Alternative packaging and wine
Should we move beyond the green bottle?

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With transport and glass packaging representing 74% of the greenhouse gas emissions produced during the lifecycle of Australian wine, these areas are obvious targets for improvement in the industry's efforts to reduce its carbon footprint. In this fourth and final article in our 'Towards Net Zero' series, the authors compare the carbon footprint of different packaging options and the technical considerations involved in their selection.

BACKGROUND

In line with the international treaty on climate change adopted by 196 countries in Paris in 2015 (the Paris Agreement), the Australian wine industry has set a target of zero emissions by 2050. An emissions reduction roadmap is being developed to guide producers on how to reach this target. As part of this process, the Australian wine industry's 2020-21 baseline emissions were measured as 1,770,997 tonnes of carbon dioxide equivalents (t CO2-e). Of this total, 49% of emissions were directly related to industrial processes and supply chain factors, with another 29% of emissions directly related to transport.

This assessment aligned closely with the Australian wine industry life cycle analysis (LCA) recently undertaken by the Australian Wine Research Institute (Hirlam *et al*. 2023) updating a similar study conducted by the AWRI in 2016 (Abbott *et al*. 2016). The updated LCA showed that transport and glass packaging (i.e. production and supply chain emissions) were hotspots that together represented 74% of the total life cycle. As such, it is obvious that packaging and transport must be a primary focus in the wine industry's efforts to reduce its carbon footprint.

WINE PACKAGING

Over the history of wine, packaging has continued to evolve, from the days when wine was shipped and dispensed from clay and ceramic amphoras, to the evolution of the glass wine bottle and cork stoppers in the 17th century, through to current day where packaging options include different types of glass, bag-in-box, kegs, aluminium cans, plastic bottles, paper bottles and plastic pouches. When comparing the carbon footprint of different packaging options, it's important to consider not just the energy used to produce the packaging, but also how it affects emissions related to transport, which make up a significant part of wine's overall footprint. Figure 2 shows differences in greenhouse gas emissions associated with five packaging formats under a domestic distribution scenario (Hirlam *et al.* 2023).

TECHNICAL CONSIDERATIONS FOR ALTERNATIVE WINE PACKAGING FORMATS

When evaluating the performance of wine packaging, the key factors are whether it will preserve the wine without tainting (adding unwanted flavours) or scalping (removing characteristic flavours), and whether it will sufficiently exclude oxygen and other environmental contaminants. Assessing these factors can be complex as they depend on the nature of the product, the environmental conditions it is likely to experience and the required shelf life.

Flavour impacts

Tainting and scalping are generally relatively well controlled in modern packaging, with well-defined protocols for the assessment of new packaging materials. It is still important, however, that all new variations on materials are carefully assessed, as the interactions with wine components are hard to predict, and unintended outcomes are possible. One example is the recent move to package wine in cans (a packaging format that has been well established for other beverages). Early adopters of this format found that a large proportion of wines developed 'reductive' characteristics after as little as three or four months in the package. While this was initially attributed to the low oxygen transmission rate of the can, recent research conducted at Affinity Labs and other locations has identified a different cause. Imperfections in the plastic lining of the cans have been shown to allow contact between the wine and the aluminium of the can, which then interacts with the SO_2 in the

