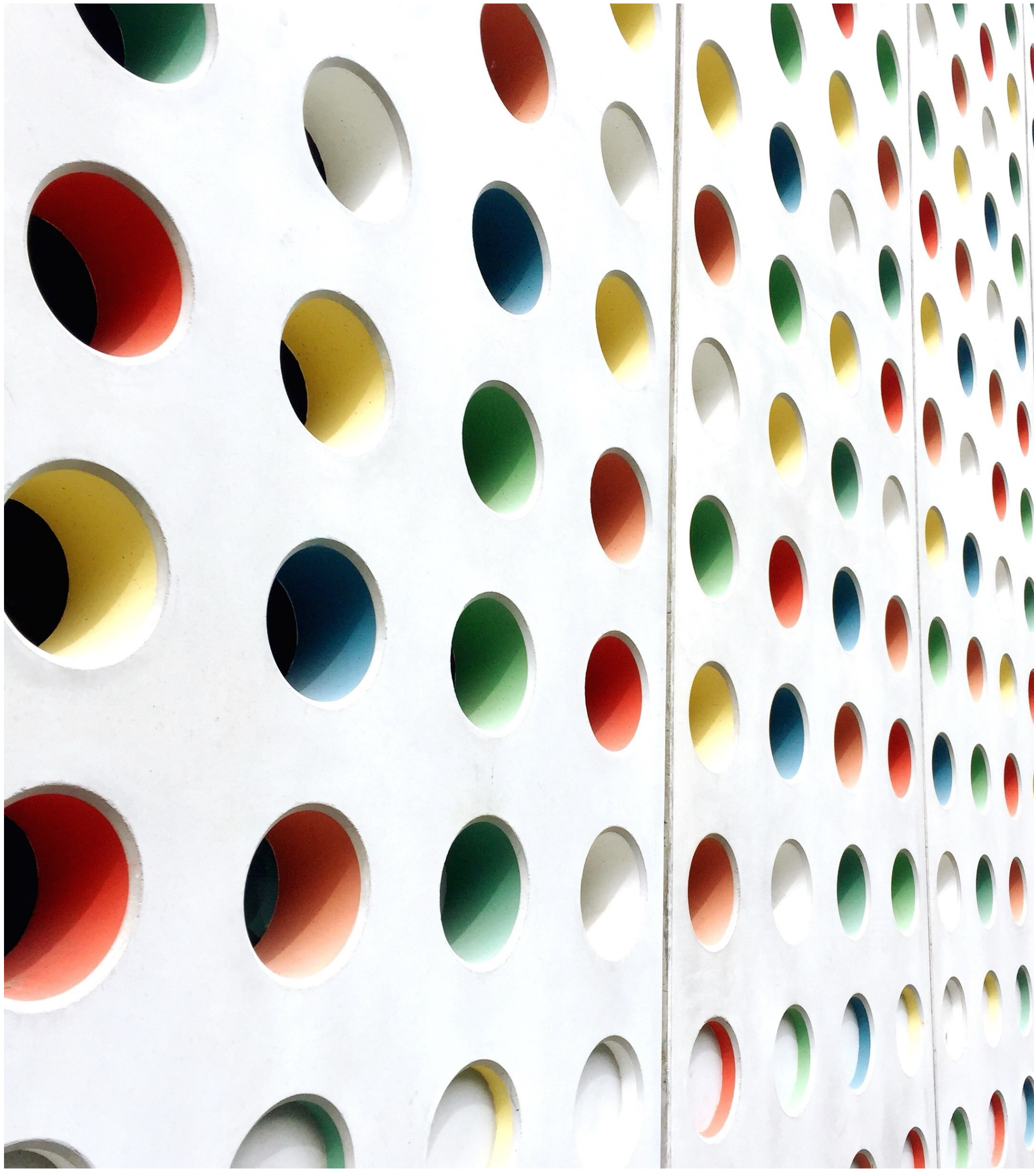

Introduction to fining: improving clarity, stability, and sensory appeal

GENCO EDUCATIONAL SERIES

Bruce Hagen

Fining: not simple

- complex, technically demanding
- requires some understanding of chemistry, sensory evaluation, timing, attention to detail, and some math
- many variables
- can’t rely on standard doses
- must do trials

