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Increased use of screwcap closures has highlighted the problems of reduction in wines. But is reductive winemaking always a bad thing? Jamie Goode explains both sides of this complex topic and argues that more research could paint a different picture of terroir-driven wines

It's difficult to know how to pitch a piece like this. While every winemaking expert I've consulted agrees that reduction is an important topic to cover, there's no doubting that the subject is a horrendously technical one. So I'm faced with a three-way choice. First, I can write an in-depth piece that will please the experts, but alienate most readers. Second, I can dumb it down to the extent that it will be accessible to everyone, yet runs the risk of lacking depth, and the science types will feel I'm patronising them. The third option – which I've decided to attempt – is to try to present this rather technical subject in a way that makes it understandable (and even interesting) to non-scientific types, while at the same time not being scared of the hard-core wine chemistry where it's necessary for the story. Let's hope this is possible.

'I feel reduction is a key topic for the trade,' says Sam Harrop of Marks & Spencer, 'because there is a lot of confusion over just what it is. The term "reduction" is used extensively in tastings and I feel that in a lot of circumstances people don't really understand what it means.' So, just what is a 'reduced' wine, and what do people mean by 'reduction character'?

We need to start with some elementary chemistry. It's all about oxygen. 'Reduction and oxidation are like orient and occident,' explains Richard Gibson of Scorpex Wine Services, 'opposites that depend on the relative absence of oxygen (reduction) and the relative presence of oxygen (oxidation).' The precise definition depends on measuring what is known as the redox potential, which compares the affinity of substances for electrons. According to Gibson, this measure is rarely carried out in wines.

Redox potential is measured in millivolts (mV). Typically, an aerated red wine will have a redox potential of 400–450 mV, whereas storage in the absence of air for some time will reduce this to 200–250mV. If levels get as low as 150mV then there is a danger that reduction problems can occur. Exposure to oxygen through winemaking practices such as racking, topping up barrels and filtering increases the level of dissolved oxygen in the wine and increases the redox potential, which will then return to 200–300mV. The effect of oxygen exposure is more severe in white wines, which have a lower buffering capacity (their redox state will change more easily) than reds. Another variable here is the level of free sulphur dioxide in the wine, which as an antioxidant will act protectively by absorbing the oxygen. Yeast lees also scavenge oxygen and protect the wine in a similar fashion, helping to lower the redox potential.

That's probably still too scientific for many readers, so let's try to unpack it a bit. Most people are familiar with the idea that if you expose wine to air (which contains oxygen) for long enough it becomes oxidised. And with the exception of just a few wines that are deliberately made in an oxidised style – such as Madeira, vin jaune and Sherry – this is a bad thing. Well, reduction is the opposite. 'In wine,' explains Gibson, 'it is enough to say that a state of reduction applies when air is absent. Thus when grape harvest, fermentation, maturation and bottling are carried out without air contact or with lashings of antioxidant, reductive winemaking practices have been followed.'

So, oxidation is bad, reduction good, it seems. 'In Australia,' says Gibson, 'reductive winemaking has been central to the development of fruit-driven white styles with crisp palates. In reds, reductive winemaking tends to produce a "tighter", more fruit-driven style.' He adds that, 'Brian Croser taught reductive winemaking in Australia, at Riverina College, in the late 1970s, and it has been central to the rise in Australian white wine quality, especially for aromatic varieties.'

The dark side of reduction

So, where is the catch? While keeping a wine away from oxygen is usually a good thing, reduction has a dark side. The danger is that it can encourage the development of reduced sulphur compounds, which have a significant effect on the flavour of wines, even at tiny concentrations. This results in what is described as a 'reduced' or 'reductive' character, and when the term 'reduction' is used in a wine context, it is the presence of these sulphur-containing compounds to which people are invariably referring. This is a major headache for winemakers who work reductively.