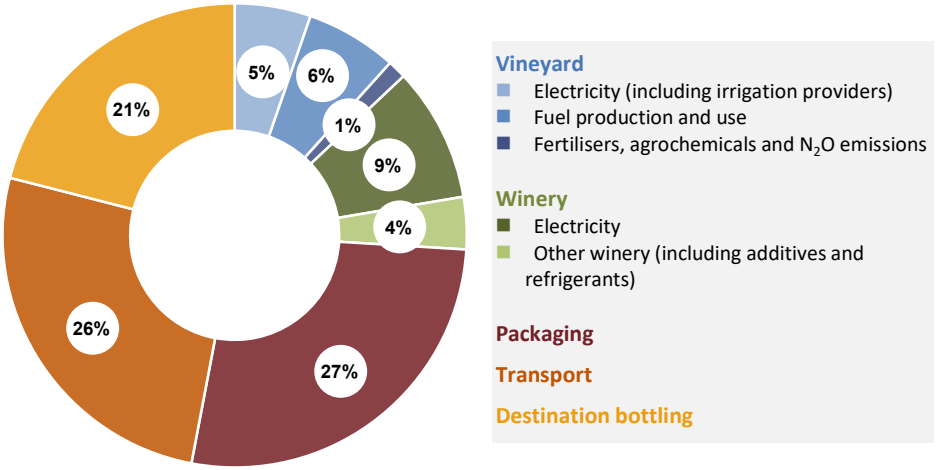

Figure 1. Relative impacts of different production aspects on the carbon footprint of packaged Australian wine. Destination bottling incorporates wine exported in bulk and packaged within the export market (Hirlam *et al.* 2023).

wine to form hydrogen sulfide (rotten egg gas). This process can be accelerated by higher levels of chloride in wine and the presence of copper. The same packaging format works well with other beverages, both alcoholic and non-alcoholic, because they do not have the same unique combination of components as wine (and ciders).

As the wine industry moves to less well-characterised options such as paper and flax packaging, understanding the possible interactions can only be achieved by well-designed and implemented trials. Alternative packaging materials that include naturally-occurring components such as cellulose and lignin have a high potential to react with wine components with yet-to-be-understood results. This also extends to the use of coatings inside the packaging such as waxes. These materials, while inert to many typical beverages, can potentially absorb low concentrations of aroma and flavour compounds that are important in wine. In short, the success of a package for other beverages does not mean that it will be suitable for wine, but this does not mean that such options should not be tried.

Oxygen ingress

The rate of oxygen transmission is a very important factor for wine packaging. The presence of oxygen leads to a number of reactions in wine, some of which are beneficial to its development. Generally, however, increased exposure to air/oxygen results in decreased shelf life and lower quality. It should be noted that, apart from sealed glass ampoules, all wine packaging allows some oxygen ingress. In traditional glass bottles, after the first three months in package, oxygen ingress is limited to that through the closure, leading to a controlled and relatively optimal environment for maturation and extended shelf life. However, this is not the case for some alternative packaging formats. For example, in bag-in-box packaging the collapsible plastic liner allows a much greater transmission of oxygen than a wine bottle closure, leading to a typical shelf life of less than 9 to 12 months. This shelf life can be extended by use of different polymers for the bag, some of which include oxygen scavenging material, but the gains seen in commercial applications to date have been limited. This demonstrates an obvious trade-off between the lower environmental impact for transport (lighter packaging and much greater space efficiency) and a significantly reduced shelf life.

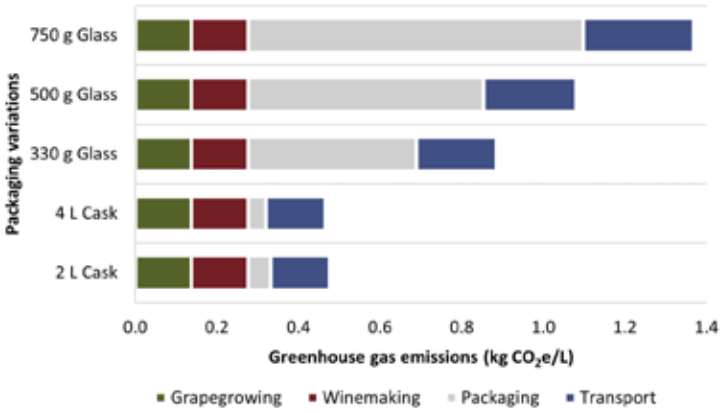

Figure 2. Differences in greenhouse gas emissions associated with packaging type as modelled for domestic distribution from a recent life cycle analysis of Australian wine (Hirlam *et al.* 2023)

