The lesser known wine acids – Succinic acid

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There are several different types of acids found in wine, with the most prevalent acids being tartaric, malic, citric acid. The most abundant of the wine acids arise in the grapes themselves and carry over into the wine. However, there are also some acids that arise as a result of the fermentation process from either yeast and/or bacteria. Winemakers often work with tartaric and malic acid, however, readily available and usable information regarding the "lesser known" acids are limited. This blog post aims to provide more information regarding **succinic acid**.

Is succinic acid present in grape berries?

Succinic acid is only present in **trace quantities in the berries** of *Vitis vinifera* cultivars (<0.1 mg/kg)[1].

How is succinic acid formed?

Succinic acid is a natural **by-product of alcoholic fermentation**[2,3]. It is the main non-volatile carboxylic acid produced by yeast during wine fermentation[4,5].

How much succinic acid is formed during fermentation?

The increase in succinic acid during fermentation can lead to an increase in the wine's total acidity. The formation of non-volatile organic acids during fermentation could **contribute about 1 to 4 g/L to the titratable acidity** (expressed as g/L tartaric acid)[5]. **Succinic acid accounts for about 90%** of the observed increase in acidity[1].

What does the yeast use to form succinic acid?

Succinic acid might derive from either **sugar or amino acid** catabolism by yeast depending on the growth conditions and available nutrient sources[1].

What are the concentrations of succinic acid in wine?

A survey of 138 Australian wines[1] (93 red wines and 45 white wines) showed that succinic acid concentration in finished **red wines ranged from 0 to 2.6 g/L** with a mean concentration of 1.2 g/L. In the **white wines, the succinic acid concentration ranged from 0.1 to 1.6 g/L** with a mean concentration of 0.6 g/L. In general, the concentration of succinic acid in white wines is about half the concentration of succinic acid found in red wines. Winemaking processes such as clarification might contribute to the differences observed.

How does succinic acid contribute to the increase in the titratable acidity of wine?

Usually, a decrease in titratable acidity is observed during fermentation. This is due to the decrease in solubility of potassium bitartrate (KHT) as the alcohol levels increase resulting in the precipitation of the salt. When an increase in titratable acidity is observed, it is usually due to a significant increase in succinic acid during fermentation. These increases are usually more evident in situations where the precipitation of KHT during fermentation was minimal. **The minimal precipitation in combination with the formation of succinic acid could result in increases in titratable acidity during fermentation.**

How much will 1 g/L succinic acid contribute to the titratable acidity value?

One (1) g/L of succinic acid will contribute approximately 1.3 g/L to the titratable acidity value expressed as g/L tartaric acid[1].

How does succinic acid contribute to the sensory perception of a wine?

Succinic acid dissolved in water has an **unusual salty and bitter taste**[1,6]. When compared to solutions of tartaric acid, tasters reported that succinic acid solutions in water (0.5, 1.0 and 2.0 g/L) were unpleasant and indicated that the unusual taste lingered after expectorating[1]. Generally, the relevance of these attributes in wine-like matrices (rather than water-ethanol solutions) has not been well studied[7].

Why is succinic acid a poor candidate for acid adjustments?

Succinic acid is a **weak acid** and the relatively high ethanol content in wine makes it even weaker. Together with the **high buffer capacity of wines**, **even large quantities of succinic acid will have little**

effect on wine's pH[8–10]. For example. 1.0 g/L succinic acid will lower the pH of wine by only 0.018 units when it has an ethanol content of 14% v/v, a pH of 3.5 and buffering capacity of 50 mM/L/pH[8]. However, succinic acid production by fermenting yeasts can be manipulated to manage the titratable acidity of wine, which influences the wine's sour taste[10].

Is succinic acid stable?

Succinic acid is chemically very stable and resistant to microbial attack under anaerobic conditions[6,11].

What are the main factors that influence the production of succinic acid during fermentation?

It is difficult to predict whether a fermentation will produce a higher than usual amount of succinic acid, however, the likelihood of increased succinic acid production could be increased/decreased by employing or avoiding the winemaking practices known to influence the production of this organic acid.

1) Yeast strain

The yeast strain is an important variable affecting the amount of succinic acid produced. One research group found that **cryotolerant or cold-resistant yeast strains were high producers of succinic acid**, compared to non-cryotolerant or mesophilic strains (which produced about half the concentration of succinic acid compared to cryotolerant strains)[12,13]. Cryotolerant strains were defined as those that ferment at temperatures between 6 and 30°C, whilst non-cryotolerant, or mesophilic strains, were defined as those that ferment at temperatures between 12 and 36°C.

Most *Saccharomyces uvarum* (*Saccharomyces bayanus var. uvarum*) strains produce the maximum amount of succinic acid at approximately 18°C[13], but mesophilic strains of *Saccharomyces cerevisiae* usually produce the maximum amount of succinic acid at temperatures close to 24°C[13]. *Saccharomyces uvarum* yeasts are capable of producing much more succinic acid than most *Saccharomyces cerevisiae* yeasts during fermentation of grape juice.

2) Fermentation temperature

Fermentation temperature can significantly affect the concentration of succinic acid formed mainly due to **temperature's influence on the yeast strain** inoculated[13].

In a study[13] investigating the production of succinic acid by cryotolerant *Saccharomyces* yeast strains, researchers found that for all the yeast strains studied, the **succinic acid production increased as the fermentation temperature increased from 6 to 18°C**. Between 18 and 30°C, the concentration of succinic acid either remained the same or decreased slightly for most of the strains studied. No significant temperature effect was observed for the eight mesophilic *Saccharomyces* yeast strains studied.

