the foundation, because it is the one source of variance you cannot season or titrate your way out of after the fact. If the raw heat is wandering 42%, no amount of downstream care will hold the finished sauce to a spec. Fix the raw material first, then the formulation can be tuned to hit a number and *stay* there.

This is the deepest reason the design platform matters to a founder, deeper than reaching a heat no pepper reaches. The extreme flagships make the headlines; the tolerance makes the business. A thousand live, purchasable constructs each come with a profile *and* a CV, and the CV is the half of the spec that a tasting will never reveal and a reorder will always punish. When you choose a designed cultivar you are buying reproducibility, and reproducibility is what lets you make a promise and keep it ten thousand times. That is what a brand is. Not a flavor — a flavor anyone can stumble into once. A brand is a flavor you can swear to. Design for the swear.



PART III OF V

Formulation

building the liquid — acid, ferment, fruit, depth, and the finish

Chapter 9 · Acid, pH & the Spine of a Sauce — *vinegar is structure, not just tang.*

Beginners think vinegar is the sour note in a hot sauce. It is that, but to stop there is to miss that acid is the *spine* — the thing that holds the sauce upright, preserves it, sharpens the onset of the heat, and quietly decides whether your bottle is safe on a shelf or a liability. Before you tune a single flavor axis, you set the acid, because the acid is the structure everything else hangs on. Get it right and the sauce stands up for a year. Get it wrong and nothing else you do matters.

Begin with the number that governs legality and safety: pH. A hot sauce is, in regulatory terms, usually an *acidified food* — a low-acid base (peppers, fruit, vegetables) brought below a pH of 4.6 by added acid, the threshold under which *Clostridium botulinum* cannot grow. That 4.6 line is not a flavor target; it is a safety floor, and it is non-negotiable. In practice you design well below it, to a pH of 3.2 to 3.6, both for a margin of safety and because that is where the brightness sings. A sauce that drifts up toward 4.0 is both duller and riskier. The spine holds the sauce up and holds the botulism down, and it does both with the same protons.



Acid is measured, not tasted-for. The bright, held structure of a designed fruit in the dish.

Two numbers describe the acid and you need both. **pH** is the strength of the acid — the active proton concentration, what the microbes feel, what the safety line is drawn in. **Titratable acidity** is the *total* acid available, the quantity your tongue reads as sourness. They move together but they are not the same: a sauce can hit a safe pH with relatively little total acid, or carry a high total acidity at a given pH, and the two feel different in the mouth. You design to a pH for safety and a titratable acidity for taste, and you verify both — a

pH meter for the first, a simple titration for the second. This is the first place a sauce-maker becomes a formulator: you stop tasting for "sour enough" and start measuring.

The acid you choose shapes the flavor as much as the pH. Distilled white vinegar is clean, cheap, and flavor-neutral — the Louisiana spine, the one that lets the pepper and the ferment speak. Apple-cider vinegar brings a fruity roundness. Citric acid, from lime or as the isolated acid, gives a brighter, higher-toned sourness that flatters fruit-heat sauces. Lactic acid — the acid a ferment makes for you, the subject of the next chapter — is softer, rounder, less aggressive than acetic, and it is why a fermented sauce reads mellow even at the same pH as a sharp vinegar one. Many great sauces blend them: a vinegar base for the clean spine, a squeeze of citrus for lift, the lactic softness of a ferment underneath. The acid is not one decision. It is a small composition of its own.

And the acid bends the burn curve, which is why it belongs in a design manual and not just a safety appendix. Recall that TRPV1 is proton-gated — low pH primes the channel, lowers its threshold, makes it readier to fire. So a more acidic sauce delivers a *sharper, faster onset* of heat at the same capsaicinoid load. This is a real design lever: if your brief wants a bright, immediate strike, pull the pH down and let the protons prime the receptor; if it wants a slow brooding bloom, carry the heat in a rounder, higher-pH, fat-forward base. The acid is simultaneously your preservative, your brightness, your safety margin, and a dial on the shape of the fire. Set it first, set it with a meter, and everything downstream gets easier.

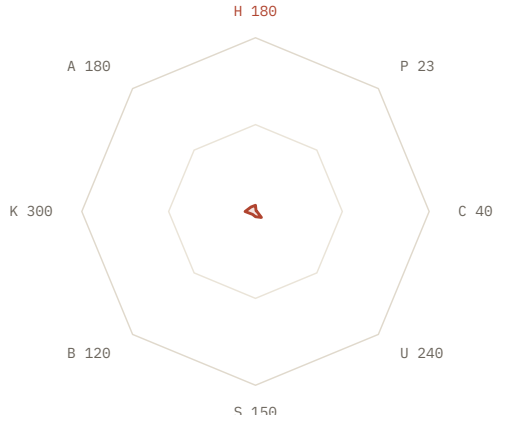
Here is the first complete reference build — the classic vinegar-aged red, the Louisiana spine in its purest form, the sauce every founder should be able to make before anything fancier.

```
HOUSE VINEGAR-AGED RED  ·  the clean Louisiana spine
MAKES ~750 ml  ·  target pH 3.4  ·  CV-friendly, 12-month shelf
──────────────────────────────────────────────────────────────

280 g   red Fresno / cayenne-class chilies, stemmed
 15 g   fine sea salt (≈5% of mash weight)
320 ml  distilled white vinegar (5% acidity)
 60 ml  water
  6 g   garlic, lightly roasted (kokumi lift)
  —     no sugar, no gum; structure only
```

1. Blend chilies, salt, and roasted garlic to a coarse mash. Weigh it; confirm salt is near 5% of mash weight.
2. Pack into a clean jar, cover loosely, and ferment at 20–22 °C for 10–14 days until the bubbling settles and the smell turns bright and sour. (Skip this step for a cooked "fresh" version; you will lose the lactic roundness.)
3. Transfer mash and vinegar and water to a nonreactive pot. Bring to a gentle simmer for 5 minutes — no hard boil, which flattens the aromatics.
4. Blend smooth. Check pH with a meter; it should read 3.3–3.5. If above 3.6, add vinegar in 10 ml steps and re-check. **Do not bottle above 3.6.**
5. Strain for a pourable body, or leave rustic. Hot-fill into sanitized bottles, cap, invert 2 minutes, cool.

IFI PROFILE



IFI-H		180
IFI-P		23
IFI-C		40
IFI-U		240
IFI-S		150
IFI-B		120
IFI-K		300
IFI-A		180

That radar is the whole philosophy of a table sauce: a modest, warming heat at 180, a real kokumi floor at 300 from the salt-ferment and the roasted garlic, acid you read as brightness rather than on any single axis, and everything else kept low on purpose. It is not trying to impress. It is trying to earn a place on the table, which is harder.

Chapter 10 · The Ferment — *time as an ingredient.*

There is an ingredient in the best hot sauces that you cannot buy and cannot rush, and it is time. Fermentation is the one process in this book that adds flavor the maker does not put in — it recruits a living culture to build, over days and weeks, the umami and the kokumi and the rounded lactic acid that a cooked sauce can only approximate. A fermented mash is not a flavored liquid. It is a small ecosystem you have set in motion and then stepped back from, and the depth it develops is the clearest line between a sauce that tastes made and a sauce that tastes *grown*.

The mechanism is lactic-acid fermentation, the same process behind sauerkraut and kimchi and the great chili mashes of the world. You submerge the pepper mash in a brine — 2 to 5% salt by weight — and the salt does two jobs: it selects for the salt-tolerant lactic-acid bacteria (chiefly *Lactobacillus* and its relatives) that live on the pepper skins, and it suppresses the spoilage organisms that cannot take the salinity. The lactobacilli consume the fruit's sugars and excrete lactic acid, and the pH falls — from near-neutral down through 4.6 and on toward 3.4 — and as it falls, the environment becomes one only they can live in. The sauce preserves itself by becoming too sour for anything that would rot it. It is self-securing chemistry, and it has fed people safely for thousands of years.



A living build: the mash mid-ferment, where lactobacilli turn pepper sugar into acid, umami, and depth.