There are similar issues for PET bottles, which are quite gas permeable compared to glass. In many cases the impacts of oxygen ingress in this format are similar to those seen for bag-in-box. Again, more advanced PET options include oxygen scavengers that can increase shelf life, but these present logistical problems as they need to be used as soon as possible after the bottle is formed to have the maximum possible effect. Currently there is limited information on the performance of plastic pouches and other newer alternatives such as paper and flax bottles. Aluminium cans and bottles do have potential to protect wine from oxygen at least as well as glass bottles but, as has already been discussed, a membrane must be included to prevent contact between the wine and the aluminium.

Transporrt

Another important aspect of wine packaging is the ability to transport the product, with weight, robustness and packing efficiency all being important factors. Heavier packaging takes more energy to transport and this is the driver behind the development of lighter-weight glass bottles that are increasingly being used in the Australian wine industry. Many of the decisions on how much glass can be removed from bottles to reduce their weight comes down to the robustness of the package to the rigours of domestic or international transport. Similarly, other alternative packaging formats must be robust enough not to break during transport and also be able to resist scuffing or other external damage to ensure that the product is presentable when it reaches its final market.

Overall, alternative packaging can provide a viable alternative to glass bottles, achieving a lower carbon footprint through lower-energy production and transport energy savings from being lighter and more space efficient. There is a trade-off, however, with the shelf life of the products being generally shorter. Technology is continuing to evolve and newer materials that address these issues may become available in the future.

LONG-TERM WINE AGEING

Given a large proportion of wines are consumed just a few hours after being purchased, it is worth considering how important it is for wine to be in a package (such as a glass bottle) that supports long-term, multi-year ageing. One response to this point is that some wines do require bottle ageing, either because they are marketed as premium products that are suitable for cellaring, or due to specific legal requirements of their production area. In these cases it is obvious that the use of a packaging format with the shelf life of glass is important. While alternative packaging options may one day be able to give the required low levels of oxygen transmission for long-term maturation, no current alternative has proven suitable.

While this requirement exists for some wines, many wines are intended for immediate consumption, which might suggest a lower requirement for extended shelf life. However, the time from purchase to consumption is often by far the shortest part of the supply chain. The shelf life of a product must take into account the time from when it is packaged, through storage in a warehouse until it is purchased by the retailer or sold through cellar door. There is also the delivery time to market, which can be six to 12 weeks for some destinations. Finally, many major retailers demand at least six months of shelf life on products before they enter their distribution system to ensure they are not left with unsalable stock. This means

that most wine producers prefer to have at least 12 months of usable shelf life on products to ensure their stock lasts through to the next vintage. Even for high-volume products that may be packaged many times during the year, the requirements of the supply pipeline realistically mean that a minimum of six to nine months' shelf life are needed. This length of shelf life is achievable with bag-in-box packaging, indicating that it is possible to meet these timeframes with alternative packaging formats. It is also possible that supply chains may evolve to allow packaging closer to market and with smaller packaging runs, which would allow much shorter shelf life requirements.

WHICH PACKAGING FORMATS HAVE THE LOWEST EMISSIONS?

In 2010, the two Nordic alcohol monopolies Systembolaget and Vinmonopolet conducted a study through Bio Intelligence Service S.A.S (Tostivint *et al*. 2010) comparing life cycle impacts, including greenhouse gas emissions, for a range of packaging systems spanning glass, bag-in-box, stand-up-pouch and PET formats. The data and results are specific to the products selected, the Nordic market and the transport conditions between the winery locations and the packaging locations. In this study glass fared very poorly compared to other options, with 10-litre bag-in-box (BiB) having the lowest emissions, and all other alternatives having at least half the CO_2 footprint of a traditional 750mL bottle (Figure 3). This study also showed interesting observations about packaging volume, showing that smaller volume wine packages exhibited higher emissions intensity than larger equivalents (e.g. 375mL glass bottles exhibited 32% more emissions than 750mL glass bottles).

