The Wine EXPERT

Practical Winemaking Information

ACETALDEHYDE MANAGEMENT DURING WINEMAKING

What is acetaldehyde?

Acetaldehyde (or ethanal) is the most important volatile wine carbonyl compound and can be formed both biologically (through yeast activity) and chemically (by wine oxidation). It is a small and highly reactive molecule with a green grass, apple-like or nutty aroma. It is very volatile and flavour active (Nykanen, 1986) with a sensory threshold of approximately 100 mg/L in table wines, and chemically very reactive.

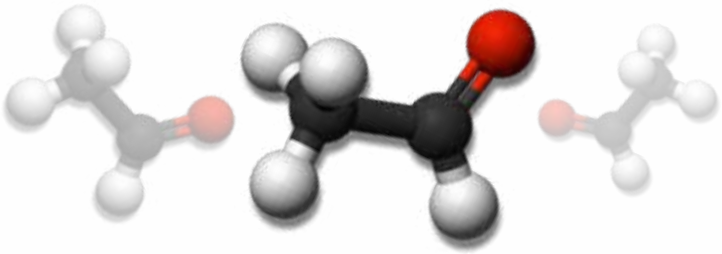

Figure 1: Molecular structure of acetaldehyde.(CH_3CHO)

Why it is important in wine?

Jakowetz *et al.*, (2011) determined that the most relevant SO_2 binding compounds were acetaldehyde, pyruvic and α-ketoglutaric acids because of their binding properties and their usually high concentrations in wines. Acetaldehyde typically accounts for 75% of the bound SO_2 in white wines and 50% in red wines.

Its reactivity and ability to bind with sulfites explain to a large extent why wines need varying amounts of SO_2 and why sulfur dioxide management is important in winery operations and post bottling stability.

Considering growing consumer awareness of the adverse health reactions associated with SO_2 (Yang and Purchase, 1985; Snelten and Schaafsma, 1992), there are considerable efforts to reduce SO_2 contents of wines, and since wines with higher acetaldehyde require more SO_2, this can be a concern. Moreover, acetaldehyde has toxicological relevance itself. It readily binds to proteins (Tuma and Sorrell, 1985) and DNA (Hemminki and Suni, 1984).

How is acetaldehyde managed?

Wine Yeast: The highest concentrations of acetaldehyde are formed by yeast metabolism at the very beginning of alcoholic fermentation. Wine yeast, whether spontaneous or selected *Saccharomyces cerevisiae*, excrete acetaldehyde during the initial phases of alcoholic fermentation. After reaching a peak value, acetaldehyde is then re-utilized to a certain degree. The amounts yielded are quite variable and affected by fermentation conditions and the dominant yeast involved (Ebeler and Spaulding, 1999; Millau and Ortega, 1988, Cheraiti *et al.*, 2009). Other species besides *Saccharomyces cerevisiae* produce acetaldehyde in wines, such as *Schizosaccharomyces pombe* and *Zygosaccharomyces bailii*.

Acetaldehyde production can be reduced by choosing the appropriate yeast (Romano *et al.*, 1994, Cheraiti *et al.*, 2009, Jackowetz *et al.*, 2012). It is mainly strain dependant but is independent of the amount of biomass produced. In many cases, a yeast strain with the highest population is not necessarily one with the highest acetaldehyde production or for that matter, degradation.

How is acetaldehyde managed?

There are always two values that are evaluated when acetaldehyde is measured. The maximal level, which is reached and measured at the end of the exponential phase; and the final level, which is reached and measured at the end of the AF. This final value is important for several reasons. On one hand, if high levels of acetaldehyde are found, there are consequences in terms of SO_2 being bound by this molecule, but on the other hand, in rosé and red wines, certain levels can help stabilize color but if the levels again are above threshold, they impact the sensory characters of herbaceous/green apple/nutty aromas that are not always wanted. It is then important to make the right choice in terms of yeast acetaldehyde production for the wine style desired.

Usually wines, produced by modern vinification methods display fairly low amounts of acetaldehyde at the end of alcoholic fermentation, around 20 ppm in reds and 40 ppm in whites. With regard to re-utilization of acetaldehyde by yeast, winemaking practices that maintain a large number of viable yeast throughout the fermentation allow a better re-utilization of acetaldehyde. Accordingly, adding yeast nutrients and maintaining a moderate temperature (20°C) lead to reduced acetaldehyde residues, while maintaining a cool temperature (12°C) throughout fermentation and no addition of any nutrients lead to larger residues (Jackowetz *et al.*, 2012). Jackowetz *et al.*, (2012) showed that yeast produce more acetaldehyde in response to SO_2 additions.