But preservation is the least of it, for a sauce-maker. What the ferment *builds* is the savory architecture. As cells break down over the days, proteins are hydrolyzed and free glutamate accumulates — and free glutamate is the ligand for mGluR1, the umami receptor. The mash grows an umami floor it did not start with. At the same time, γ-glutamyl peptides form, and those are the agonists of CaSR, the kokumi receptor — so the ferment builds body and continuity alongside the savor. This is why a fermented sauce reads deep and

full where a fresh one reads flat and sharp: the fermentation has, in a real molecular sense, grown new flavor onto two of the eight axes. Time did what no bottle of additive quite can.

> A sauce you fermented is a sauce that is partly alive. The depth is not seasoning you added. It is flavor the culture built while you waited.

You can push the savory build further with a designed pantry. Pitch a koji culture — *Aspergillus oryzae*, the mold behind miso and soy sauce — alongside the lactic ferment and its enzymes will hydrolyze proteins and starches faster and further, driving glutamate higher still; koji is one of our umami host organisms for exactly this reason. Fold in an engineered soybean base, tuned for umami and kokumi, and you are stacking three sources of savor: the pepper's own ferment, the koji's enzymatic reach, and the soybean's designed depth. The axes compose. A brief that calls for a big savory floor under the heat is a brief for a ferment, deepened with the pantry.

The discipline of fermenting for a *brand* — as opposed to for a kitchen — is the discipline of hitting the same endpoint every time, which brings us back to consistency. Pitch temperature, salt concentration, time, and final pH are your four controls, and you hold all four. Ferment at a steady 20–22 °C, not on a fluctuating counter. Weigh the salt to the mash, do not eyeball it. End the ferment at a target pH read on a meter, not at a day on the calendar, because the culture moves faster when it is warm and a fixed number is a truer endpoint than a fixed date. A ferment run to a pH target, from a designed cultivar with a held CV, is reproducible. A ferment run by feel is a different sauce every season, no matter how good any one season tastes.

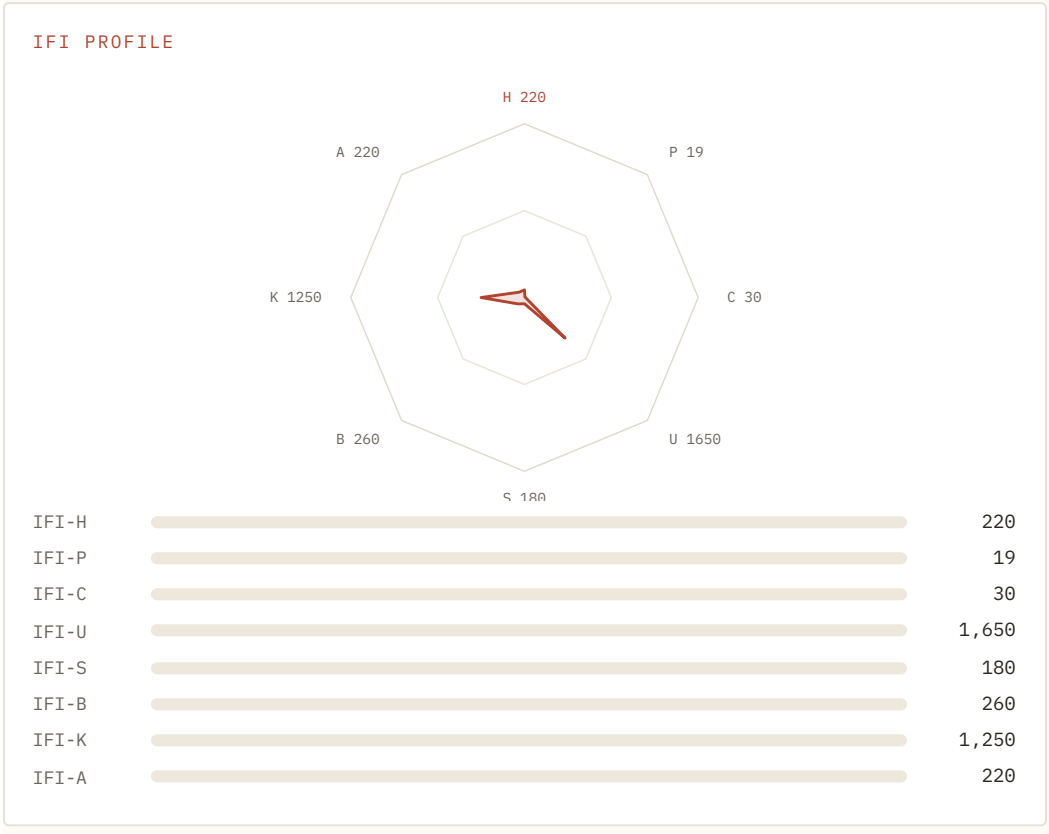
Here is the fermented reference build — the deep, round, savory mash sauce that the vinegar sauce of the last chapter can only hint at.

```
FERMENTED MASH SAUCE  ·  the savory, living build
MAKES ~700 ml  ·  target pH 3.4  ·  4–6 week ferment
──────────────────────────────────────────────────────

300 g   red chilies (habanero-class for fruit; cayenne for clean)
 60 g   engineered soybean / cooked, for the umami floor (optional,
deepens U·K)
 18 g   sea salt (≈4% of total mash weight)
   1    koji pinch, or 1 tbsp unpasteurized live brine as starter
200 ml  spring water, to submerge
120 ml  cider vinegar, added only at the finish to set pH
```

1. Blend chilies and soybean to a coarse mash; weigh; stir in salt to ≈4% of mash weight. Add the koji pinch or live-brine starter.
2. Pack into a jar, press to submerge under the liquid line, weight it, and cover with an airlock or a loose lid burped daily. Ferment at 20–22 °C.
3. Let it run 4–6 weeks. It is ready when the pH reads 3.6 or below and the aroma is deeply sour, bright, and faintly funky — not sharp or solvent-like.
4. Blend smooth. Add cider vinegar in steps to pull the finished pH to 3.3–3.5 and set the spine. Re-check with a meter.

5. Strain to your body. Hot-fill, cap, invert, cool. Age a further two weeks in-bottle if you can; the kokumi rounds further.



Look at what the ferment did to the radar against the vinegar sauce: umami climbed from 240 to 1,650 and kokumi from 300 to 1,250, while the heat barely moved. That is the signature of a fermented sauce — not hotter, *deeper*. The fire now stands on a floor. This is the build to reach for when a brief wants a sauce that eats like food rather than like a condiment, and it is, not incidentally, the most nourishing way to build one: a whole-plant mash, a live culture, nothing isolated or propped. Time as an ingredient, and the body to show for it.

Chapter 11 · Sweet Heat — *the swicy axis, done with intent.*

The most important flavor trend of the last decade has a clumsy name and a clean mechanism: swicy, sweet-heat, the deliberate pairing of IFI-H with IFI-S. Hot honey on pizza, chili-chocolate, the Asian sweet-heat sauces that conquered the wing — all of it is the discovery, made independently in a hundred kitchens, that sweetness does not merely accompany heat but *transforms* it. A designed sauce-maker does not stumble onto that discovery. They specify it, because now they can.

The mechanism is a conversation between two receptor systems. Heat is TRPV1; sweetness is the TAS1R2·R3 heterodimer. They do not share a receptor, but they share a *perception* — the brain integrates them, and sweetness blunts the pain signal from the heat while the heat sharpens the pleasure of the sweet. The result is a heat that reads as *rounded* rather than aggressive, a burn you want to return to, and a sweetness that reads as lively rather than cloying because the heat keeps it from going flat. Swicy is not two flavors side by side. It is a single integrated sensation that neither axis makes alone.



The swicy lead, grown sweet to the fruit: an engineered strawberry, sweetness tuned to meet the fire.