ARE THERE WAYS TO IMPROVE THE EMISSIONS ASSOCIATED WITH GLASS?

The Nordic study assumed single use glass; however, in recent times there has been a push in some markets to introduce a mandatory re-use target for glass packaging. The wash and re-use process does have the potential to address some of the emissions associated with glass bottle manufacture. There are, however, obvious challenges for such schemes in many markets, primary among them being the need for stewardship programs to ensure that used glass gets back to the source for reuse. Without an efficient program and the required infrastructure to achieve this, it is difficult to effectively implement such programs.

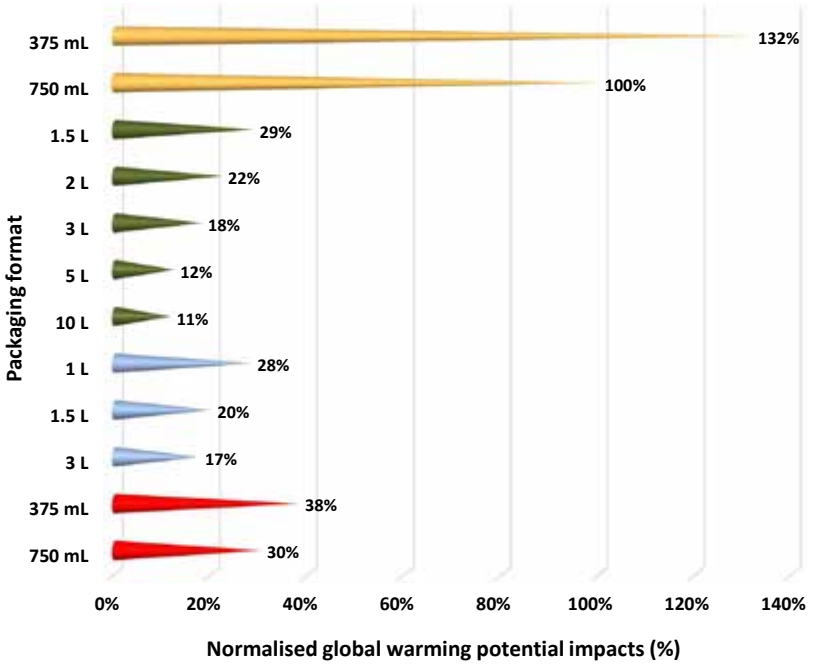

Figure 3. Normalised comparison of emissions (global warming potential) for different wine packaging formats and sizes. Selected formats include glass, bag-in-box (BiB), stand-up-pouch (SuP) and PET packages. Data has been normalised against a standard 750mL glass bottle and represents emissions intensity for 1000L of product packaged and distributed within the defined market. Data sourced from Tostivint *et al*. (2010).

Mandatory programs also present significant challenges for wine in bottle that is transported internationally, with it unclear how such bottles would be returned for re-use.

The glass industry is also addressing its emissions with significant research and commitment to alternative energy sources, such as the use of hydrogen rather than carbon-based fuels. There is also a move by producers to use oxygen rather than air in glass production to improve efficiency. These measures have the potential to significantly reduce the emissions from glass production; however, they cannot address the transport emissions associated with the weight of the packaging and the high proportion of unused space in a wine carton. In these respects, lighter packaging that is much more space efficient will always have a significant carbon footprint advantage, regardless of the distance that a product must travel.

RECYCLING OF DIFFERENT PACKAGING MATERIALS

In 2018 the Australian Packaging Covenant Organisation (APCO) set recycling targets for 2025, which include:

- a move to 100 per cent reusable, recyclable or compostable packaging
- 70 per cent of packaging being recycled or composted
- 50 per cent average recycled content across all packaging
- the phase out of 'problematic and unnecessary single-use plastics packaging'.