Wine – a complex liquid:

- H_2O, alcohol, dissolved substances: sugars, acids, minerals, aroma cmpds, some nitrogen-based cmpds., phenolic cmpds. (tannins, anthrocyanins, pigments)
- many suspended particles: bits of skins, pectins, pulp, dead yeast, bacteria, proteins, tannins (phenolics), and bitartrates
- particles exist as <u>colloids</u> … aggregations of molecules with an affinity for each other – generally not visible!
- colloids carry an electrical charge: key to fining

Colloids interact and form complexes:

- polyphenols
- proteins
- polysaccharides
- phenolic-protein complexes
- polysaccharide-protein complexes
- polysaccharides-tannin complexes
- polysaccharide-tannin-protein complexes
- anthrocyanins-tannins
- polysaccharide-aromatic complexes
- pectins, glucans
- yeast mannoproteins
- metal ions

Complexes: influence color, stability, mouthfeel, clarity, and aging

- polysaccharide complexes – increase stability
- anthocyanin–tannin complexes, increase color and stability
- tannin–polysaccharide complexes: reduce astringency, add viscosity, increase smoothness, reduce dryness, prevent tannin polymerization into harsh forms
- mannoproteins bind with tannins, anthocyanins, aroma compounds: soften tannins, increase mid-palate weight, stabilize color, enhance aroma retention

Colloids exist in a dynamic balance:

- they evolve continuously during winemaking — they polymerize, bind (form complexes), break apart, lose charge, become larger or more compact
- electrical charge can shift with chemistry, temperature, blending, destabilizing equilibrium or promote aggregation
- these changes alter stability, clarity, mouthfeel, color, and filtration

Colloids associated with instability (hazes):

- unstable proteins
- protein–phenolic complexes
- phenolic colloids (oxidized phenolics, aggregated tannins)
- polysaccharides: pectins may cause turbidity
- hazes also caused by microbs, and excess tartrate (cold haze)
- each requires different interventions

Wine – fundamentally unstable:

- subject to oxidation, bacterial spoilage
- small shifts in temperature, pH, oxygen, can push colloids from “clear and stable” to “hazy and reactive.”
- cloudiness or sediment can develop when colloid equilibrium shifts

Fining from Middle English and Old French, meaning to make fine, make clear, to refine, or perfect …

Definition … the addition of an agent to juice/wine to bind with unwanted components, increasing their size and weight, causing them to settle out

Objectives:

- stabilize whites by removing unstable proteins, oxidized phenols
- increase clarity, add sparkle
- prevent or remove hazes caused by other compounds
- remove ‘green’ or harsh tannins and bitterness (reds)
- soften over-extracted tannins, improve mouth-feel
- correct or stabilize color
- remove off-flavors

Fundamentally, fining is about removing specific stuff, with the least collateral damage …

‘There be dragons’ or risks involved

Fining is:

- often frowned on
- confused with simple clarification
- widely misunderstood: the why, how, what, when, and potential outcomes – rarely explained, or oversimplified
- based on chemistry, so winemakers often don't mess with it, or use intuition
- it can be risky, but there are real benefits as well

So, what are the concerns:

- over-fining and stripping
- loss of desirable aroma, flavor, body, color, mouth-feel, complexity
- *"thin, muted, short, washed-out, and prematurely aged, unstructured, with diluted color, and suppressed aromatics"*
- residual fining agent in the wine
- instability

Why things go wrong:

- fining unwarranted
- wrong agent
- overdosing–failure to do bench trials
- not measuring
- mathmatical error
- waiting too long
- improper prep., poor mixing/incorporation
- using agents in wrong order
- not enough contact time
- ignoring important factors like pH, temperature, alcohol, levels (loads) protein- and phenolic
- delayed racking

Fining: not just about clarification and stabilization:

- includes agents like polysaccharides, mannoproteins, and tannins (fermentation, maturation or finishing)
- primarily to improve stability and sensory appeal
- intended to remain in the wine

Polysaccharides/mannoproteins:

- improve colloidal stability (prevent hazes and sediment)
- stabilize color (reds)
- interfere with oxidation
- increase protein stability (reduce need for aggressive fining)
- protect aroma compounds
- reduce astringency and enhance mouthfeel

How fining works:

- involves the physical or chemical attraction (bonding) between the agent and unwanted compounds
- the result is larger, heavier particles that settle out of suspension

Mechanism of bonding:

- electrostatic bonding, simple covalent (+) to (-)
- ‘adsorption’: molecules stick to agent’s surface through non-electrostatic forces: hydrogen- bonding, hydrophobic interactions, Van der Waals forces, or physical entrapment, etc.