How is acetaldehyde managed?

Wine bacteria : After alcoholic fermentation and removal of the yeast, few alternatives for the reduction of acetaldehyde remain. Wine bacteria have been shown to contribute to acetaldehyde degradation for a long time (Somers and Wescombe 1987). In a more recent study Jakowetz *et al.*, (2011) have shown changes in acetaldehyde values during vinifications. Figure 2 from Jakowetz *et al.*, (2011) show the initial biological formation by yeast is followed by a partial re-uptake. The second increase is due to involuntary chemical oxidation of ethanol. At 27 days, the wine was inoculated with bacteria to induce malolactic fermentation, which essentially removed all of the acetaldehyde. Because acetaldehyde can be used by wine bacteria, and because yeast can produce various amount of this compound, co-inoculation of yeast and bacteria can be an interesting winemaking practice to consider. For example, in white wines, the contribution of acetaldehyde is mainly negative as it increases bound and hence total SO_2 levels. Co-inoculation becomes a great choice to control the production of acetaldehyde, amongst all the other advantages of co-inoculation (faster MLF, sensory contribution).

Malolactic fermentation also leads to the substantial reduction of pyruvic acid, and partial reduction of α-ketoglutaric acid. Hence, malolactic fermentation can make a significant contribution towards achieving lower bound and total SO_2 levels by degrading these SO_2 binding compounds. If a maximum degradation of acetaldehyde is desired, wines should not be stabilized until seven to ten days after malic acid depletion.

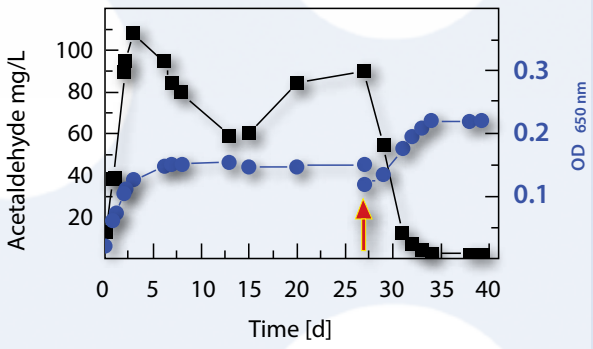

Figure 2: Typical course of acetaldehyde levels during AF and MLF. The blue line marks the turbidity and shows the growth of yeast and bacteria. MLF was induced after 27 days (indicated by arrow).

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Ramón, Professor of Enology at the École d'Ingénieurs de Changins in Switzerland, leads the wine analysis and enology laboratory after having been on faculty at Cornell University (USA) and the University of Guelph (Canada). His research centers on wine yeast and bacterial metabolism and interaction, as well as fermentation automation. He has studied the occurrence of acetaldehyde and its metabolism by yeast and bacteria since 1999. He has authored 30 articles in scientific journals and technical publications, 90 presentations at conferences world-wide, and has supervised 22 graduate students and Post-Docs.

A WORD FROM OUR EXPERT

To understand sources and sinks (formation and degradation) of acetaldehyde in wines, microbiological and chemical aspects have to be considered separately. Acetaldehyde is formed by yeast during the early fermentation phase, and degraded by both yeast (in the second AF phase) and malolactic bacteria. Chemically, it is formed by the oxidation of ethanol through reactive oxygen species that are formed when wines are aerated, either on purpose (e.g. by pumping over or microoxygenation) or involuntarily, notably from oxygen pickup during racking, pumping, filtration or bottling. The speed of such reactions greatly depends on the temperature and requires the presence of transition metals (Cu, Fe) and phenolic substances. Other chemical reactions, such as the polymerization of phenolic substances can lead to its consumption.

