Grapes 101

Just make up your mind! The science behind cold-stabilization and tartrate removal in the winery

Grapes 101 is a series of brief articles highlighting the fundamentals of cool climate grape and wine production.

By Gavin Sacks

Figure 1. Research wines undergoing cold stabilization. Note the whitish potassium bitartrate precipitate in the wines in the bottom right. (Image by Gavin Sacks)

If you have poured a chilled wine and noticed something that looked like broken glass, rest assured – it was probably harmless potassium bitartrate crystals. Also known as “tartrates,” these crystals may look dangerous, but tartrates from grape juice are a common food additive. When finely ground they become the “cream of tartar” in your baking cabinet. Knowing this, you may now regret storming into your local wine store (or wine tasting room) to demand a refund and an apology. Nonetheless, keep in mind that most wine producers have met similarly irate consumers, and will often attempt to prevent tartrates from forming in bottle by using what are known as “cold-stabilization” techniques. This is because tartrates are most likely to form when the wine is chilled. Why do potassium bitartrate crystals form, and how is cold-stabilization accomplished? Before we tackle these questions, we first need to understand why grapes are unique.

What makes you think you’re special? Chemically, what makes grapes unique compared to other plant-based foods? The short answer is “not much.” Grapes can accumulate a lot of sugar – so much in fact that sugar alone can represent over...
20% of a grape berry’s weight. While this is higher than many fruits, pineapple and dates can have similar or higher sugar concentrations.

Color? Red grapes make pigments called anthocyanins, but so do other red and purple fruits. For example the amount of anthocyanin in black currants is ten times more than the typical red grape.

How about tannin, which gives red wines their “drying” sensation? Sure, they’re in grapes, but also in apple peels and cranberries, and these all pale in comparison to cocoa beans, where tannin concentrations can be 20 times higher than in grapes.

Aroma compounds? What about the “black pepper” aroma of some red wines? The same odor compound has been implicated in black pepper and certain grapes . . . but concentrations are 1000× higher in black pepper.

So, what is distinct about grape chemistry?

The answer: Tartaric acid.

Grapes are nearly alone with this compound as their major organic acid – sometimes, nearly 1% of a grape berry’s weight. Tamarind is the other fruit with tartaric as a major acid, but grapes and tamarind made a mutual agreement centuries ago. While grapes focus on wine, tamarind has a near-monopoly on the chutney market.

Organic acids are important to food preservation because they reduce pH (increase acidity), which discourages the growth of many spoilage organisms. However, unlike other common fruit acids (malic, citric), tartaric acid isn’t metabolized by most microbes, and residual tartaric acid can still be found in ancient wine containers. The persistent effect of tartaric acid on wine pH, in tandem with alcohol, helps explain wine’s resistance to microbial spoilage.

**Is this a snow globe or a wine?** One curious feature of tartaric acid is that it can react with dissolved potassium to make potassium bitartrate crystals. And grapes have plenty of potassium – it’s the highest concentration mineral in most grape juices and wines. The solubility of tartrates decreases when there’s ethanol around. Once the wine is cooled and fully fermented, visible tartrates that have precipitated, or in other words come out of solution, are at the bottom of the tank (Figure 1).

No need to worry though; these tartrates do not present a risk to a wine’s salability. Winemakers can easily separate tartrates out before bottling. The bigger challenge is that most wines are at risk for further tartrate precipitation.
**Supersaturation – it's ok, I guess:** If you add sugar to water and stir, it will dissolve. If you keep adding more and more sugar, the solution will eventually be saturated – the water will reach its limit in how much sugar it can hold.

Curiously, most wines on the shelf of your local store are supersaturated with potassium bitartrate. That is, if you measure the amount of potassium and bitartrate in the wine, it's often two or three times the amount that a wine-like liquid should be able to dissolve, even at room temperature.

How can this be?

**Let's get meta for a moment. Or longer:** Tartrate supersaturation is an example of metastability – a system which can appear to be stable over the short term, but over longer periods (hours, days, or even years) will change. The time necessary for metastability to be lost – that is, for visible tartrate crystals to form – will vary. Many components of wine are capable of slowing crystal growth, but given enough time, crystals may form anyways.

![The curve of tartrate metastability unhappiness](image)

*Figure 2. The relationship of Winemakers’ Headaches to the time necessary for bitartrate precipitation to occur. (Figure by Gavin Sacks)*

The loss of metastability and the timing of tartrate crystal formation is critical to winemakers' fortunes. Wines that exhibit tartrate formation within several weeks or less are usually not a concern. This is since the wine will still be at the winery and crystals can be removed before bottling. Conversely, crystal formation after several years is usually not a problem either, since most wines would be consumed before this point. Winemakers are usually most interested in avoiding tartrate formation 6-24 months after fermentation. This corresponds to the time when many wines would be bottled, sold, and consumed.
Winemakers have several ways to predict if a wine is unstable. For example, a simple approach is to chill a wine down to near its freezing point and observe if crystals form. Alternatively, they can measure bitartrate and potassium, and compare concentrations to actuarial tables that describe the risk of instability for a wine type.

**Should you stay or should you go?** There are two general approaches to decreasing the risk for potassium bitartrate precipitation post-bottling:

- **Get out now:** Put another way, decrease the concentration of potassium, bitartrate, or both in the short term so that they won't be a problem in the long term. Frequently, this is done by using conditions that greatly favor potassium bitartrate precipitation – the wine will be chilled to near freezing temperatures, often while being stirred in the presence of small potassium bitartrate crystals called “seeds” that help the precipitation start. If you walk into a winery, and see icy condensation on a tank, chances are there's a wine inside getting cold stabilized. While chilling a wine is straightforward (especially in Upstate NY in the winter), it can be expensive in regions with high energy costs or warm temperatures. Another “get out now” approach use plastic “ion-exchange” resins to bind potassium and other metals. While this can be more time and energy efficient, some wineries believe these resins also harm flavor. Large wineries may use specialized “electrodialysis” machines capable of separating out ions like potassium and bitartrate through tiny pores before bottling, although these are usually too expensive.

- **Please Stay.** Have you ever considered what some of the mystery ingredients are in ice cream? What's locust bean gum doing in my rocky road? Ice cream is another metastable system – the small ice crystals in fresh, creamy ice cream will over time make larger particles with a gritty texture. Many of the additives in ice cream will slow the rate at which this crystal growth occurs. Similar ideas exist in wine to slow tartrate formation. Some of these additives can be formed as part of fermentation – for example, yeast cell wall components (mannoproteins) can inhibit tartrate growth, which explains the low incidence of tartrates in sparkling, Champagne-style wines. These crystal inhibiting yeast extracts are now available to winemakers commercially. Other additives that can slow crystallization include gum arabic and carboxymethylcellulose, both which are common additives to ice cream.

Finally, although the majority of commercial wine in the US is cold stabilized, there are many wines where the producers choose not to stabilize. For example, red wines are usually not refrigerated, and the polyphenols in red wines will inhibit bitartrate formation. Thus, some winemakers will save the time and expense of cold stabilization only for their white wines. Other producers, especially those who
describe themselves as “natural” winemakers, find the process unnecessary at best. For these winemakers, and their consumers, the presence of tartrate crystals in the bottle is the signature of an authentic wine, not the mark of failure, in the same way that we expect handmade furniture to have slightly uneven joints. The key thing to remember – these crystals are harmless, and when it occurs in bottle the effect on wine flavor is usually imperceptible. So if you get a wine with tartrates and find them unsightly, a strainer is always an option.

**Gavin Sacks** is associate professor of enology and flavor/aroma chemistry in the department of food science at Cornell.