- colloid stability–the result of a tension between repulsive and attractive forces
- when attraction wins, stability collapses
- charge shifts with pH, temperature, and wine matrix

Fining agent	charge	Target	Notes:
Bentonite	(-)	(+) proteins	Only reliable remover of heat-unstable proteins. Strong flocculation.
PVPP	Neutral to sl. (-)	(+) phenolics	Does *not* rely on charge; binds oxidizable phenolics selectively.
Silica gel	(-)	(+) some proteins, phenols	Often paired with gelatin to form large flocs.
Gelatin	(+)	(-) tannins/phenolics	Strong tannin remover; can over-fine if overdosed.
Isinglass	(+)	(-) tannins, fine colloids	Very gentle; used for polishing and brilliance.
Casein / Potassium caseinate	(+)	oxidized phenolics (-)	Excellent for browning and oxidation correction.
Chitosan (fungal)	(+)	(-) microbes, some phenols	Strong microbial fining; also aids settling.
Egg white (albumin)	(+)	(-) tannins	Classic for softening red wine tannins.

Fining agents:

- bind with specific compounds (when used properly)
- because they are charged, sticky, or porous
- form larger, heavier particles that settle out

Fining: must be done selectively

- each targets specific wine faults
- select the right agent based on the issue and desired outcome
- some are gentle, others more aggressive
- some agents work best in combination
- if the target has harsh, sharp tannins: gelatin, egg-white are options

Common fining agents and primary target:

bentonite → unstable proteins

gelatin → ‘green’ astringent and bitter tannins

silica gel → excess gelatin

Vege protein → ripe or polymerized tannins (feels coarse, heavy, gritty, or overly extracted)

egg whites → softens harsh tannins in reds

Select agent with lowest stripping potential:

isinglass → gentle clarification, (-) charged colloids (yeast cells, creates brilliant clarity in whites, removes light phenols

casein → removes oxidized phenols, oxidative browning

PVPP → removes oxidizable phenols, browning and phenolic bitterness)

pectinase/glucanase for colloids (pectins) that slow clarification, trap solids, interfere with fining

Quick reference:

Problem	best agent	alternate	notes
oxidized phenolics	casein	PVPP	casein first, then bentonite
browning / pinking	PVPP	casein	PVPP is most selective
phenolic bitterness	PVPP	casein	
phenolic-protein haze	PVPP	bentonite	combination of the two
heat-unstable proteins	bentonite	none	only bentonite works
harsh, unripe tannins	gelatin		

Fining: a corrective tool

- when natural clarification is insufficient <u>or</u> sensory appeal is lacking
- won’t fix a dodgy wine
- a bit of a trade off
- what you use, how much, when you add it, and sequence it is added is critical

What can’t be fixed:

- true oxidation VA (vinegar ethyl acetate, acetaldehydes)
- phenolic oxidation is reversible early on
- microbial spoilage aromas
- stuck fermentation
- rot-related compounds earthy, musty, ‘mushroomy,’ etc.
- smoke taint, largely resistant
- most <u>di</u>sulfides don’t respond

Timing matters more than dose:

- agents behave differently depending on fermentation stage
- PVPP → juice or early ferment
- bentonite → mid-ferment (10–12 °Brix)
- gelatin, potato/pea protein → post-ferment
- casein → early post fermentation following oxidation events
- enzymes → juice stage
- correct timing reduces dose, improves selectivity, and protects aromatics

Fining, then is:

Balancing, integrating, adjusting the interactive network of compounds: polyphenols (tannins), polysaccharides, proteins, pigments, and other colloids for stability and sensory appeal.