The design decision that separates a thoughtful swicy sauce from a sugary one is *where the sweetness comes from and how fast it arrives*. Cane sugar is the blunt instrument — it works, but it spikes early, coats the receptor field, and blunts the peak of the burn along with the pain. A designed sweetness organism — stevia, monk fruit, an engineered sugarcane — hits TAS1R2·R3 clean and sugar-light, rounding the heat without the caloric load or the flattening coat, which is why a sauce built on designed sweetness can read sweeter *and* hotter at once. And a fruit sweetness — strawberry, mango, pineapple — brings its own acid and aromatics along with the sugar,

so the sweetness arrives as a whole flavor rather than a single note. Our roadmap's Sweet-Heat strawberry line — Warm Kiss, Sugar Burn, Candied Fang, Devil's Dessert — is the frontier expression of this: a single fruit designed to carry both axes at once, the heat grown *into* the sweetness rather than blended against it.

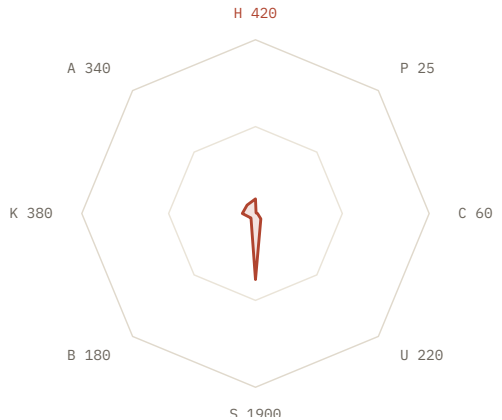
Timing is everything in swicy, and it comes back to the burn curve. If the sweetness arrives before the heat and clears before the peak, you get a candied front that gives way to a clean burn — the "sweet then heat" profile, dessert-forward. If the sweetness lingers through the decay, you get a long rounded tail, a burn that fades into sweetness rather than into nothing — the "heat then sweet" profile, more savory, better on food. You design which one by choosing fast sugars against slow, and by where in the formulation you place them: a sweetness carried in the water phase arrives fast; one carried in a fruit purée or a honey arrives rounder and stays. The radar sets the amplitudes; the curve sets the order. Both are yours to specify.

Two reference builds, because sweet-heat deserves both a sauce and a syrup. First, a fruit-forward sweet-heat sauce built on strawberry and scotch-bonnet-class heat:

```
SWEET-HEAT STRAWBERRY-SCOTCH  ·  the swicy sauce
MAKES ~700 ml  ·  target pH 3.3  ·  bright, rounded, fruit-led
──────────────────────────────────────────────────────────────
240 g   strawberry (engineered sweet-heat line, or ripe fruit + chili)
120 g   scotch-bonnet / habanero-class chilies, stemmed
 80 ml  cider vinegar
 40 ml  lime juice (citric lift, fast sweetness partner)
 20 g   designed sweetener (monk-fruit / stevia) to round without spiking
  8 g   sea salt
  4 g   ginger, grated (a pungent top note; optional)
```

1. Char the chilies lightly for depth; combine with strawberry, vinegar, lime, salt, and ginger.
2. Warm gently to just below a simmer, 4 minutes, to meld — do not boil off the strawberry's fresh aromatics.
3. Blend smooth. Add the designed sweetener in steps, tasting for a rounded, not sugary, lift. Check pH to 3.2–3.4.
4. Hot-fill, cap, invert, cool.

IFI PROFILE



IFI-H	420
IFI-P	25
IFI-C	60
IFI-U	220
IFI-S	1,900
IFI-B	180
IFI-K	380
IFI-A	340

Then the syrup that owns the trend — a hot honey, where the sweetness is the base and the heat is infused into it:

```
INFUSED HOT HONEY  ·  the swicy syrup
MAKES ~350 ml  ·  shelf-stable (low water activity)  ·  drizzle, don't pour
_____________________________________________________________

300 g   honey (or an engineered designed-sweetness syrup for vegan/sugar-light)
 10 g   dried chili, hot-class (chile de árbol / habanero flake)
 15 ml  cider vinegar (brightness + a touch of safety margin)
  1 g   salt
  —     optional: 1 strip lemon peel, for lift
```

1. Warm honey gently to 60–65 °C — never hot enough to scorch or to spoil its character.
2. Add chili, vinegar, salt, and peel. Hold at 60 °C for 20 minutes to infuse; do not boil.
3. Taste for heat; strain the solids if you want a clear pour, or leave the flake for rustic drama.
4. Bottle warm. Honey's low water activity keeps it stable; the vinegar sharpens the finish and adds margin.

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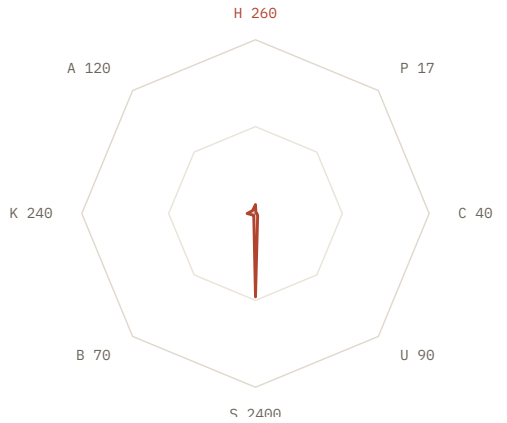

IFI-H	260
IFI-P	17
IFI-C	40
IFI-U	90
IFI-S	2,400
IFI-B	70
IFI-K	240
IFI-A	120

Two sweet-heat builds, two different shapes of the same idea. The strawberry sauce is a whole flavor — fruit, acid, a rounded heat — meant to go on a plate. The hot honey is a pure two-axis statement, S and H and almost nothing else, meant to drizzle. Both specify the sweetness on purpose, from a source chosen for how it arrives, and both round the fire rather than fighting it. That intention is the difference between swicy as a design and swicy as a sugar dump.

Chapter 12 · Depth — Umami & Kokumi — *the savory floor under the fire.*

If heat is what sells the first bottle, depth is what sells the tenth. The sauces that become staples — the ones that live on the counter and go on everything — almost all share a quality that customers cannot name and formulators can: a savory fullness underneath the heat, a floor the fire stands on, a reason the sauce reads like *food* rather than like a stunt. That floor is two axes working together: umami and kokumi, mGluR1 and CaSR. Build them, and a sauce acquires gravity. Neglect them, and even a brilliant heat feels thin.

Umami is the taste of free glutamate — the savory, brothy, mouth-filling quality of tomato, aged cheese, mushroom, soy, seaweed, cured things. The receptor is mGluR1 (with a supporting role from the TAS1R1·R3 pair), and it reports the presence of the glutamate that signals, in nature, protein and nourishment. A sauce with real umami tastes substantial; one without it tastes like flavored acid. And umami has a famous trick: it is *synergistic*. Free glutamate on its own is savory, but add a 5′-ribonucleotide — inosinate from a dried mushroom or a bit of cure, guanylate from a tomato or a ferment — and the perceived umami multiplies far beyond the sum. The receptor's response to glutamate is potentiated several-fold in the presence of the nucleotide. This is not seasoning folklore; it is a measured allosteric effect, and it is the single most powerful move in savory formulation. A little nucleotide makes a little glutamate taste like a lot.



The floor under the fire: an engineered soybean, umami and kokumi grown deep for the savory base.

Kokumi is the stranger axis and the more valuable one, because almost no one formulates for it deliberately. Kokumi has no taste of its own — you cannot sip a kokumi solution and name a flavor. What it does is make every *other* flavor feel fuller, more continuous, and longer-lasting. The receptor is CaSR, the calcium-sensing receptor, and its ligands are the γ-glutamyl peptides — glutathione and its

relatives, built by ferments, by aging, by alliums, by yeast. Kokumi is the difference between a flavor that arrives and departs and a flavor that *sustains*, that fills the mouth and holds through the swallow. It is the bass line, the thing you feel more than hear. A sauce briefed with a real K target and formulated to hit it has a mouthfeel that a flat sauce cannot fake at any heat.

Where do you get them in a sauce? Umami from tomato — our most-engineered host at 2,040 constructs, and the classic sauce-maker's umami base — from soybean, from a ferment, from koji, from mushroom and shiitake. The nucleotide synergy from pairing any of those with a second source: a tomato floor plus a mushroom note, a soybean base plus a ferment's own developed nucleotides. Kokumi from roasted garlic and onion, from yeast, from vanilla's quiet roundness, from the γ-glutamyl peptides a long ferment builds. The move, nearly always, is to *stack* — two umami sources for the synergy, an allium or a ferment for the kokumi — so the floor is both high and wide. This is where the pantry of Chapter 7 and the ferment of Chapter 10 come together into a single deep base.

