Climate Change

Understanding carbon emissions in the wine industry

Tadro Abbott and **Eric Wilkes** from the Australian Wine Research Institute examine the carbon footprint of wine and how it could help to mitigate climate change.

Climate change has been called the largest risk to the global economy (World Economic Forum, 2016). Global warming has already reached 1°C above pre-industrial levels and drastic change is needed if warming is to be limited to 1.5°C (Intergovernmental Panel on Climate Change, 2018). In recent times there has been some discussion on the importance of carbon dioxide emissions from fermentation, in particular wine fermentations. This article seeks to put these emissions in context and discusses wine's unique opportunity to positively contribute to carbon emission reduction.

The carbon footprint of wine is relatively low. Estimates of the average footprint of Australian wine range from 0.6-1.4kg carbon dioxide equivalent per litre (CO_2e/L) depending on how it is packaged and the destination market (Abbott *et al*., 2016). The weighted average based on the overall Australian production mix (glass vs. bulk, domestic vs. export, large vs. small wineries) was 1.2kg CO_2e/L. This equates to an Australian industry footprint of approximately 1.6 million tonnes of CO_2e in 2017. This includes glass production, transport and bottling of bulk wine in its final destination, which together make up the bulk of the footprint. Winemaking itself contributed 17% of the footprint (0.27 million tonnes CO_2e) and grapegrowing contributed 15% (0.24 million tonnes CO_2e). To put this in context, civil aviation in Australia (domestic and international) contributed 22 million tonnes CO_2e (Department of Infrastructure, Regional Development and Cities, 2019) and transport in general contributed 101 million tonnes CO_2e (Department of the Environment and Energy, 2018). Many wine producers are already making efforts to reduce carbon emissions by measures such as using solar energy and reducing fuel use in vineyards. Importantly, as explained below, CO_2 released during fermentation does not contribute to the wine industry's carbon footprint.

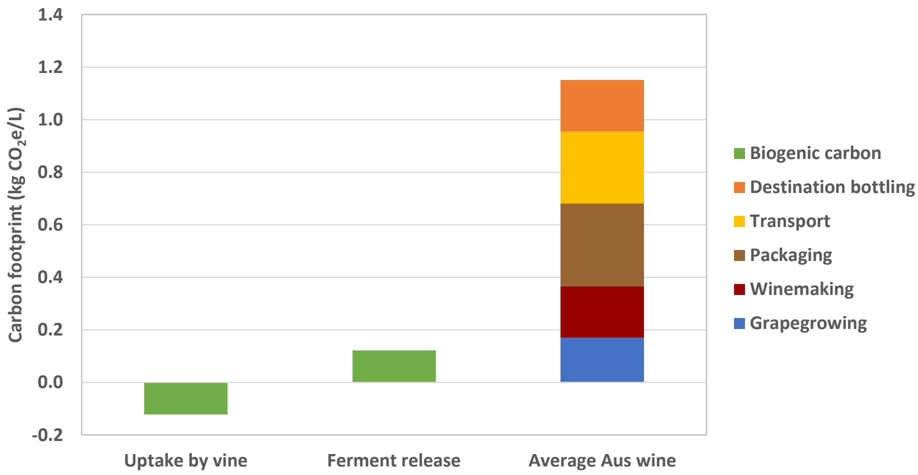

Figure 1. Fermentation emissions in the context of the lifecycle carbon footprint of wine.

How do emissions from ferments factor in?

Fermentation is a biological process that converts sugar into ethanol, with carbon dioxide as a by-product. This complex process can be approximated by the chemical formula:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Every gram of sugar fermented produces approximately 0.49 grams of CO_2. For juice at a typical 14° Baume (~250g/L of sugar) this equates to approximately 122g CO_2/L of juice fermented, or 62L of CO_2 gas at standard temperature and pressure.