Don't forget about acid adjustment

Colloids form complexes: influence color, stability, mouthfeel, clarity, and aging

mannoproteins: (released during autolysis, bind with):

- tannins
- anthocyanins
- aroma compounds (stabilize)

impact:

- improve mouthfeel
- stabilize color
- enhance aroma retention
- reduce astringency

Natural clarification:

- given time, gravity causes most suspended lees to settle
- can take many months, and several rackings
- whites, primarily, may show indications of oxidation, browning, or off-aromas, or bitterness after fermentation
- reds made from underripe or over-extracted grapes are often tannic (bitter or astringent) tannic, ‘dry’
- most of these issues respond well to fining

Early use of pectolytic enzymes reduce need for fining …

- pectins interfere with juice release, clarification, and can form a pectin-haze (glucanase for Botrytis)
- reduces viscosity
- eases pressing, increases free-run juice
- enhances settling and clarification
- improves aroma, flavor, and color extraction (reds)
- improves extraction of polysaccharides (stabilizing)

Preventative practices:

- harvest at peak ripeness, avoid unripe grapes, rot, botrytis, damaged fruit
- water-back (lower's alcohol)
- gentle handling of fruit gently, chill, sulfite early
- correct free-SO_2, limit air exposure
- oxidation control
- use pectolytic enzymes
- cold-settling (some turbidity is desirable)
- remove seeds (reds) before pressing
- gentle pressing, separate press cuts
- adjust acidity early
- yeast nutrition
- avoid excessive tannin extraction
- excessive and aggressive punch-downs, particularly first 48 hrs.
- avoid hot fermentations
- monitor ferment for sluggishness, H2S
- avoid excessive lees contact

Common problems solved by fining:

- haze due to soluble (unstable) protein
- harsh or green tannins
- bitterness
- excess ‘ripe’ tannins (coarseness, dryness)
- non-protein haze (colloidal instability)
- color instability
- reduction with early intervention (CuSO4)
- early oxidization of phenolics: browning and off-aromas

Practices favoring over-extraction:

- aggressive early cap management
- high fermentation temperatures >85°F
- hard pressing and including hard-press fractions
- lengthy extended maceration without daily tasting
- high ethanol levels
- oxidative handling that ‘hardens’ tannins

Reds generally don’t need fining, unless …

- **wine is overly extracted**, or from unripe fruit (**‘green tannins’**) – green seeds and stems … hits quickly, sharp, angular and dries the mouth aggressively
- best option: **gelatins**
- mannoproteins will help
- cloudy, have a specific sensory fault, or their sensory appeal is less than you would like

Gelatin: post-fermentation

- for green tannins: sharp, bitter, angular, and drying
- safer when combined with silica gel to act as a counter-fining agent
- gelatin is (+) and silica gel is (-) so it binds with excess gelatin to prevent stripping
- add silica gel first, wait 12 to 24 hours, then the gelatin
- lees settle faster and more compactly

Vegetable (pea/potato) proteins when tannins are 'ripe':

- 'ripe': condensed (polymerized) tannins in fully developed grapes, primarily the skins, that produce a rounder mouth-feel, add structure and are less harsh, mouth-drying than unripe tannins
- coarse, gritty, astringent
- vege-proteins: best for over-extracted wines with ripe tannins: coarse, hard, grainy, thick without suppleness, broad, mid-palate, 'hot'
- egg white (optional, a 'gentle touch')
- mannoproteins (post-fermentation)

Whites typically need fining:

- clarity important
- haze, or sediment – a big issue
- delicate flavors, aromas, and bitterness more noticeable
- lack tannin structure that helps remove unstable proteins
- phenolics are very reactive, leading to enzymatic browning and early oxidation damage, bitterness

For whites/rosés, universal problem is: unstable proteins:

- **Bentonite**: <u>only</u> agent that selectively binds heat-unstable (haze-forming) proteins
- bentonite (-) binds with (+) colloids like **proteins** and **phenolics**
- once unstable proteins are bound, bentonite starts working on phenolics, polysaccharides
  - can strips aroma, flavor, color, and mouthfeel
  - so, dose rate important! – do bench trials

Bentonite:

- best time: halfway through fermentation (the single best way to avoid over-fining)
- good suspension and contact
- minimum aroma loss
- good lees compaction
- do bench-trials to determine the lowest dose that will do the job