The main baddie here is hydrogen sulphide. 'This is easily formed by yeast during fermentation, whenever there are stresses – including nutrient deficiency,' explains Phil Spillman, winemaker with New Zealand's Villa Maria. 'When a yeast cell finds its preferred nitrogen source [ammonium and amino acids] in limited supply, it can turn to the two sulphur-containing amino acids, liberating the sulphur in them as hydrogen sulphide. Winemakers find that many conditions of non-nutritional stress (e.g. temperature-change or dry goods additions) can also cause yeast to produce hydrogen sulphide, so we usually add some diammonium phosphate [DAP, a yeast nutrient] whenever such conditions are encountered or imposed.'

Spillman continues: 'Mercaptans are a group of larger, sulphur-containing molecules, which are formed slowly where hydrogen sulphide is not removed promptly. These compounds are more worrying for winemakers, because they are difficult to remove. So, good winemaking practice includes protocols for removing hydrogen sulphide (by copper sulphate addition) before there is any chance for them to evolve into mercaptans.'

Time to talk to an expert on wine flavour chemistry. Dr Leigh Francis is a senior research chemist with the Australian Wine Research Institute (AWRI), and he has a particular interest in sensory analysis. I quizzed him about how he would define 'reduced' in the context of wine tasting. 'The word is usually reserved for aromas arising from what are presumed to be sulphur compounds,' he explains. 'Often, tasters at the AWRI would have sufficient technical knowledge to be aware of how particular sulphur compounds smell, and often use the chemical name rather than an evocative descriptor.' Francis then explains the descriptions of some of these compounds in sensory analysis work. '"Reduced"', he says, 'would encompass aromas such as:
• hydrogen sulphide (and only rarely would a taster go the extra step of delineating the aroma as "rotten eggs",

or similar);
• mercaptans, or thiols: and tasters would define these aromas with words such as cabbagey, rubbery, burnt rubber;
• sometimes a more general term would be used, such as “sulphidic”, which would encompass both of the above;
• struck flint;
• there is at least one other specific sulphur compound that tasters are aware of, and this may sometimes be included in the term “reduced” – DMS (dimethyl sulphide), which has its own normally distinctive aroma of cooked vegetables. At high levels these are reminiscent of cooked corn or canned tomato; at lower levels, they are similar to blackcurrant drink concentrate. And sometimes, wines showing an apparent DMS aroma will have a “reduced” stinky note as well.’

In addition, Francis points to recent research carried out by Denis Dubourdieu and colleagues at the University of Bordeaux. ‘4-mercapto-4-methylpentan-2-one, 3-mercaptohexan-1-ol and 3-mercaptohexyl acetate are relatively newly identified compounds responsible for the tropical fruit/passion fruit aroma at particular concentrations, and cat’s urine aroma at higher levels,’ says Francis. ‘These compounds have been found in Sauvignon Blanc, but also in other white varieties and even in red wines, where they probably don’t provide a tropical fruit aroma, but may contribute to blackcurrant character. Work has been done to indicate that yeast strains will strongly influence the levels of these compounds during fermentation.’

And there’s more: ‘Benzenemethanethiol has recently been implicated in smoky/gun flint aromas, and oak-derived thiol compounds have been implicated in coffee oak character,’ he adds. But it’s not a simple case of avoiding these reduced characters altogether. ‘Most commonly reduced aromas would be considered a negative by our panellists, but not always,’ he explains. ‘And often, our panellists are simply instructed to rate the intensity of particular attributes, rather than give a quality judgement. Usually, the term in a tasting note would indicate that a wine had a “stinky” cabbagey/rubbery/sewage note that, depending on the intensity, could render it faulty and unpleasant, but it may be only a slightly noticeable character. If the compound responsible is hydrogen sulphide, it can disappear with a swirling of the glass, and make a final decision more difficult for the taster.’

Researcher and consultant Dr Pascal Chatonnet also sees reduction as a double-edged sword. ‘An excess of reduction can produce off-flavours, coming from an excess of volatile sulphur compounds,’ he says. ‘But a good equilibrium permits the maintenance of some very sensitive aromatic products involved in the “flowery” and “fruity” character of young wines.’

The winemaking tightrope

Richard Gibson states that, ‘walking the tightrope between enough oxygen exposure to give wines complexity without reaching a level that causes apparent oxidation is one of winemaking’s big challenges’.