Glass packaging has a recycling rate of more than 70% in Australia, largely attributed to the well-established glass recycling infrastructure in the country, as well as ongoing efforts from major glass producers to increase the rate of glass recycling across their plants. The proportion of cullet (recycled glass) used as a feed for glass production can vary depending on the availability of recycled glass, market demand and the technological capabilities of glass manufacturers. In Australia, the average proportion of cullet used in glass production is typically around 35%. Incorporating higher levels of cullet in glass production can lead to slight variations in colour or transparency. However, advancements in glass sorting and processing technologies have significantly improved the quality of recycled glass, making it more suitable for high-quality bottle production. Using more cullet in glass production has a positive impact on the recyclability of glass bottles and can also enhance production efficiency and lower production costs. It can also result in reduced fuel consumption required for glass melting, and lower greenhouse gas emissions; however, there is a need to determine how this applies to products tailored for the wine industry, including different coloured and lightweight glass formats.

PET is one of the most commonly used plastics in beverage bottles, especially for wine products. The recycling rate for PET bottles is lower than glass (APCO 2021), but it has been steadily improving in recent years. The current recycling rate for PET is estimated to be around 36% in Australia. Efforts to increase recycling rates for PET have been underway, including increased public awareness and infrastructure investments. PET recyclability is influenced by the content of recycled PET (rPET) in new PET packaging and the degree of cross-linking present. The higher the content of rPET in new PET packaging, the greater the reduction in the use of virgin plastic and the overall environmental impact. However, there are limitations on the amount of rPET that can be used in certain applications due to performance, safety and regulatory requirements. When looking at alternative packaging material, replacing virgin PET with rPET may reduce greenhouse gas emissions by 50% (Paben 2018).

Overall, for post-consumer recycled content, glass packaging currently has a higher recycled content than plastic packaging, such as PET, with current levels trending towards the 2025 APCO targets (37% at 2019-20, targeting 50% by 2025). In comparison, the recycled content currently being achieved for plastic packaging is well below the 2025 APCO targets. Although PET is trending slightly better (14% at 2019-20, targeting 30% by 2025), on average, significant efforts still need to be made for PET packaging to achieve the 30% target, while providing the structural and protective aspects required for wine packaging.

As highlighted above, the recycling rates for PET are a target of industry and have the potential to significantly reduce the carbon footprint of this form of packaging. However, the liners used in a range of products such as BiB present their own unique issues. The majority of these liners are a multilaminate of different plastics and a metallic layer. This makes them difficult to recycle as they first need to be separated into the different constituents, which is not a straightforward process. There are efforts underway to introduce new technologies to facilitate this process, but since it is a specialised process, a dedicated stewardship program would be needed to ensure that the material ends up at an appropriate facility. Unfortunately, all too often, when such material is put into normal recycling streams it ends up in landfill because it does not fit under the simple plastics classification.

There are similar issues for a range of other alternative packaging options such as Tetra Pak and other paper-based options. If they are made up of multilaminates including plastics or metallic layers, they cannot easily be recycled under general recycling programs. Even the natural wax-based layers used in some alternative beverage containers make them unsuitable for recycling (although they do have better compostability in landfill). To ensure the recyclability of any of these options, programs and infrastructure need to be in place to allow the material to be reprocessed meaningfully and not just go to landfill.

CONCLUSIONS

There is a direct and pressing need for all aspects of society to reduce greenhouse gas emissions and the wine industry needs to play its part. An obvious target is to reduce the impact of both the production of packaging materials and the related energy cost of transportation. Moves to adopt alternative packaging have significant potential to achieve these goals; however, these alternatives must be able to meet the requirements of wine to ensure it reaches the consumer in optimal condition. At the same time, investments are needed by both industry and governments in infrastructure and stewardship programs to allow the efficient use of alternative packaging and to ensure that its use is consistent with the overall goals of reducing waste and increasing recycling. Another important aspect is consumer acceptance of non-traditional packaging formats, but that is an area to be explored at another time.

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