It is important to consider, however, the actual source of the sugar used in the fermentation process. CO_2 released from fermentation is part of the short-term carbon cycle, also called biogenic carbon. This is carbon that has been taken out of the atmosphere by the grapevine to grow the grapes, vine and leaves. The carbon that ends up in the juice is returned to the atmosphere during ferment and subsequent consumption. If the grape juice was simply consumed directly, the same net carbon return to the atmosphere would occur. This cycle of uptake by plants and re-release as the material breaks down repeats in a closed, net neutral cycle, and is the same for all plant-based food products (e.g. wheat, apples, melons). There is no net increase to atmospheric carbon levels over time, so these processes are not included in carbon footprint calculations. This contrasts with fossil fuels which were stored and formed in the earth over millions of years, and then released in a very short time through combustion, resulting in a significant net increase in atmospheric carbon levels.

The scale of carbon emissions from ferments is shown in context of the overall carbon footprint of wine in Figure 1. As can be seen, a much greater impact on industry contributions to greenhouse gas emissions can be made by more efficient packaging and transport than in simply addressing the release of CO_2 during fermentation. That is not to say that the capture and reuse of CO_2 does not have a part to play.

So why worry about ferment CO_2?

The world needs to drastically reduce the amount of carbon being put into the atmosphere in order to limit global warming to 1.5°C as prescribed in the Paris Agreement (United Nations Framework Convention on Climate

Change, 2018). There are several mechanisms proposed for doing this. A major one is to reduce global reliance on fossil fuels. Another is to capture and store carbon emissions, preventing them from entering the atmosphere. It is incontrovertible that carbon emissions from fossil fuel use are a major contributor to overall increases of carbon in the atmosphere; however, on a per volume basis, the carbon content of combustion exhaust from fossil fuels is actually quite low at around 14% (Audi, 2000). This is because the majority of the exhaust gas is nitrogen, due to the fact that the fuel is mixed with air prior to combustion. This makes capturing and compressing the exhaust gas rather inefficient, as one needs to process seven volumes of gas per volume of CO_2.

Fermentation exhaust is a much more concentrated source of CO_2 (up to 90% depending on fermenter design and stage of fermentation) so would be a more efficient source for carbon capture per tonne of carbon produced. While wine is not a significant carbon emitter, wine and other alcoholic fermentation industries have a unique opportunity to interrupt the biogenic cycle and remove carbon from the atmosphere. The fermentation process would then be carbon negative and count as a credit towards the product's carbon footprint. This is one of the opportunities for wine to make a positive, if small, contribution to the mitigation of climate change, while understanding that initiatives in packaging and transport are likely to have a greater overall impact.

What are the options for capturing CO_2 during wine production?

The brewing industry has a long history of collecting CO_2 for reuse, but this does not remove it from the carbon cycle as it is just reintroduced into the product during carbonation and released on consumption. The process however does reduce the need for production of CO_2 from other sources that would otherwise be needed. The nature of the brewing process, with a limited number of fermenters in constant use, also makes adding the infrastructure to capture and reuse the CO_2 much more cost effective than in a typical winery situation.

There are a few examples of companies making use of ferment CO_2 for other purposes in the winery. Vivelys has a system for monitoring ferment progress by measuring CO_2 gas flowrate out of the fermenter (Nordestgaard, 2018). Parsec also measures ferment progress by measuring and periodically venting tank pressure. Enomet (2016) and Oresteo (2019) both capture and compress ferment CO_2 for reuse around the winery (e.g. mixing ferments, tank cover, etc.). All of these solutions still ultimately vent the CO_2 to atmosphere but gain some value from it beforehand. In the case of using CO_2 as a gas cover in tank, this also reduces the need to source (and release) CO_2 from other sources. Appropriate piping after the intended use could enable subsequent capture and storage/conversion for other uses.