In yeast metabolism, acetaldehyde serves as the terminal electron acceptor of the alcoholic fermentation and, hence, is essential for the redox balance of yeast and their ability to create energy through glycolysis. If acetaldehyde is bound by SO_2, whether produced by the yeast or added by the winemaker, it is not available to fulfill this important role. Yeast will compensate such binding by an increased acetaldehyde formation that, eventually, leads to increased levels of bound SO_2 in wines. Malolactic bacteria, too, can increase the energy efficiency of their metabolism by reducing free acetaldehyde to ethanol. On the other side, degradation of SO_2 bound acetaldehyde has an inhibitory effect since intracellularly released SO_2 delays MLF. While white wines typically have around 40 mg/l of acetaldehyde (binding about 60 mg/l of SO_2!), its concentration in reds is 20-25 mg/l because of the effect of malolactic fermentation.

If total SO_2 concentrations are sought to be reduced, understanding the acetaldehyde metabolism of yeast and bacteria is essential. The initial excretion of acetaldehyde can be reduced by diminishing SO_2 addition and choosing low acetaldehyde producing yeast. Where desired, MLF can contribute significantly to the reduction of SO_2 requirement by degrading acetaldehyde as well as other SO_2 binding carbonyls.

Simultaneous AF and MLF are interesting in this context, because bacteria will degrade acetaldehyde immediately as it is formed by yeast. This leads to lower acetaldehyde residues which contribute to lower SO_2 needs in whites. In reds, where acetaldehyde may contribute positively to colour and mouthfeel, it could be shown that aerations (e.g. by pumping over) neutralize the effect of bacterial degradation.

THE RESULTS

The first results shown are those of a study done on a synthetic must with 3 different yeasts, Lalvin S6U, Lalvin ICV D254 and Lalvin QA23. All those yeast have different fermentation rates. In Figure 3, we can see that there is a strong increase in acetaldehyde production during the exponential phase. It is then followed by a reduction until the end of alcoholic fermentation. In this study, the concentration varied at the maximum between the Lalvin S6U at 0,147 g/L, 0,087g/L for the LalvinQA23 and 0,05 g/L for the Lalvin ICV D254. The Lalvin ICV D254 had the faster fermentation rate and the lowest acetaldehyde production, whereas the slow fermenting Lalvin S6U had a higher acetaldehyde production. However, the final concentration is quite similar for all three yeasts, even though the maximum levels varies.

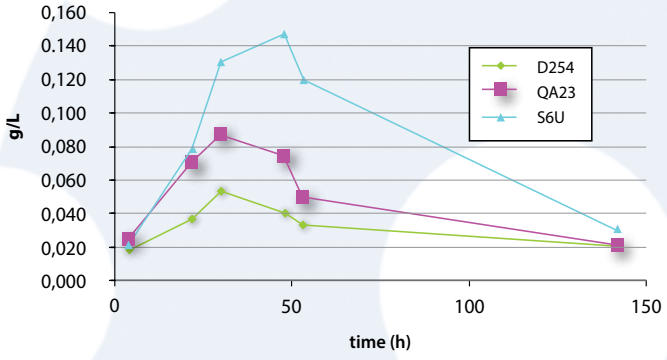

Figure 3: Acetaldehyde production for three selected yeast in a synthetic must (MS300, 24°C, 25g/hL).

THE RESULTS

Lallemand wine yeasts were characterized for acetaldehyde production in a synthetic must during alcoholic fermentation. We can see in Figure 4a and 4b that even though some yeasts have very high maximum concentration of acetaldehyde at mid-fermentation (Figure 4b), it can differ from the final concentration (Figure 4a). For example, the yeast 21, has up to 120 mg/L during the maximum production, one of the highest levels, but the final concentration is a medium level at 15 mg/L. Generally, it is also found that there is no correlation between the maximum level found and the final level found.

A new yeast, Lalvin ICV OKAY® is a not only a very low final acetaldehyde producer, but it has the capacity to produce no or extremely low level of SO_2 and H_2S. This is a characteristic that is very important with wine consumer concerns about SO_2 levels, and ultimately, acetaldehyde production due to the SO_2 binding properties of this compound.