Here is the depth-forward reference build — a smoky, savory sauce where the floor is the point and the heat rides on top.

```
SMOKED UMAMI-FORWARD SAUCE  ·  the savory floor, built high
MAKES ~750 ml  ·  target pH 3.4  ·  deep, round, food-first
──────────────────────────────────────────────────────────
200 g   engineered tomato, roasted (umami base, source 1)
 80 g   rehydrated dried mushroom + soaking liquor (nucleotide synergy,
source 2)
120 g   chilies, hot-class, half of them smoked/charred
 40 g   roasted garlic + 30 g roasted onion (kokumi)
 90 ml  cider vinegar
 12 g   sea salt
  —     optional: 1 tsp koji or a spoon of miso, for a deeper U·K stack
```

1. Roast tomato, garlic, and onion until soft and caramelized; char or smoke half the chilies.
2. Rehydrate the mushroom; keep the dark soaking liquor — it carries the nucleotides that power the synergy.
3. Combine everything (including the mushroom liquor and optional koji/miso); warm to a gentle simmer for 8 minutes.
4. Blend smooth and glossy. Adjust vinegar to a pH of 3.3–3.5.
5. Hot-fill, cap, invert, cool. This one rewards a two-week in-bottle rest; the kokumi deepens.

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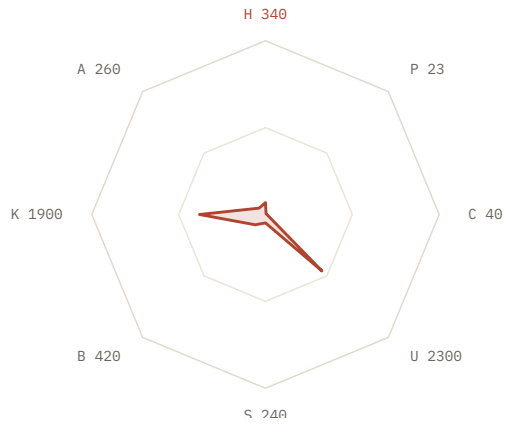

IFI-H		340
IFI-P		23
IFI-C		40
IFI-U		2,300
IFI-S		240
IFI-B		420
IFI-K		1,900
IFI-A		260

That is a radar built from the floor up: umami at 2,300 from the tomato-plus-mushroom synergy, kokumi at 1,900 from the roasted alliums and the optional koji, a real but secondary heat at 340 riding on top, and the bitterness kept attenuated so the depth reads clean rather than acrid. It is a sauce that eats like a reduction, like something simmered for hours, and it is the clearest demonstration in the book that heat is only ever as good as the thing it stands on. Build the floor. The fire takes care of itself.

Chapter 13 · The Finish — Cool, Pungent, Astringent Accents — *what the sauce does after you swallow.*

A sauce is judged twice: once when it lands, and once after you swallow, in the half-second the mouth spends deciding whether it wants more. That second judgment is the finish, and it is governed by the three axes we have not yet built a sauce around — cool, pungent, astringent — because these are the accent axes, the ones that rarely lead a sauce but constantly decide its character. A great finish is why one sauce makes you reach for the next bite and another, equally hot, sits unfinished. The finish is designed, like everything else, and these three axes are the tools.

Pungency is the sharp, volatile, front-and-finish sting of mustard, wasabi, horseradish, ginger, raw garlic, cinnamon — a different sensation from chili heat and a different receptor. Where capsaicin works on TRPV1, these work on TRPA1, the channel next door, which responds to the pungent isothiocyanates and the allyl compounds. TRPA1 pungency arrives *faster* than TRPV1 heat and clears faster — it is the snap at the top and the sharpness at the very end, the ginger bite, the wasabi rush to the nose. A touch of designed ginger or mustard or garlic gives a sauce a bright, lifted edge that pure chili heat cannot, and it reads as *liveliness*. Our black-mustard host, at 2,790 constructs, is the deep well for this axis; a little goes a long way.



The finish, grown sharp: engineered ginger, TRPA1 pungency for the snap at the top and the lift at the end.

Cool-burn is thermomodulation — the menthol cool of mint, the camphor lift of eucalyptus, and, at its most interesting, the *tingle*. The receptor is TRPM8, the cold sensor, the mirror of TRPV1: where capsaicin tells the tongue a false heat, menthol tells it a false cold, lowering the channel's warm threshold so body temperature reads as coolness. In a hot sauce, a measured cool is a stunning finish — it does not cancel the heat but *reframes* it, a coolness that arrives as the fire recedes, cleaning the palate for the next bite. And where cool meets pungency you reach the most sophisticated finish in all

of chili cookery: the *málà* tingle of Sichuan pepper, a buzzing numbness that is neither heat nor cold but a vibration, a near-anesthetic shimmer that sits on top of the burn. That tingle is a composition — TRPM8 and TRPA1 together — and it is the finish that defines a whole cuisine.

Astringency is the tannin tug — the drying, puckering, slightly rough sensation of strong tea, red wine, pomegranate, unripe fruit. It is not a taste at all; it is a *tactile* event, the salivary proline-rich proteins binding tannins and precipitating out, so the mouth loses its slick for a moment and reads as dry. In a sauce, a measured astringency gives structure and a grown-up, considered finish — it makes a sauce taste like it was built by someone who thought about the end, not just the start. Grape, blueberry, pomegranate, tea: the astringency pantry. Used lightly, it is the difference between a finish that fades to nothing and one that resolves, like the dry finish of a good wine.

Two reference builds for the finish, because the accent axes are best shown against each other. First a bright herbaceous verde, where cool-green and pungency lead and the heat is a supporting player:

```
BRIGHT VERDE  ·  the cool-green finish
MAKES ~700 ml  ·  target pH 3.4  ·  fresh, lifted, herbaceous
──────────────────────────────────────────────────────────
220 g   green chilies (jalapeño / serrano-class), half charred
 60 g   tomatillo, for a tart green body
 40 g   fresh herbs (cilantro + a little mint for the TRPM8 lift)
 20 g   ginger + 10 g raw garlic (TRPA1 pungency up front)
 90 ml  lime juice + 30 ml cider vinegar (bright, fast acid)
 10 g   sea salt
```

1. Char half the green chilies and the tomatillo for depth; keep the rest raw for brightness.
2. Combine everything raw and cooked; blend smooth and vivid green.
3. Keep it bright — a short warm, not a cook. Adjust acid to pH 3.3–3.5.
4. Fill. This one is best fresh and refrigerated; its lifted top notes fade with long shelf storage.

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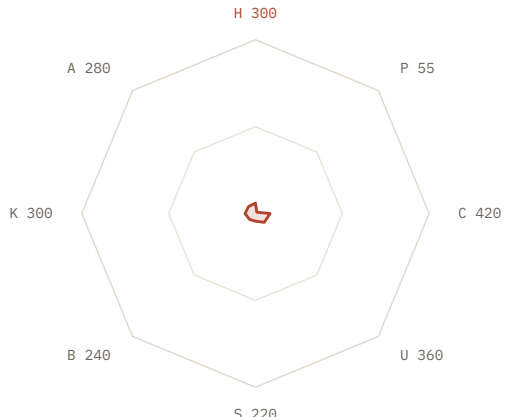

IFI-H	300
IFI-P	55
IFI-C	420
IFI-U	360
IFI-S	220
IFI-B	240
IFI-K	300
IFI-A	280

Then the málà chili crisp, the numbing-heat intersection, the finish that defines a cuisine — an oil-based build where cool-tingle and pungency sit on top of the burn:

```
MÁLÀ CHILI CRISP  ·  the numbing-heat finish (H × C × P)
MAKES ~400 ml  ·  oil-based, shelf-stable  ·  spoon it, crunch it
──────────────────────────────────────────────────────────────
250 ml  neutral oil (holds capsaicinoids; stretches the burn curve)
 40 g   dried chili flake, hot-class, mixed coarse + fine
 15 g   Sichuan pepper (the TRPM8 tingle; the "má")
 30 g   fried garlic + 20 g fried shallot (kokumi, crunch)
 10 g   ginger, minced and fried (TRPA1 snap)
  8 g   salt + 6 g sugar + 1 tbsp fermented soybean, for the floor
  —     optional: star anise + cinnamon, warming aromatics
```

1. Fry garlic, shallot, and ginger in a little of the oil until gold and crisp; reserve the solids.
2. Heat the remaining oil to ~130 °C. Combine chili flake, Sichuan pepper, salt, sugar, and fermented soybean in a heatproof bowl.
3. Pour the hot oil over the aromatics — it will bloom and foam. Stir; let the Sichuan pepper's tingle compounds infuse as it cools.
4. Fold the fried solids back in. Jar in oil; the oil phase keeps it stable and carries the heat long.