‘Mastering reduction during the winemaking process and during ageing is the only way to protect the “fruity” character of wines (red included)’, says Chatonnet. ‘Some oxygen is, of course, necessary to prevent any excess of reduction with synthesis of off-flavours. It is more difficult with red wines, because we need oxidation to promote the positive evolution of the tannins and colour stabilisation, while at the same time knowing that a strong oxidative stress can destroy the original fruit.’

Gibson emphasises that it is important to use the right technique for the right wine. ‘Aromatic whites benefit from reductive winemaking, which allows the clear expression of the varietal character, unsullied by oxidation. The same applies for lighter, fruit-driven white styles. Bigger reds need air during maturation, because the phenols absorb oxygen, which leads to polymerisation and complexity.’

Gibson also thinks it is important to use the right technique at the right time. ‘Oxidative juice handling for whites is a pretty popular technique. Grapes are picked without sulphur dioxide and the juice is processed with air contact. All the susceptible phenols polymerise and the juice goes a horrid brown. Ferment as normal. The phenols precipitate and the resultant wine is relatively free of phenolics. From then on handle the wine reductively.’

Along similar lines, some red grape varieties are regarded as reductive (e.g. Syrah and Mourvèdre), and others as oxidative (e.g. Grenache and Pinot Noir). ‘For winemaking, some varieties are originally very reductive,’ says Pierre Perrin, of Château de Beaucastel. ‘We have to give oxygen to them, but not as much as they need, to keep a little reduction for bottling. The varieties which are sensitive to oxygen are kept away from it.’

Toying with reduction

So it seems that while the development of reduced sulphur compounds in wine is normally best avoided, there are some circumstances where they can contribute something positive. Indeed, some winemakers have deliberately set out to use reductive winemaking techniques to encourage the development of these compounds as complexing agents in their wines. This is currently quite a hot topic in winemaking, it seems, although few research studies have addressed it directly.

James Healey, winemaker at Cloudy Bay, comments that ‘toying with reduction is a risky business that requires a bit of courage, experience and knowledge, mixed in appropriate portions’. He continues, ‘Reduction can be a very positive thing in certain wine types and not in others. For example, in Champagne the bready/brioche character from ageing for a period on lees is a result of a certain type of reduction in association with autolysis [self-destructive breaking down of structure] and liberation of the contents of yeast cells into the wine. The reductive characters from fermentation of Chardonnay juice containing highish solid concentrations result in accentuated nuttiness and improved texture after ageing on lees for some time. And the “cat’s pee”, or sweaty character, that develops during fermentation of Sauvignon Blanc from cooler climates is the result of a certain reduction-related compound. In fact,’ says Healey, ‘the sweaty character is so close to hydrogen sulphide that one must be careful that the sweat doesn’t mask the sulphide in a young wine about to go into bottle. I have seen wines spoiled as a result of the sweat diminishing with time and sulphides becoming more evident. Obviously, the sweaty story could be seen as good reduction or bad reduction, depending upon your liking for Sauvignon.’

Dr Leigh Francis agrees that reduced characters aren’t always negative. ‘Overall, as always with flavour chemistry and sensory properties, it is hard to be too definitive about negative/positive. A small amount of a particular character in a wine that has other fairly strong aroma attributes will likely be accepted and liked. It’s

when the aroma dominates that the [reduced sulphur] compounds could be considered negative, but this is probably the case with any aroma you can think of: too much of a good thing can be too overwhelming and make the wine too simple – and not attractive enough to drink too much of it. For sulphur compounds in general it does seem, however, that when they're at very high concentrations an unpleasant note becomes evident, no matter how pleasant they seem at lower levels, which is not the case for many other flavour compounds. It is likely that hydrogen sulphide will be negative, no matter what level.'

Phil Spillman sums it up well. 'In a broader sense, the hundreds of aroma, flavour and tactile compounds that make up wine are in various states of reduction or oxidation. Both processes have a bad name in wine, because the words are used to describe extremes. Reduced is used to describe a wine that is generally sulphidic, and oxidised for one that is aldehydic. However, attractive compounds can also result from these processes.'