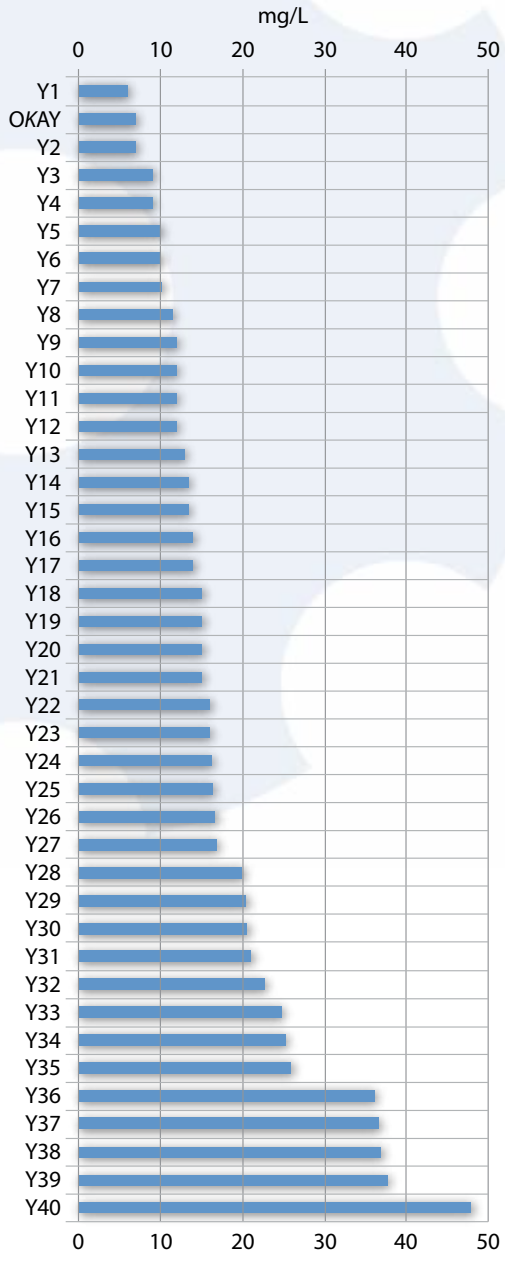

Figure 4a: Classification of yeasts with their final acetaldehyde production assayed during the alcoholic fermentation

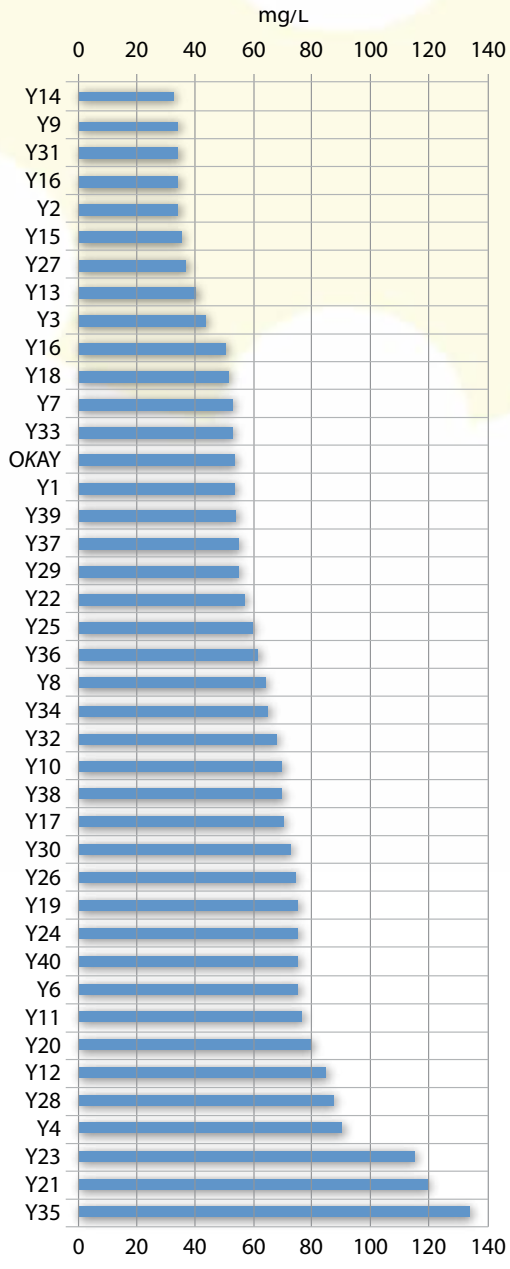

Figure 4b: Classification of yeasts with their maximum acetaldehyde production assayed during the alcoholic fermentation

