The winemaker's guide to wine in a can

CARIEN COETZEE

BASIC WINE

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WINE INDUSTRY NETWORK OF EXPERTISE AND TECHNOLOGY

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THE WINEMAKER'S GUIDE TO WINE IN A CAN
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Introduction

Canned wine has gained popularity in the international market and its trending success has encouraged wineries to join the canned wine segment. However, for most wine producers, the process is new and seemingly complex. Lack of experience and familiarity can be intimidating. Winemakers need to understand the packaging materials and consider the interactive nature of the packaging (aluminium) and the corrosivity of the wine medium, which was not a factor that had to be considered previously.

As canned wines gain momentum, winemakers pondering a future with packaging other than glass bottles are asking for more information on how to prepare wines destined to be sold in an aluminium can and how this process differs from wine produced for conventional glass bottles. Using aluminium cans as a packaging material for wine can pose challenges as it can be harder to maintain consistency and quality. Therefore, all wines made for canning can also be packaged in glass bottles, but not all wines prepared for glass bottles can be canned.

The winemaking process for the different packaging options is fundamentally the same. However, there are a few key parameters or risk factors which need to be carefully considered in order to maximise the product's shelf life, ensure customer satisfaction, and prevent product loss. Consumer acceptance of this new type of packaging already poses concerns and the additional challenges associated with the development of wine faults and a shortened shelf life could harm the potential market growth.

It is important to investigate and identify key pathways and risk factors that support the formation of off aromas and other unwanted properties post-packaging and gain a better understanding of the potential role of the internal protective coating of the can in these processes.

PART 1

Understanding *aluminium* packaging

The *aluminium* can

The most commonly used beverage can is made of an aluminium alloy (typically containing 1% manganese and 1% magnesium). The aluminium metal is highly reactive and the surface rapidly and spontaneously oxidises to form an outer oxide layer when exposed to the environment (Allison, Sacks, Maslov Bandić, *et al.*, 2020; Vargel, 2004) (Figure 1). This protective oxide film or passive layer (Sacks, 2021) is relatively inert and serves as a shield. However, the passive layer is only stable in a pH range of 4.5 to 8.5 and will eventually deteriorate, especially when in contact with an acidic medium such as wine. The reductive conditions inside the filled and sealed can will lead to the regeneration of a less compact and less protective passive layer, which could lead to increased contact between the wine and the reactive aluminium alloy.

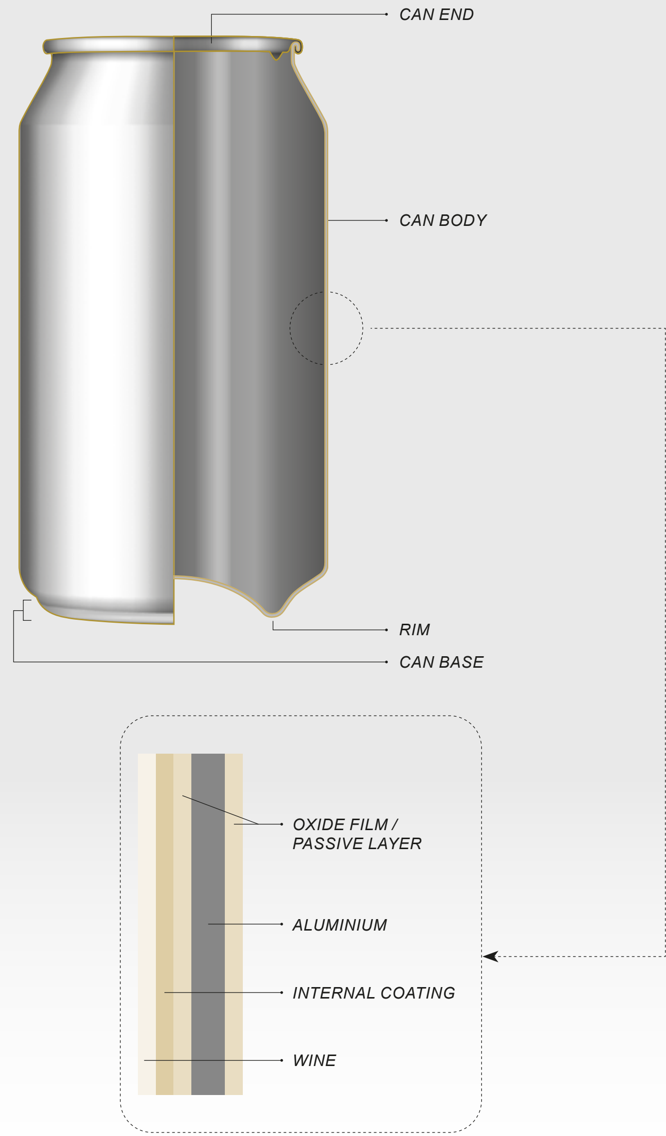


Figure 1. Composition of an aluminium beverage can.