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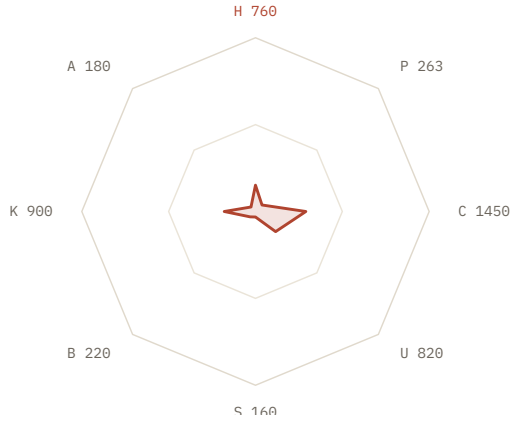
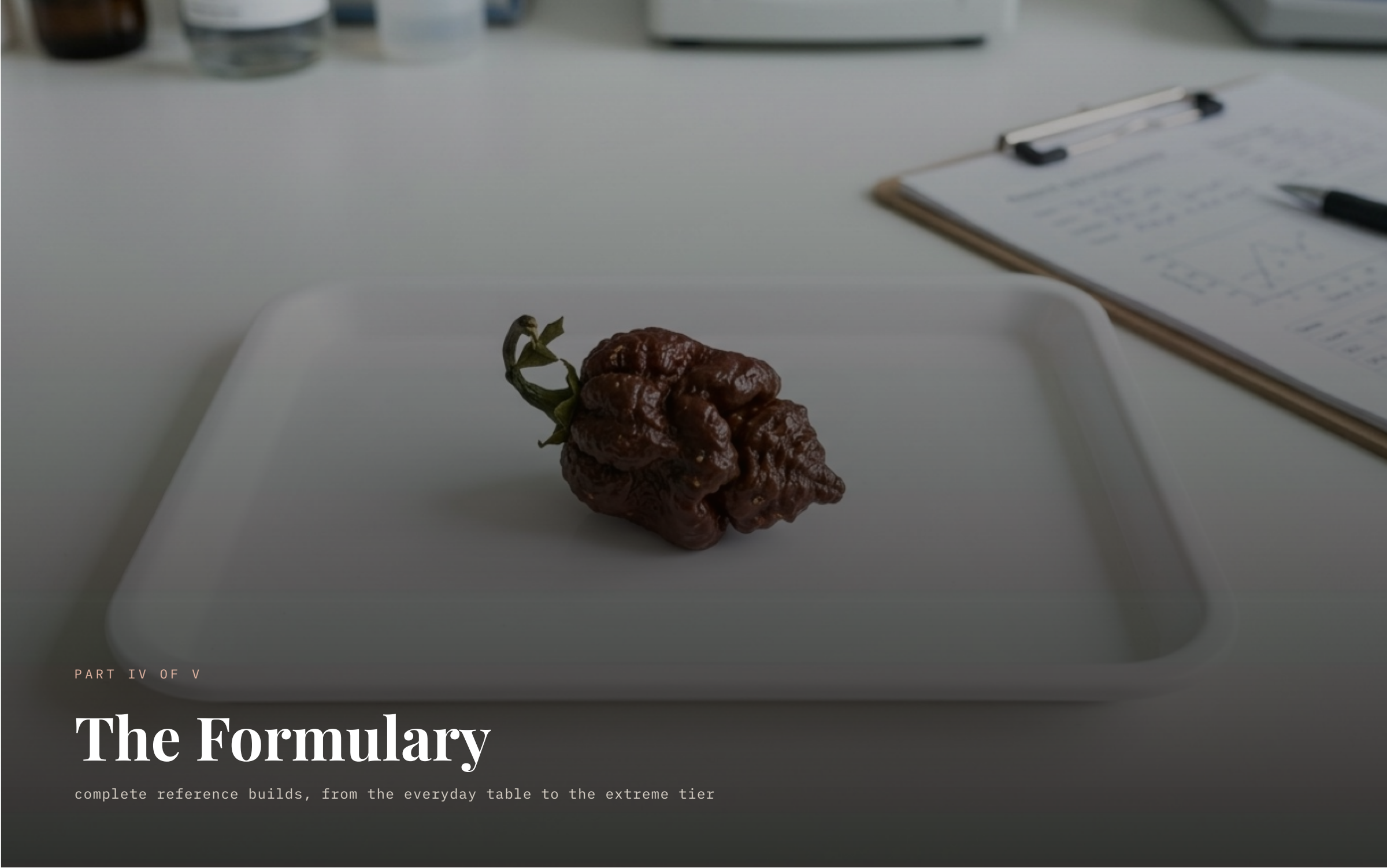


IFI-H		760
IFI-P		263
IFI-C		1,450
IFI-U		820
IFI-S		160
IFI-B		220
IFI-K		900
IFI-A		180

Look at that last radar and you see a sauce designed almost entirely on the finish. The heat is real at 760, and the loudest spokes are cool at 1,450 (the TRPM8 tingle) and pungency at 263 (the TRPA1 snap) — with a kokumi floor at 900 under them. That is the málà signature written in the Index: not the hottest sauce in this book, but the one with the most *happening at the finish*. It is the proof that the accent axes, the three we build sauces around least often, are where a sauce acquires the character people remember. Design the finish. It is the last thing the mouth tastes and the first thing it asks to taste again.



PART IV OF V

The Formulary

complete reference builds, from the everyday table to the extreme tier

Chapter 14 · The Table Sauces — *everyday to medium, the ones people actually finish.*

Everything to this point has been method — the brief, the plant, the acid, the ferment, the axes. This Part is a formulary: complete builds you can take to a kitchen or a co-packer, organized by where they sit on the heat ladder. And it begins where the money is, which is not the extreme tier. It is the everyday sauce — the warm-to-medium bottle that lives on the table and goes on everything, the sauce a household buys again and again. The extreme sauces make the reputation. The table sauces make the business. Design them with the most care, not the least.