There are also examples of wineries trialling capture and conversion technologies. Smith Haut Lafitte in Bordeaux is capturing ferment CO_2 and converting it into solid sodium bicarbonate to sell as a by-product for other uses (Kevany 2017). In some cases, the CO_2 is re-emitted on use of the bicarbonate but it is offsetting other bicarbonate production. In 2017 the winery produced about eight tonnes of bicarbonate from ferment gas. Bodegas Torres in Spain has a research program that has trialled eight different technologies, including converting ferment CO_2 into methane to use as a tractor fuel, and converting it into solid carbonate for storage in the earth (Eads 2017). Perhaps the best way to maximise value of carbon capture technology from ferments is to combine some of these options so that the cost of the required plumbing and equipment can be shared over different uses. Ferment CO_2 could first be used for ferment monitoring, then compressed and used around the winery for mixing and tank cover, then finally recaptured and converted for storage. In any case, there are clearly opportunities to make greater use of the concentrated CO_2 stream generated by fermentation, and for the wine industry to make a positive contribution to human efforts to reduce carbon emissions. CO_2 emissions from fermentation may only represent 10% of the available process carbon in wine production (and not carbon that is contributing to the overall footprint); however, it is accessible to current technologies and represents a viable option to offset some carbon emissions. It is important, however, that focussing on carbon capture does not limit efforts in other aspects of wine production that could provide significant overall reductions in carbon emissions.

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References

Abbott, T.; Longbottom, M.; Wilkes, E. AND Johnson, D. (2016) Assessing the environmental credentials of Australian wine. *Wine Vitic. J.* 31 (1):35-37. Available from: https://www.awri.com.au/wp-content/uploads/2013/01/1792-abbott-WVJ-31-1-2016.pdf.

Audi (2000). Motor Vehicle Exhaust Emissions http://www.volkspage.net/technik/ssp/ssp/SSP_230.pdf, viewed 1/3/2019.

Department of Infrastructure, Regional Development and Cities (2019) Aviation Emissions. https://infrastructure.gov.au/aviation/environmental/emissions/index.aspx. Accssed 1 March 2019.

Department of the Environment and Energy (2018) Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2018. http://www.environment.gov.au/system/files/resources/4391288e-fc2b-477d-9f0b-99a01363e534/files/nggi-quarterly-update-sept-2018.pdf. Accessed 1 March 2019.

Eads, L. (2017) Bodegas Torres: Green sky thinking. The Drinks Business. https://www.thedrinksbusiness.com/2017/10/bodegas-torres-green-sky-thinking/. Accessed 4 March 2019.

Enomet (2016) Galileo. www.enomet.it/en/prodotti-enomet/galileo/?portfolioID=1442. Accessed 1 March 2019.

Intergovernmental Panel on Climate Change (2018) Special Report: Global Warming of 1.5°C Summary for Policymakers. www.ipcc.ch/sr15/chapter/summary-for-policy-makers. Accessed 3 March 2019.

Kevany, S. (2017) Smith Haut Lafitte is producing baking soda. Meininger's Wine Bus. Int. www.meininger.de/en/wine-business-international/smith-haut-lafitte-producing-baking-soda. Accessed 1 March 2019.

Nordestgaard, S. (2018) Trends in wine production technology & future challenges, Winery Engineers Association Conference 2018, https://s3.amazonaws.com/wea-website-files/2018_WineEng_SA/AWRI+Simon+Nordestgaard+-+Trends+in+Wine+Production+%26+Future+Challenges.pdf, viewed 1/3/2019.

Oresteo (2019) www.oresteo.com. Accessed 1 March 2019.

Parsec. Management of alcoholic fermentation. www.saen5000.com/en/alcoholic-fermentation. Accessed 1 March 2019.

United Nations Framework Convention on Climate Change 2018. The Paris Agreement, www.unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Accessed 1 March 2019.

World Economic Forum 2016. More Walls, More Warming, Less Water: A World at Risk in 2016, http://reports.weforum.org/global-risks-2016/press-releases/. Accessed 4 March 2019.

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