THE RESULTS

Wine bacteria also have the capacity to metabolize acetaldehyde. As shown in figure 5, during malolactic fermentation, the wine bacteria will degrade, after a short delay, acetaldehyde along with the degradation of malic acid. This is an important factor when choosing the wine bacteria, as it not only should be compatible with the yeast fermenting the must, but also a positive synergy between the yeast ability to produce acetaldehyde and the wine bacteria to use it efficiently can be factored in when pairing the micro-organisms for post-AF or co-inoculation. In a study done by Wei *et al.*, (2011), it was shown that acetaldehyde concentrations peaked during early phases of Chardonnay fermentation regardless when the MLB were inoculated. However, the pH had a strong effect on the maximum acetaldehyde concentration depending if co-inoculation was used or post-AF inoculation (Table 1).

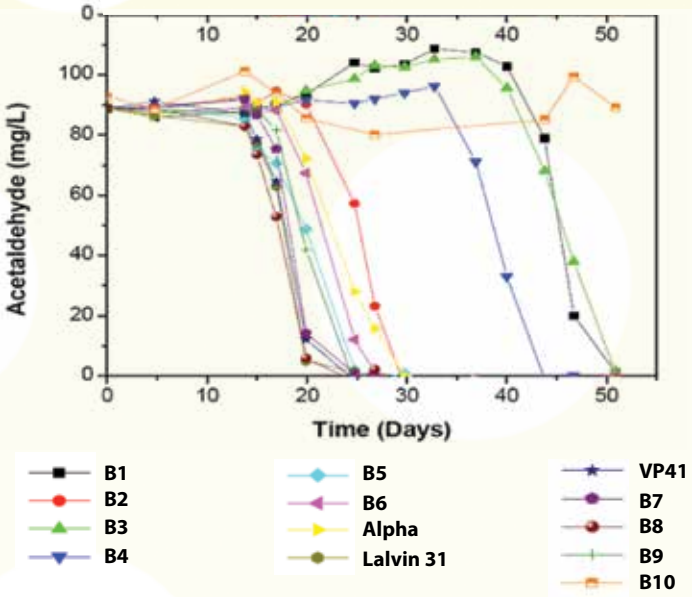

Figure 5: Acetaldehyde degradation by wine bacteria in a Riesling wine (M.de Orduña, 2010)

Final Value		pH 3.2	pH 3.35	pH 3.5	pH 3.65
Acetaldehyde mg/L	Post-AF	29.6	30.4	16.0	12.6
	Co-inoculation	19.0	12.5	15.4	7.3

Table 1 : Acetaldehyde values in Chardonnay wines produced from post AF or co-inoculation at 4 diffirent initial pH values (adapted from Wei et al 2011)

When the pH was higher, there were less differences between the inoculation techniques. After reaching the maximum, acetaldehyde levels decreased in all fermentations but the decrease was faster in co-inoculation and correlated with malic acid degradation. The residual acetaldehyde levels were lower in wines produced by co-inoculation which was reflected by the bound SO_2 levels.

Jackowetz *et al.*, (2011) also correlated the decrease in carbonyl compounds such as acetaldehyde with the bound SO_2 levels. Across all wine bacteria strains, the decrease in average bound SO_2 levels during MLF was 22%. The largest reduction in wine carbonyl content occurred in the week after completion of MLF and was a 53% (reduction from 107 mg/l to 34 mg/l) calculated as bound SO_2.

A QUICK SUMMARY

The topic of acetaldehyde is very interesting as this compound has SO_2 binding properties. The proper choice of wine yeast and bacteria are key factors in determining the final levels of acetaldehyde produced. If SO_2 concern is an issue, then choosing a yeast with low final acetaldehyde production such as the Lalvin ICV OKAY® is very important. Wine bacteria can also be an ally as they will use acetaldehyde during malolactic fermentation. If color is an issue, and since acetaldehyde can help stabilize color, than a yeast with medium to high production can be used. When co-inoculation of wine yeast and bacteria is preferred, the acetaldehyde production by the yeast is used by the wine bacteria during malolactic fermentation. A proper fermentation management and nutrition has also been shown to influence the concentration of this compounds, as well as judicious oxygen management. With more and more conscious effort to properly manage the SO_2 levels in wines, knowing how the wine yeast and bacteria were characterized for acetaldehyde production becomes a valuable tool for winemakers.

Available on the App Store
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