Internal coating

Purpose of internal coating

Direct contact between the aluminium alloy and certain wine constituents can result in corrosion forming galvanic pits/blisters (Figure 2). To separate the aluminium from the wine, the interior of the can is coated by applying a thin, corrosion-resistant, non-porous lacquer (typically 1-10 µm thick) (Crouchiere, 2020; Du Randt, 2020; Robertson, 2012). The purpose of this internal coating is not only to form a barrier between the wine and the aluminium, thereby preventing corrosion and protecting the structural integrity of the can, but also to prevent aluminium from contaminating the wine (possibly resulting in a white haze in severe cases (“Instabilities and problems from other metals”, n.d.)). It also prevents interaction between the beverage components and the aluminium, which could result in the formation of off-odours such as hydrogen sulphide (H_2S) (more details on this interaction in Part 2).

Structural segments

The internal lacquer coating is applied to two structural segments of the can (Figure 1):

1. **CAN END.** The internal surface of the can end is coated when it is still in the metal sheet phase (before cutting) in a process called coil coating.
2. **CYLINDRICAL BODY AND BASE.** This coating is applied to the internal surface of the body and base of the can when the can is already in a cylindrical shape.

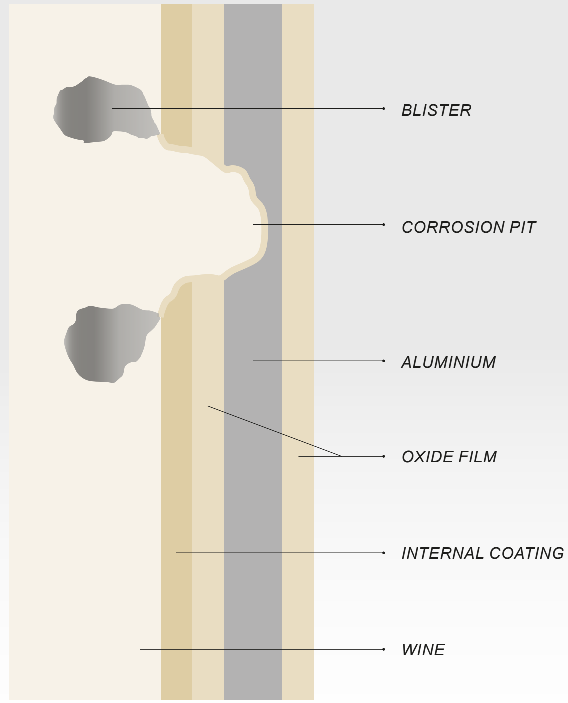


Figure 2. Cross-section of an aluminium can wall showing the corrosion of aluminium.

Epoxy resins have been mainly used for interior coating of food and beverage cans traditionally.

Coating composition

Different lacquers can be used for the internal coating of the can and the lacquer used for the can end coating may differ from the lacquer used for the body and base. Epoxy resins have been mainly used for interior coating of food and beverage cans traditionally. Most epoxy coatings are synthesized from bisphenol A (BPA, CAS 80-05-7) and epichlorohydrin forming bisphenol A-diglycidyl ether epoxy resins. However, institutions from all over the world are engaging in continuous research and developmental work to improve coating properties for different beverages.

Can suppliers differ in their lacquer offering, each with unique properties. South Africa's largest aluminium can producer, Nampak Bevcan, uses a customised Food and Drug Administration (FDA) approved epoxy phenolic lacquer for "hard-to-hold" beverages such as wine (Du Randt, 2020). But the demand for Bisphenol A non-intent (BPA-NI) internal coatings is gathering momentum as government agencies across the globe start to regulate BPA more strictly. This trend has resulted in a shift toward BPA-NI packaging in some markets such as the European Union and California (Scrimgeour, 2021).

The properties (composition and weight/thickness) of the coating can be adjusted for different products. Cans and internal coatings made for "hard-to-hold" products, such as wine and energy drinks, require higher film weights and stricter coverage specifications (Peinke, Julius, Themba, *et al*., 2020) to ensure optimal barrier function.

Internal coating coverage

Uniform coverage of the internal coating is essential. Too little spray may result in a porous layer, incomplete film coverage and/or pinholes. These create vulnerable spots potentially causing direct contact between the wine and the aluminium. However, too much spray can produce bubbles, puddles, and blisters that can trap the coating, leading to poor curing/setting of the lacquer. The speed of the production line can affect the evenness and the thickness of the coating applied (Scrimgeour, 2021).

Some suppliers have resorted to applying two internal coats to ensure complete and uniform coverage. However, increased coating thickness is not always a viable solution to corrosion issues as it can affect the adhesion and performance of the internal coating barrier (Du Randt, 2020). Thicker coatings can also result in the "scalping" of the beverage (Sacks, 2021) where beverage components are lost due to its migration into the packaging material.

Coating application

It is important to ensure that the aluminium surface to be coated is clean and free of any dust particles before the lacquer is applied (Du Randt, 2020). At the production facility at Nampak Bevcan, cameras are installed to monitor the coating process and packs with imperfect applications are removed from the production line (Du Randt, 2020). Frequent tests and checks are also conducted during the manufacturing process to ensure that the products adhere to strict specifications. This is especially important for the production of aluminium cans for the packaging of "hard-to-hold" products such as wine.