A study conducted using South African grape musts confirmed that cryotolerant *Saccharomyces cerevisiae* and mesophilic *Saccharomyces cerevisiae* strains will produce **moderate to high levels of succinic acid in fermenting grape juice at temperatures above 18°C**[8].

3) Initial pH and total acidity

It seems that a **higher initial pH and lower total acidity** might **favour the production of succinic acid** during fermentation. In a study conducted[5], succinic acid production was only slightly affected when the initial pH of the juice ranged between 3.0 and 3.8. However, when the pH of the juice was increased to between 3.8 and 4.4 there was a large increase in the non-volatile acidity (mainly attributed to succinic acid). The researchers reported that the increase in the percentage of non-volatile acidity was the largest when the initial total acidity was low[5].

4) Aeration

Aeration during fermentation significantly increased the production of succinic acid by the yeast[8]. Researchers[14] reported that aeration increased the level, or activity, of the enzymes responsible for the production of succinic acid. Even though aeration could potentially increase the production of succinic acid, it does not seem to be a prerequisite.

5) Nitrogen source

Results from a study using South African grape musts showed that **succinic acid production was influenced primarily by the concentration of the metabolizable fraction of the yeast available nitrogen** (YAN)[8]. In this study, the **succinic acid production by fermenting yeast was favoured by moderate amounts of metabolically available nitrogen** (around 300 mg/L) (grape juice with 200 g/L fermentable sugar). Too much metabolizable nitrogen (> 450 mg/L) decreased the amount of succinic acid produced by the yeast[8].

In another study[2] conducted using a synthetic medium containing nitrogen concentrations of up to 500 mg/L, an increase in yeast cell growth and succinic acid formation was observed. However, nitrogen concentrations higher than 500 mg/L did not influence succinic acid production.

During the investigation of the influence of 21 amino acids and ammonium sulphate on the production of succinic acid by *Saccharomyces cerevisiae* in synthetic medium[2] results showed that the **largest amount of succinic acid was produced when glutamic acid was the nitrogen source**. Relatively high concentrations of succinic acid were also obtained in the presence of proline, glutamine, threonine and asparagine, however, the formation was lower when compared to glutamic acid.

Winemaking practices that could affect the nitrogen content in the juice (for instance clarification) could therefore potentially decrease the production of succinic acid during fermentation.

6) Availability of yeast nutrients

Studies have shown that a **lack of essential nutrients pantothenic acid, thiamine, biotin or pyridoxine will decrease the amount of succinic acid produced** by fermenting yeasts[8,15,16]. Generally, grape musts contain sufficient micronutrients to allow yeast growth, however, there are certain conditions that can lead to the juice lacking some of these important micronutrients resulting in lowered succinic acid production:

- soil composition
- degree of infection by moulds
- juice stored for an extended period
- juice treated with high sulphur dioxide additions
- juice subjected to ion exchange
- highly clarified juices

7) Flavonoids and lipids

The presence of **flavonoids and unsaturated long-chain fatty acids in grape juice stimulates the production of succinic acid** by fermenting yeasts[1]. Press juice will contain higher concentrations of flavonoids and lipids than the free-run juice[10,17], which means that **more succinic acid might be formed during the fermentation of press juice when compared to the fermentation of free-run juice.**

Oleic acid, glycerol-oleic acid esters or commercially available yeast hulls (inactivated yeasts, yeast ghosts) can be used to increase the unsaturated fatty acid and sterol contents of clarified grape juice.[18,19]

8) Sulphur dioxide concentrations

Lower concentrations of succinic acid are formed during fermentations conducted in the presence of high bisulphite concentrations. This is due to the interference of sulphur dioxide in the formation mechanism[20] as well as depleting the medium of essential nutrients needed for the production of succinic acid.

9) Sugar concentration

Studies done by the Australian Wine Research Institute (AWRI)[1] showed that the increase in **succinic acid concentration correlated with the decrease in the concentration of sugar** (glucose + fructose). There was also a **correlation between the initial sugar concentration and the final succinic acid concentration** after the fermentation of commercial wines. However, when the succinic acid production was tested using juices varying in sugar content (a range of 15.3°B to 35°B (ameliorated with sucrose)), results showed that the highest concentration of succinic acid was obtained from the juice that contained 24°B[21]. Similarly, a study performed using South African musts found **that succinic acid production by fermenting yeast was favoured by high sugar content (20-24°B)**[8].

10) Clarification

The **degree of clarity of the must** before fermentation might influence the amount of succinic acid formed during fermentation. White musts are often clarified using pectic enzymes and cold settling

before fermentation. More highly clarified musts would contain lower concentrations of nutrients such as amino acids, lipids and vitamins, resulting in lower production of succinic acid.

Why is succinic acid concentrations lower in white wines compared to red wines?

Considering the factors and oenological processes that influence the succinic acid formation, it becomes clear why white wines would contain lower concentrations of succinic acid when compared to red wines. White wines are usually clarified before fermentation resulting in lower concentrations of nutrients such as amino acids and vitamins (factors promoting succinic acid production). White musts also often have lower pH values and are regularly fermented at lower temperatures when compared to red wines. White wine fermentations are rarely aerated which could also contribute to lower succinic acid production.

Even though lower quantities of succinic acid are found in white varieties, it is interesting to note that 24% of the white wines investigated by the AWRI contained succinic acid in the range 0.8 to 1.4 g/L. This concentration represents an equivalent titratable acidity range of about 1.0 to 1.8 g/L expressed as tartaric acid. **This would suggest that succinic acid might be contributing to the titratable acidity of many white wines.**

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