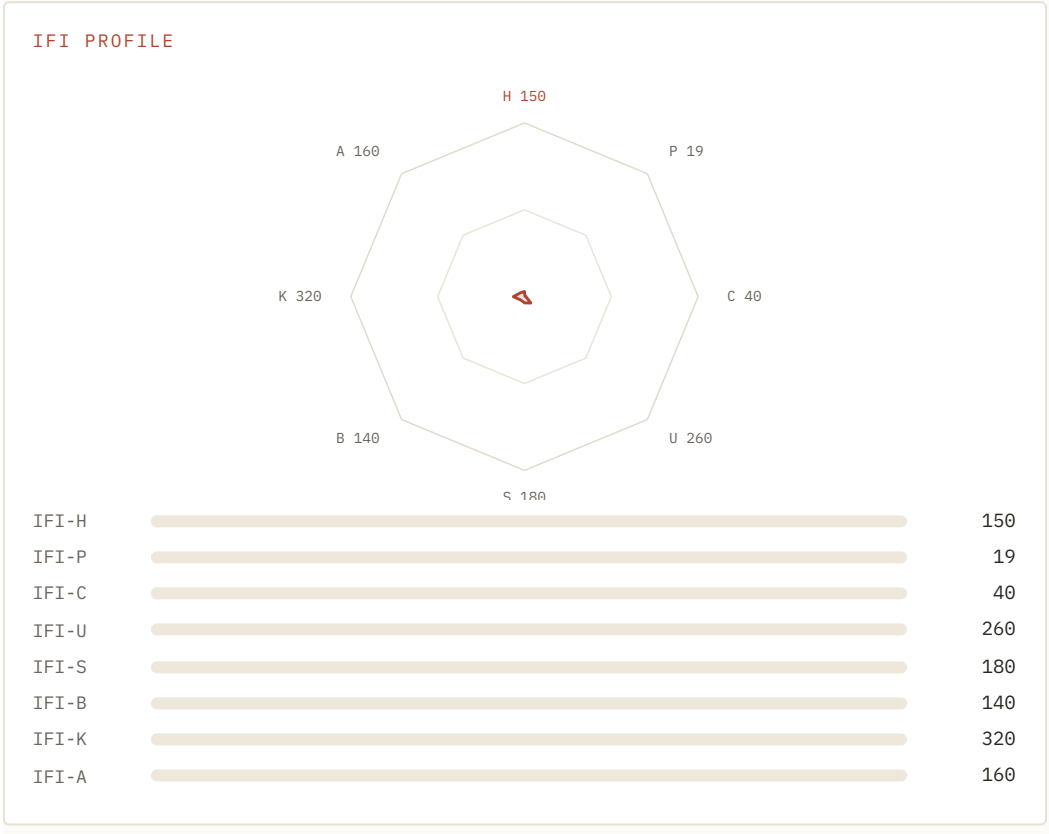
The design challenge of a table sauce is counterintuitive: the heat is the easy part, and restraint is the hard part. A daily sauce has to be interesting enough to reach for and mild enough to pour without thinking, which means the brief leans away from H and toward the floor — the umami and kokumi that make it read like food — and toward the brightness that keeps it lively. Our everyday-sauce brief from Chapter 4 was exactly this shape: heat at 150, a kokumi floor at 320, a real umami at 260, everything else a whisper. Here is that brief, built.



The sauce that earns the table: a designed fruit at the warm, daily end of the ladder.

```
EVERYDAY TABLE SAUCE  ·  warm band (~5,000 SHU)
MAKES ~800 ml  ·  target pH 3.4  ·  the daily pour-on
──────────────────────────────────────────────────────
220 g   warm-band chilies (Fresno / mild cayenne-class)
 80 g   engineered tomato, for the umami floor
 40 g   roasted garlic + onion (kokumi)
280 ml  distilled white vinegar
 60 ml  water
 12 g   sea salt
  8 g   designed sweetener, a whisper to round the acid
```

1. Lightly ferment the chili-garlic-onion mash 7–10 days for lactic roundness (optional but recommended).
2. Roast the tomato; combine all; simmer gently 6 minutes.
3. Blend very smooth — a table sauce wants a clean, pourable body. Strain if needed.
4. Set the pH to 3.3–3.5 with the vinegar. Add the sweetener last, by taste, just to round.
5. Hot-fill, cap, invert, cool.



That radar lands the brief almost exactly, and the thing to notice is how *low and balanced* it is. Nothing shouts. The heat is the smallest working number on the card, the floor carries the sauce, and the result is a bottle you can put on eggs and rice and tacos and not think about — which is the whole point. People do not finish bottles that demand to be noticed. They finish the ones that quietly make everything better.

Step up one band to medium — the classic hot-sauce heat, the 15,000-to-25,000-SHU range where most of the category actually lives — and the design shifts. You can let the heat come forward, lean on fruit for interest, and build a sauce with more personality because it is no longer trying to be invisible. Here is a medium fruit-heat sauce, the habanero-and-mango archetype, built on our habanero host.

```
HABANERO-MANGO FRUIT-HEAT  ·  hot band (~40,000 SHU)
MAKES ~750 ml  ·  target pH 3.3  ·  the personality bottle
──────────────────────────────────────────────────────────
140 g   habanero-class chilies (engineered, 3,190-construct host)
200 g   ripe mango, for sweetness + body + aromatics
 40 g   carrot, cooked, for a rounded sweet body (the classic trick)
 90 ml  cider vinegar + 40 ml lime
 10 g   sea salt
  6 g   designed sweetener, to extend the fruit without sugar-spiking
```

1. Char the habaneros lightly for depth; cook the carrot soft.
2. Combine with mango, vinegar, lime, and salt; warm 5 minutes to meld.

3. Blend silky. The mango and carrot give a lush body with no gum needed.
4. pH to 3.2–3.4; round with the sweetener to taste.
5. Hot-fill, cap, invert, cool.

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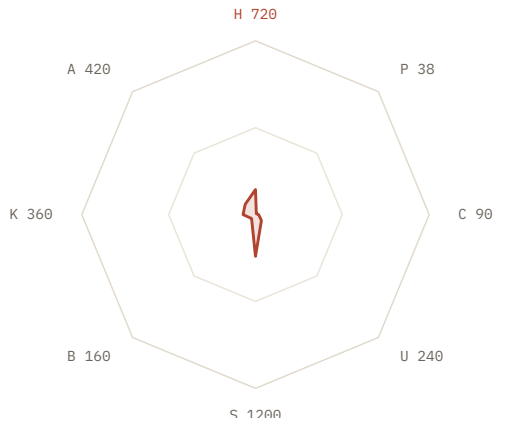


IFI-H	720
IFI-P	38
IFI-C	90
IFI-U	240
IFI-S	1,200
IFI-B	160
IFI-K	360
IFI-A	420

Now the heat leads — 720, a real presence — but it is caught by a big fruit sweetness at 1,200 and a surprising astringency at 420 from the mango and lime, which gives the finish a bright tannic lift that keeps the sweetness from cloying. This is swicy in its everyday form, the sauce that converts people who think they do not like heat, because the fruit makes the fire a pleasure. Between these two builds — the invisible everyday pour and the fruit-forward personality bottle — sit the majority of sauces anyone will ever sell. Master the table before you climb to the tier that climbs the headlines.

Chapter 15 · The Extreme Tier — *superhot, extract-free, the threat-level build.*

Now the headlines. The extreme tier — the half-million to three-million SHU band, the flagship country — is where the reputation of a hot-sauce brand is forged, and where the most sauces go wrong. The temptation is to reach for a capsaicin extract, a cheap and brutal way to push a number, and the result is a sauce that is hot the way a cut is sharp: a chemical sting with no flavor, no floor, no reason to exist beyond the dare. We build the extreme tier differently, and the difference is the whole positioning: **no extract, all plant.** The heat comes from the fruit, the whole designed fruit, which means the sauce carries flavor *and* fire even at a heat that could stop a conversation.

This is only possible because of the flagship cultivars. An extract exists because, historically, no pepper could carry a sauce past a ghost-pepper heat without the sauce becoming all pepper and no room for anything else. Our flagships — Ember through Phoenix, SS-0087 through SS-0096 — break that ceiling: a fruit our model predicts at approximately 2.9 million SHU is a fruit you can build a *sauce* around, not just a chemical you dose. And because they are engineered to a held CV at or under seven percent, an extreme sauce built on them is reproducible, which an extract-spiked sauce built on wild superhots never is. The extract shortcut is not just less flavorful. It is the admission that your raw material could not get there honestly.



Handled with respect: an extreme-tier fruit at the handoff, the no-extract heat that carries its own flavor.