Bentonite: things you should know

- protein instability increases with pH (whites <3.4)
- **NA-based bentonites: fluffy lees**, best with **silica gel** to compact the lees, *after* bentonite has already done its protein-binding work 24 to 48 hours
- **CA-based bentonites** produce **compact lees** (higher yield), but more is needed, but a light silica-gel dosage is beneficial
- Scott, NACALIT Pore Tec, Fermobent Pore- tec
- Rate 20 to 150ml/HL

Whites: preemptive-fining:

- reduces suspended solids
- removes unstable proteins
- removes phenolic compounds before they oxidize. Prevents browning, pinking, (preserves color and aroma)
- reduce harshness, bitterness, astringency … softer, cleaner palate
- best: use a blend like Claril SP, AF (Enartis) Scott's Bentolact S, or Polylact (casein and PVPP), followed soon after with Bentonite)

Clarification and protein stability (juice)

silica gel + gelatin/vegetable protein + bentonite (oxidizable phenols and prevents browning, and protein stability

- sequence: silica gel first → wait 15 to 30 min. → gelatin or pea/potato protein → add bentonite within 30 min
- cold settle: 12 to 24 hours, rack and inoculate
- not as selective for phenolics as PVPP
- silica gel great for clarifying wine by removing colloidal hazes, and phenolics, proteins, but not unstable protein hazes

The most selective, efficient, and least aromatic-stripping combination for phenolics:

- PVPP + bentonite (juice or after inoculation) fermentation)
  - PVPP (first): oxidizable polyphenols, prevents browning, softens bitterness. Alternative: plant proteins
  - Bentonite (second): to remove heat-unstable proteins, and improve settling and compact, add @12 to 15°Brix

Early post-fermentation removal of phenolic oxidization (whites):

- remove browning, restore brightness
- casein/potassium caseinate (oxidized phenols, browning)
- PVPP (optional and synergistic) (removes oxidative phenols and bitter tannins)
- combined with bentonite (unstable protein)

Phenolics (bitterness, browning, harshness):

- PVPP – best for oxidiz<u>able</u> phenolics, bitterness, pinking, browning
- casein / potassium caseinate – best for oxidiz<u>ed</u> phenolics, color correction
- gelatin – removes medium-large tannins; softens harshness, best for green tannins
- potato protein – removes large, ripe, polymerized tannins (coarse, heavy, or overly extracted)
- egg whites – gentle tannin softening (mostly for reds)
- **best-in-class:** PVPP (white/rosé), gelatin (reds)

A word of caution:

- most fining agents non-selective, they bind with polysaccharides, tannins, and colloids … compounds that provide: texture, weight, and length
- you have to get it right

Examples: the two most important agents:

- bentonite (-) binds with (+) charged colloids (proteins and phenolics), but once unstable protein bound up
- it goes after phenolics, stripping aroma, flavors, color, and mouthfeel
- protein-fining agents (+) mostly target (-) polyphenols) but other important colloids as well …
- that's why you want the least amount

If you ID a problem:

- determine what needs to be done
- select most efficient approach or agent(s)
- prepare correctly, add it at right time, and use the least amount

Bench trials: to avoid over-fining

- check recommended rates
- prepare a stock fining-solution, start at lowest recommended rate to the highest
- use small samples (100mL)
- determine the lowest dose
- mix gently and let settle
- evaluate clarity, aroma, color, or tannin changes

Preparing, mixing agents:

- hydrate, dissolve, or form a slurry in water as directed
- incorporate
- allow contact time for aggregates to form, flocculate, and settle
- keep wine stable and cool
- monitor clarity and lees formation
- rack
- re-check aroma, flavor, color, and mouthfeel

Variables that make fining less predictable

- protein content (load) and type
- phenolic/tannin content
- pH influences charge interactions
- colloidal content (amount of suspended particles
- temperature affects solubility, reaction rates, and settling behavior; fining temperature must match bench trial conditions
- dosage, mixing, temperature, sequence, contact time
- fining agents not consistent

Establish minimum effective rate

Run a **heat-stability test** on the juice or a small pre-ferment sample

- Test a range (e.g., **0.3–1.2 g/L or .03 - 0.12 g/100ml of wine**) depending on variety and protein load
- Select the lowest dose that passes the heat test

Using a 5% bentonite slurry (5 g in 100 mL water)
Prepare multiple test vials with increasing bentonite doses (e.g., 0.2, 0.4, 0.6, 0.8, 1g/L)
Add settle 24–48 hours
Run the heat-test on each