Spillman also has a specific suggestion for how reduction might combine with oak barrels to add complexity. 'An oak compound, furfural, is reduced in wine to furfuryl alcohol, and I have heard conjecture that this compound can react with the old devil, hydrogen sulphide, to produce a compound that possesses a coffee-like aroma. Unfortunately, I am not aware of any literature that can substantiate this, but, as a winemaker, I am interested in playing around with such ideas, in the pursuit of complexity. But all such exploration should occur in the early stages of wine production, well before bottling, a point at which all quality aspects should be well refined.'

Deconstructing terroir?

Sam Harrop has a fascinating idea, albeit one that may prove difficult to test. In chemical terms, minerality is an ill-defined quality in wine, but when it does occur it is commonly explained as being a terroir character. But what if it is actually a consequence of reduction, caused by a combination of volatile sulphur compounds at low levels? 'Wines from many of the best wine regions in France show mineral/reductive qualities,' says Harrop. 'Perhaps these qualities are derived in the winery and not the vineyard.'

'I do believe that minerality and reduction are related,' says Healey. 'It could be a result of struggling ferments coupled with nutrient deficiency/vine stress, but I don't think that this is why great white Burgundy or Riesling achieve this character. I think these wines derive this character because the producers understand how to get it from their vines and vinifications. I suppose that someone could fluke it from time to time, but there are many great producers that consistently hit the nail year after year.'

Gibson is less sure about this effect on terroir characters. When I asked him about minerality and reduction his response was, 'You expect an Australian to answer this with a straight face? "Minerality"? This is a very difficult term to define.' He adds, 'I think terroir characters are unlikely to be a function of reduction. Reductive characters favour varietal expression. The situation in the south of France and Italy with Australian-style winemaking highlights this.'

Screwcap reduction

One reason why reduction is currently a hot topic is because of the increasing adoption of screwcaps. Because screwcaps provide a tighter seal than tree bark and synthetic corks, they encourage reduction. The potential hazards here were emphasised in the ongoing AWRI trial on closure types, where the Semillon wine used in the trial developed a rubbery reductive taint after bottling with screwcaps.

This issue was recently addressed in a Technical Review from the AWRI, which confirmed that the aroma was due to chemical reactions of sulphur compounds in the reduced environment of the screwcap seal. Interestingly, this smell didn't diminish over time.

But this is by no means a consistent feature of screwcapped wines, and there is no solid data suggesting that this is more likely to be a problem with screwcaps than with natural cork. Even if negative reduced aromas turn out to be a general screwcap hazard, they could be eliminated by measures such as bottling with a bigger headspace, using less sulphur dioxide at bottling, avoiding ascorbic acid use (antioxidant) and taking care to eliminate sulphide compounds in the wine at bottling.

Conclusions

So, lots of questions, few solid answers, and plenty of room for further research. The chemistry of reduced sulphur compounds is fairly complicated, but an increased understanding of their evolution in wine would permit winemakers to manipulate their levels with a view to increasing complexity. There's even the tantalising prospect that some of the 'terroir'-like characters in Old World styles could be understood in terms of sulphur chemistry, and perhaps allow the production of more 'terroir'-like New World styles.

There are several other issues related to reduction that, because of space restrictions, I haven't touched on here. One is the role of micro-oxygenation, a technique that is becoming increasingly popular. Could micro-oxygenation be used as a tool to eliminate reduction in situations where reduced sulphur compounds would be a problem, such as leaving white wines on their lees in the anaerobic confines of a tank? Then there is the vexed but crucial issue of the role of oxygen exposure in the development of fine wines in bottle over many years. Is there enough dissolved oxygen in the wine at bottling to support extended ageing? This is critical to the potential adoption of screwcaps for fine red wines.

This leads to a final – and intriguing – question. Would a technically perfect wine be boring? Chemically, wine is bewilderingly complex. Is it the case that there exist components of wine which at low levels impart complexity, at higher levels are considered as faults, and vice versa? And how can winemakers walk the winemaking tightrope of encouraging the development of these complexing factors, while avoiding faulty wines? More research, please.