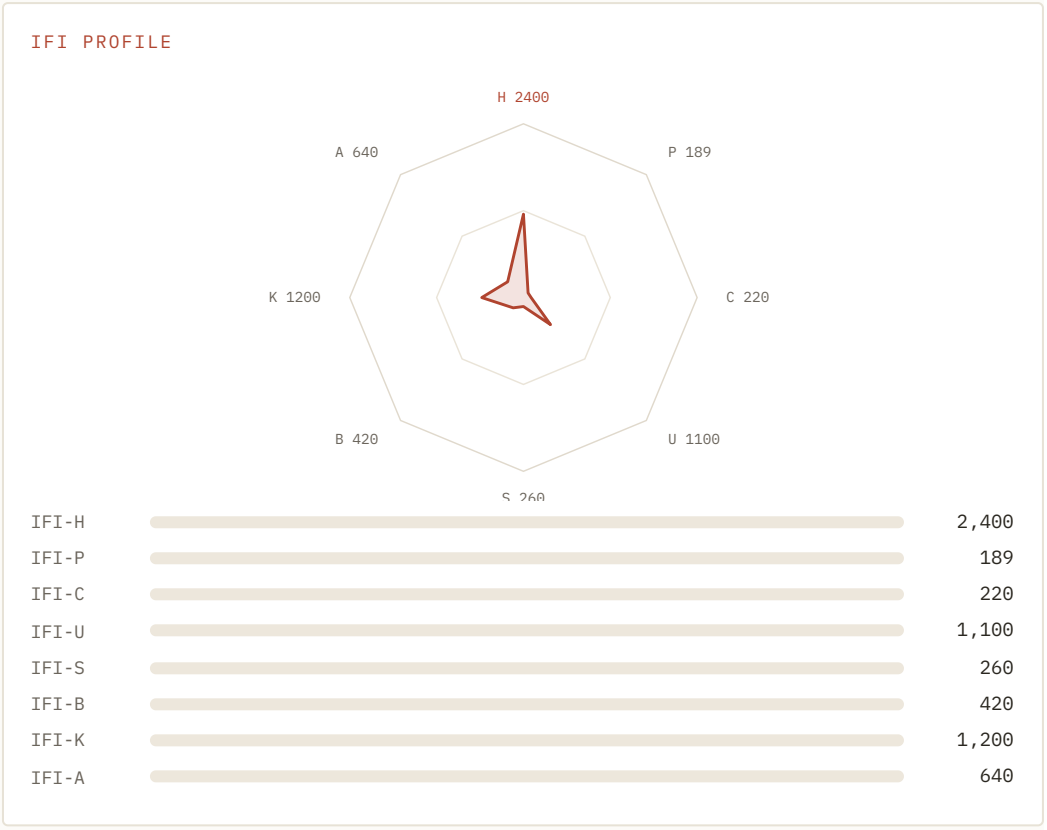
The design discipline at this tier is *dilution with intent*. You are not making a sauce to be poured; you are making a sauce to be *dosed*, a drop at a time, and that changes everything. The flagship mash is extraordinarily hot, so the bottle is mostly the floor — the umami, the kokumi, the fruit, the acid — with the heat present but diluted to a level a brave person can taste rather than merely survive. The goal is

a sauce where, at a single drop, the flavor arrives *first* and the heat blooms *after*, so that even at the extreme the eater tastes the designed fruit before the fire takes the room. That is the opposite of an extract sauce, which is all fire and no fruit. Here is the build.

```
THE THREAT-LEVEL BUILD  ·  extreme band, no extract
MAKES ~500 ml  ·  target pH 3.3  ·  dose by the drop, never the pour
──────────────────────────────────────────────────────

120 g   flagship mash (Blaze SS-0091 / Firestorm SS-0094 class)
160 g   engineered tomato + 40 g roasted red pepper (the flavor floor it
rides on)
 50 g   roasted garlic + onion (kokumi, to hold the heat)
 30 g   fermented soybean / miso (deep U·K; catches the fire)
110 ml  cider vinegar + a little lime
 10 g   sea salt
   —    absolutely no capsaicin extract; the fruit is the heat
```

1. **Handle the flagship mash with gloves and ventilation.** At this heat, the aerosol alone will clear a kitchen. This is a safety instruction, not a flourish.
2. Roast the tomato, pepper, garlic, and onion into a deep, sweet, savory floor.
3. Combine the floor with the flagship mash, soybean, vinegar, and salt. Warm gently 6 minutes — do not boil hard, which drives capsaicinoid aerosol into the air.
4. Blend smooth. Taste **with extreme care, by the pinhead.** Adjust the floor-to-mash ratio so flavor leads and heat blooms after. Set pH to 3.2–3.4.
5. Hot-fill into small bottles — this is a dosing sauce, not a table sauce — with a reducer insert so it comes out by the drop. Cap, invert, cool. Label the heat honestly.



Read that radar against an extract sauce's and the whole philosophy is visible. The heat is enormous at 2,400 — this is a serious sauce — but it is not alone: umami at 1,100, kokumi at 1,200, a real pungency and astringency structure, all of it grown from the floor the flagship mash rides on. An extract sauce at the same heat would be a single

spike with nothing around it. This one is a *flavor* that happens to be ferocious, which is the only kind of extreme sauce worth making and the only kind that honors the plant that made it.

A closing word on honesty and the law, which this tier demands. The heat claim on an extreme sauce is a safety communication, not just marketing — people need to know what they are about to dose, and a held CV is what lets you make the claim truthfully. Put the SHU on the label and mean it; the seven-percent tolerance is what lets you mean it. Write the warnings plainly. And resist, always, the extract that would let you push a bigger number with a worse sauce. The threat-level lore — the names, the warnings, the ritual of the drop — is a pleasure the community loves, and it is honest only when the heat behind it is real fruit. Build the extreme tier the hard way. It is the only way it is worth building.



PART V OF V

From Kitchen to Shelf

texture, color, stability, scale, and the law — turning a recipe into a company

Chapter 16 · Texture, Color & Stability — *the half of the sauce that is not flavor.*

A sauce can be perfectly designed on all eight axes and still fail on the shelf, because a bottle is a physical object before it is a flavor, and customers judge it with their eyes and their wrist before it ever reaches their tongue. Texture, color, and stability are the half of the product that the Index does not measure and the customer notices first — the pour, the cling, the hue, the dreaded layer of separated liquid at the neck. A founder who masters flavor and neglects physics ships a sauce that tastes right and looks broken. This chapter is the physics.

Start with **rheology** — the science of how the sauce flows. The thing you are designing is viscosity, and more precisely you usually want *shear-thinning* behavior: a sauce that holds thick in the bottle (so it does not separate or pour out in a rush) but thins when shaken or squeezed (so it comes out willingly and spreads). This is the texture of ketchup and of every good hot sauce, and it comes from the pepper and vegetable solids themselves, from a fine enough blend, and sometimes from a tiny addition of xanthan gum — a fraction of a percent, enough to suspend the solids and stop separation without making the sauce slimy. The art of xanthan is using almost none; a heavy hand gives a gloopy, artificial body that reads cheap. A well-built sauce with enough natural solids — a fermented mash, a tomato or carrot body — may need no gum at all, and that is the more elegant bottle.



Color is chemistry you can lose: the vivid, held pigment of a designed fruit in cross-section.

Separation is the most common cosmetic failure and it is a rheology problem. A sauce separates when the solids are too coarse or too heavy to stay suspended and gravity pulls them down, leaving clear vinegar at the top — harmless, but it reads as "spoiled" or "cheap" to a customer. The fixes are a finer blend (smaller particles settle slower, by Stokes' law), enough natural pectin or gum to hold a gel-

like suspension, and sometimes a gentle emulsion if the sauce carries oil. A chili-crisp, being oil-based, has the opposite texture problem — keeping the solids distributed in the oil — and is solved by the solids themselves and by jarring rather than bottling. Decide your texture target as deliberately as your flavor target: pourable and smooth, or rustic and shakeable, or spoonable and crunchy. Each is a different physics.

Color is the first axis the customer reads, and it is chemistry that you can lose if you are careless. The reds of a chili come from carotenoids — capsanthin and its relatives — which are relatively heat-stable but light-sensitive, so a sauce bottled in clear glass on a sunny shelf will fade. The vivid reds and purples of fruit come from anthocyanins, which are *pH-sensitive*: red in acid, shifting toward blue and gray as pH rises — which is one more reason to hold your acid down, because the same low pH that keeps the sauce safe keeps a fruit-based sauce vividly colored. The greens of a verde come from chlorophyll, which browns with heat and acid over time — which is why a bright verde is best fresh and refrigerated, as its recipe noted, rather than hot-filled and shelf-stored. And **browning** — the slow dulling of any sauce over months — is enzymatic and oxidative, slowed by acid, by excluding oxygen in the fill, and by the natural antioxidants the whole plant carries. Color is not cosmetic luck. It is pH, light, oxygen, and time, each of which you control.