Calculating how much bentonite for each sample needs

For a 100 mL (0.1 L) sample:

Mass of bentonite needed = R x 0.1

Where: R = **target rate in g/L**

0.1 L = 100 mL samples

Example: for **0.6 g/L**: 0.6 x 0.1 = 0.06 g bentonite

Convert bentonite mass into slurry volume

Using the slurry concentration:

Slurry volume = Mass of bentonite 0.05 (5 percent)

Example (continuing 0.6 g/L):

0.06/.05 = 1.2 mL bentonite slurry

So, you would pipette **1.2 mL** of 5% slurry into 100 mL of wine.

Ready-to-use dosing table (100 mL wine samples)

Target rate (g/L)	Bentonite needed (g)	Slurry volume (mL)
0.2 g/L	0.02 g	**0.4 mL**
0.4 g/L	0.04 g	**0.8 mL**
0.6 g/L	0.06 g	**1.2 mL**
0.8 g/L	0.08 g	**1.6 mL**
1.0 g/L	0.10 g	**2.0 mL**
1.5 g/L	0.15 g	**3.0 mL**

Types of oxidation:

Phenolic oxidation: early-stage when *phenolic compounds* (caffeic acid, catechins, flavanols) are oxidized → quinones, browning precursors, apple-skin/straw aromas or just dulled aromas: largely reversible.

Post-fermentation/aging oxidation: in the barrel, tank or bottle begins free-SO_2 is depleted. Oxygen reacts with *ethanol* → *acetaldehyde* → nutty/sherried notes, loss of fruit, structural softening *and browning* (polymerized pigments) … irreversible

PR proteins that cause haze

plant defense proteins produced by grapes in response to:

fungal pressure

environmental stress

mechanical damage

dehydration

UV exposure

Over extraction

aggressive early cap management, hot ferments >84F, long macerations, high ethanol, hard pressing, and excessive seed contact particularly during EM.

- **High Brix fruit** → more ethanol → more tannin solubility
- **Dehydrated berries** → concentrated skins/seeds
- **Sunburned fruit** → harsher phenolics
- **Under-ripe seeds** → bitter, angular seed tannins
- **Over-ripe skins**

The underlying chemistry over extraction

Over-extraction occurs when:

Seed tannins exceed colloidal capacity → bitterness, angular tannins

Skin tannins exceed polysaccharide load → coarse, gritty texture

Phenolic load exceeds fruit concentration → heaviness, dryness

Oxidized phenolics accumulate → harshness

Matrix becomes overloaded → tannins stay small instead of polymerizing

This is why over-extracted wines feel **big but not good**.

These push tannin extraction beyond what the wine can integrate.

Agent	Recommended Range	Typical Use	Red-Flag Dose
Silica gel	50–150 mL/hL	80–120 mL/hL	>150 mL/hL
Gelatin / Pea protein	5–30 g/hL	10–20 g/hL	>30 g/hL
Bentonite	0.5–1.5 g/L	0.8–1.2 g/L	>1.5 g/L

Fining agent	**Charge**	**Target**	Notes
Bentonite	(-)	(+) proteins	Only reliable remover of heat-unstable proteins. Strong flocculation.
PVPP	Neutral to sl. (-)	(+) phenolics	Does *not* rely on charge; binds oxidizable phenolics selectively.
Silica gel	(-)	(+) proteins	Often paired with gelatin to form large flocs.
Gelatin	(+)	(-) tannins/phenolics	Strong tannin remover; can over-fine if overdosed.
Isinglass	(+)	(-) tannins, fine colloids	Very gentle; used for polishing and brilliance.
Casein / Potassium caseinate	(+)	oxidized phenolics (-)	Excellent for browning and oxidation correction.
Chitosan (fungal)	(+)	(-) microbes, some phenolics	Strong microbial fining; also aids settling.
Egg white (albumin)	(+)	(-) tannins	Classic for softening red wine tannins.

Where the tannins come from

✓ Ripe-grape tannins (skins + lignified seeds)

- Long-chain polymeric tannins
- Higher proportion of **epicatechin** vs. catechin
- More pigmented tannin complexes
- Interact with polysaccharides and mannoproteins
- Naturally soften with time, oxygen, and polymerization

Green tannins (under-ripe seeds, stems, skins)

- Short-chain flavan-3-ols (catechin, epicatechin gallate)
- High proportion of **seed tannins**
- Low polymerization
- High reactivity
- Resistant to natural softening

This difference in **polymer length** and **origin** is the root of the sensory difference.

•At low temperatures, **tartrate solubility drops**.
•Potassium bitartrate or calcium tartrate begin to **nucleate.**
•Before they grow into visible crystals, they appear as a **milky haze**.
•When warmed, they **redissolve**, so the haze disappears.

unstable proteins, phenolic–protein complexes, polysaccharides, pectins/glucans, tartrate crystals, and oxidized polyphenols.

White wines contain **small, highly reactive phenolics** (caffeic acid, caftaric acid, coutaric acid). When exposed to oxygen, they convert into:

- **quinones** (brown, bitter, oxidative precursors)
- **polymeric phenolics** (muddy color, harshness)
- **pinking compounds**
- **browning precursors**
- **aroma-stripping oxidative complexes**

- unstable proteins
- phenolic–protein complexes
- polysaccharides
- pectins

Wine is a delicate equilibrium of:

- acidity
- phenolics
- aromatics
- texture
- colloids and complexes
- over-fining disrupts this balance, often in ways that are hard to fix later
- so, getting it right is important

Polysaccharides:

Yeast-derived polysaccharides–mainly mannoproteins produced by the yeast during fermentation and autolysis, or from cultured yeast–play a role in wine stability

Wine Problem	Best Fining Agent	Alternatives	Key Notes (Winemaker-Critical)
Protein haze (PR proteins: chitinases, TLPs)	Bentonite	None	Only agent that removes PR proteins; heat test required; silica gel does *not* remove proteins.
Oxidized phenolics / browning	Casein / Potassium caseinate	PVPP; Activated carbon (aggressive)	Casein removes brown pigments; PVPP removes quinones; carbon strips aroma.
Phenolic bitterness	PVPP	Casein (if oxidation also present)	PVPP targets low-MW oxidized phenolics; excellent for harsh press fractions.
Phenolic haze (phenolic-protein complexes)	PVPP + Bentonite (combo)	Casein (if oxidation involved)	Bentonite removes protein portion; PVPP removes phenolic portion; silica gel does *not* fix phenolic haze.
Metal haze (Fe, Cu complexes)	Citric acid + Ferrocyanide (EU only)	Citric acid alone; Bentonite (partial)	Rare today; ferrocyanide prohibited in US; citric chelates Fe^{3+}.
Excess polysaccharides / colloidal instability	Bentonite	Pectinase enzymes	Polysaccharides protect proteins → higher bentonite dose needed.
Aroma loss from oxidation precursors (quinones)	PVPP	Casein	PVPP removes quinones before they bind thiols; casein helps if browning is visible.
General clarification (not stability)	Isinglass	Silica sol (flocculant only)	Isinglass is gentle; silica sol improves settling but does *not* remove proteins or phenolics.

Low-protein varieties

Chardonnay, Chenin, Albariño → **0.5–0.8 g/L**

Moderate-protein varieties

Pinot Gris, Riesling, Viognier → **0.8–1.2 g/L**

High-protein varieties

Sauvignon Blanc, Muscat, Gewürztraminer → **1.0–1.5 g/L**

Instability	Cause	Best fining agent	Why it works
Protein haze	protein charge collapse	**Bentonite**	removes proteins
Phenolic haze	tannin polymerization	**Gelatin**	binds medium/large tannins
Oxidative haze	quinones, metal complexes	**Casein**	removes oxidized phenolics
Bitterness	small phenolics	**PVPP**	removes small phenolics
Coarse astringency	large tannins	**Gelatin**	reduces polymerized tannins
Browning	oxidation	**Casein**	removes quinones
Cold haze/crystals	tartrate nuclei	**Cold stab / CMC / KPA**	stops crystal growth

Oxidative ‘hardening’:

- crushing/destemming with too much air exposure
- cold soak with oxygen ingress
- long lag phase before fermentation starts
- pressing with excessive splashing
- racking without inert gas
- post-MLF handling before SO_2 is added