Stability ties it together: a sauce that holds its flavor, texture, and color over a year on a shelf. The levers are the ones already in your hands — a low pH that both preserves and protects color, a hot-fill that excludes oxygen and pasteurizes in the bottle, a tight headspace, and opaque or UV-protective packaging for light-sensitive pigments. Shelf stability is tested, not assumed: a founder runs real-time and accelerated aging (samples held warm to simulate months in weeks) and tastes and measures them against the spec. The sauce you ship is not the sauce on day one; it is the sauce on day three hundred, and the only way to know that sauce is to have aged a bottle and met it. Design for the bottle the customer opens, not the one you just made.

Chapter 17 · Scaling & Quality Control — *holding the spec when the batch is a thousand gallons.*

A sauce that is perfect in a 750-milliliter test batch is a hypothesis. The company is whether it is still perfect at a thousand gallons, run by someone who is not you, on equipment you do not own, from raw material that arrived on a truck. Scaling is where most of the consistency you fought for in Part II either holds or evaporates, and it is a discipline of its own — the translation of a recipe into a *specification* that a co-packer can execute and a QC lab can verify. This is the least romantic chapter in the book and the one that decides whether you have a company or a very good hobby.

The first translation is from recipe to **spec sheet**. A recipe says "ferment until bright and sour"; a spec sheet says "ferment at 21 ± 1 °C to a terminal pH of 3.4 ± 0.1 over 28–35 days." A recipe says "adjust the acid"; a spec sheet says "finished pH 3.3–3.5, titratable acidity 1.8–2.2% as acetic." A recipe trusts your tongue; a spec sheet trusts a meter, because the person running the thousand-gallon batch does not have your tongue and should not have to. Every judgment call in your recipe has to become a number with a tolerance. The sauce you can describe only by taste is a sauce you cannot scale.



The discipline of scale: the controlled chamber, where a spec is held to a number rather than a feeling.

The spec sheet has a **critical-control section** that is not about flavor at all — it is about safety and legality, and it is non-negotiable. For an acidified food, the governing numbers are the equilibrium pH (at or below 4.6, and you design well under it) and the process that gets there and holds there. In the United States, a commercial acidified-food producer must file their process with the FDA and have it reviewed by a *process authority* — a qualified expert who validates that the formulation and the thermal process reliably render the product safe. This is law under 21 CFR Part 114, and the required

operator training (often called "Better Process Control School") is not optional. We will treat the regulatory detail fully in the next chapter; here the point is structural: your spec sheet carries two kinds of numbers, the flavor spec and the safety spec, and the safety spec is the one a process authority signs and the law enforces.

Now **quality control**, which is the act of proving each batch met the spec before it ships. The core measurements are few and they are the ones you have been designing to all along: pH (every batch, non-negotiable, the safety and flavor spine), heat (an HPLC capsaicinoid assay converted to SHU, verifying you hit the heat claim and that the cultivar's CV held), titratable acidity, viscosity, color, and fill weight. Each has a spec range; each batch is measured; a batch outside spec is held, reworked, or rejected — never shipped. This is where the seven-percent cultivar CV pays off most visibly: with a raw material that holds to ±7%, your finished-sauce heat lands in spec batch after batch and your QC is a confirmation rather than a lottery. With a wild 42% raw material, QC becomes a rejection engine that bleeds your yield and your margin. The cultivar you chose in Part II is the reason this chapter is easy or impossible.

Holding CV at scale is the whole art, and it is a chain: a designed cultivar with a held CV, a raw-material spec with incoming QC (you test the chilies before you buy the truck, not after), a fermentation run to a pH endpoint rather than a date, a blend measured by weight rather than volume, a finished-batch QC against the spec, and aged retention samples from every batch so that if a customer ever questions a bottle you can pull the exact batch and measure it. Each link holds the variance down; a break in any one lets it back in. The founders who scale cleanly are the ones who understood, early, that consistency is not a thing you achieve once in a test batch — it is a system you build and maintain, from the gene to the pallet. The sauce is designed in Parts I through IV. The *company* is designed here.

Chapter 18 · Compliance, Claims & the Ownable Brand — *the law, the honesty, and the name on the bottle.*

A hot sauce is a regulated food, a safety-critical product, and a story, and this final chapter is about all three at once — because the thing that makes a sauce *ownable*, in the end, is not only its flavor but its integrity: that it is legal, that its claims are true, and that its story is one you can stand behind. The founders who build something lasting are the ones who treat the law and the honesty not as obstacles to the brand but as the foundation of it. A sauce you can defend — chemically, legally, and morally — is a sauce you can build a name on.

Start with the law, plainly, because a founder cannot afford to learn it by violation. A hot sauce is almost always an **acidified food** in United States regulatory terms, which triggers real obligations: registration of the facility and the process with the FDA, a filed process reviewed by a qualified **process authority**, operator training under the acidified-foods rule (21 CFR Part 114), a scheduled process that reliably achieves and holds an equilibrium pH at or below 4.6, batch records, and the standard food-safety overlay of allergen labeling, net-weight and nutrition declarations, and good manufacturing practice. None of this is advice specific to your situation — you will retain a real process authority and, likely, a food attorney — but all of it is foreseeable, and a founder who designs the sauce in Part IV while ignoring this chapter has built a product they cannot legally sell. The compliance is not downstream of the design. It is part of the design.



The name is the last design decision: a designed fruit backlit in the greenhouse, the heat it promises grown honestly.

Then the **claims**, which is where integrity meets marketing. The heat claim — the SHU on the label — is the one customers trust most and founders fudge most, and fudging it is both dishonest and, at the extreme tier, a safety failure. The whole argument of this book is that you no longer have to fudge it: a designed cultivar with a held CV lets you put a real number on the bottle and mean it, batch after

batch. Claim the heat you actually hit, verified by assay, and let the seven-percent tolerance be what makes the claim defensible. The same discipline governs every other claim. "No extract" is a claim you can make only if it is true — and built the way Part IV argues, it is true, and it is a real differentiator. The nourishment ethos that hums under this whole library stays, here most of all, a matter of how you *build* — whole plants, live ferments, nothing isolated — and never a matter of what you *claim*: no health claims, no "detox," no "cures," no halo. The honesty of the bottle is in the building, said quietly, never on the label as a promise about the body. A sauce that lies about its heat or its health is not ownable. It is a liability with a nice label.

Finally the **name and the story**, the part founders think about first and this book put last on purpose — because a name is only as good as the sauce under it, and now the sauce under it can be exactly what you specified. The threat-level lore of our flagships — the escalating names, the warnings, the ritual of the single dosed drop — works because the heat behind it is real and reproducible; the story is the truth dramatized, not invented to cover a thin product. That is the model for an ownable brand: find the one or two axes your sauce truly owns, name the thing honestly around them, and let the Index-defined profile be the substance the story points at. A swicy sauce named for its sweetness, a málà sauce named for its tingle, a deep fermented sauce named for its floor — each a story that is *true*, each pointing at a radar you can defend. The ownable sauce is the one whose name and whose number agree.

And so we arrive where we began, at the bottle held up to the light — but now it does not drift. It was briefed on eight axes and a curve before a chili was bought. Its heat came from a plant chosen off a ladder or designed at the gene, held to a tolerance a wild pepper could never promise. Its floor was fermented and borrowed from a pantry of designed organisms, its finish composed, its acid set with a meter, its texture and color and stability engineered for the three-hundredth day and not the first, its spec held from the gene to the pallet, its claims true and its name honest. It is a designed object, at last, in the full and serious sense — and designing it, we have found, only deepened our reverence for the small burning fruit at the center of it all. We read the pepper's blueprint closely enough to change two letters of its terminal synthase, and what we mostly learned was how good it already was. That is the spirit to build in. Design the burn. Respect the plant. Keep the promise in every bottle. The rest is craft, and the craft is yours now.

These are computational designs; Scoville Splice's cultivars and constructs have not been experimentally validated in a laboratory.