Curing

After the application of the polymer coating, cans are exposed to elevated temperatures which enable proper curing. During this process, any solvents in the liner evaporate and chemical cross-linking of the coating is established providing the optimum barrier properties. If the coating is under cured, it will have weak physical and chemical properties, while over curing will result in a burnt (dark yellow/brown) and brittle lining. Metal exposure tests are conducted at frequent intervals to test for any breaches in integrity and ascertain successful and uniform application of the lacquer (Peinke *et al.*, 2020).

Coating failure

Wine is considered a chemically aggressive medium ("hard-to-hold") due to the presence of alcohol, sulphur dioxide, high acidity and low pH. This combination creates a hostile environment for innovative packaging materials such as aluminium. As mentioned previously, direct contact between the wine and the aluminium can lead to packaging issues (blisters, pits, peeling, holes, leakage) as well as a tainted beverage (H_2S). Determining the exact cause of coating failure in a unique situation is a difficult task. However, the following mechanisms have been proposed:

1. Existing micro imperfections (cracks) in the coating.
2. The degradation of the coating due to interaction with the beverage.
3. Diffusion of beverage constituents through the coating.

> *Determining the exact cause of coating failure in a unique situation is a difficult task.*

Micro imperfections

Physical imperfections (imperfect liner application and/or micro cracks) in the coating will result in barrier failure between the wine and the metal surface. This will lead to corrosion in the form of blisters and pits and the formation of H_2S.

The area most at risk for coating imperfections is likely where the metal is bent to form the double seam connecting the can body to the can end (Peinke *et al.*, 2020) (Figure 3). The metal in this area is bent, possibly causing micro cracks in the lacquer. These micro cracks will allow direct contact between the wine and the aluminium, making this area a likely target for corrosion (Peinke *et al.*, 2020).

The Australian Wine Research Institute (AWRI) tested the effect of storage orientation on aluminium breakthrough in canned wine and found slightly higher aluminium content in the wine when the cans were stored in an inverted position with the wine in direct contact with the can end and seam (Scrimgeour, 2020). This increase in aluminium in the wine can possibly be due to direct contact through micro cracks located in the vicinity of the double seam and/or imperfect coil coating of the can end (Scrimgeour, 2021).

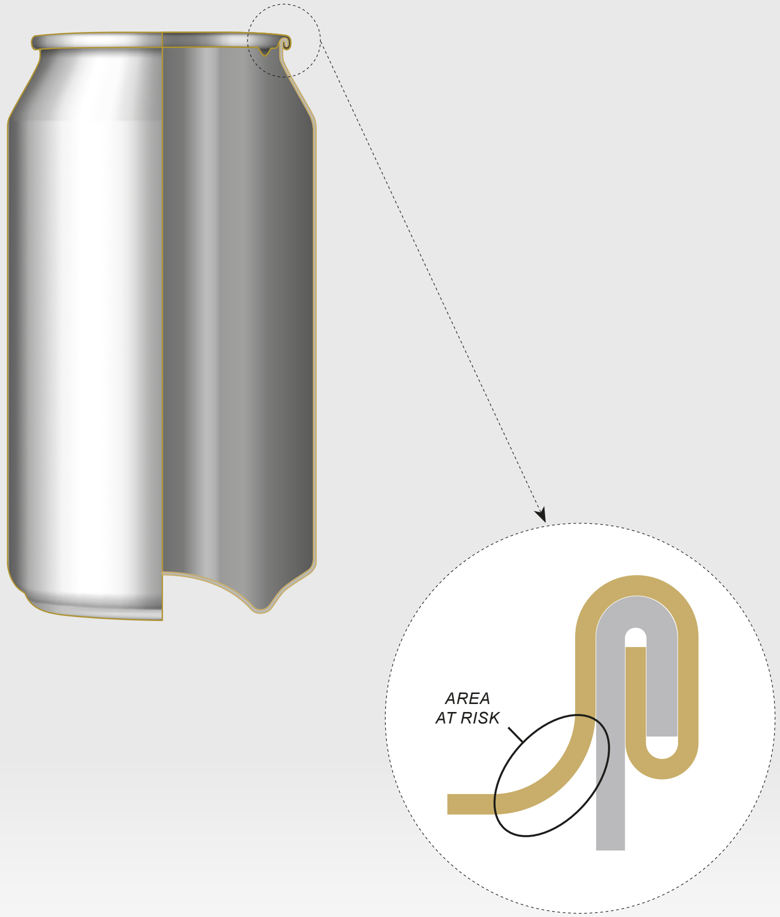


Figure 3. Cross-section of the double seam connecting the body and the can end.

Degradation of the coating

Wine components and properties (alcohol, sulphur dioxide, high acidity, low pH, etc.) either alone or in combination can degrade the liner or change the coating properties during prolonged storage. This will result in direct contact between the wine and the metal surface, causing blistering/pitting and further loss in coating integrity (Sacks, 2021). The severity of the degradation will depend on both the coating and the wine's composition.

Diffusion

Certain wine constituents (specifically molecular SO_2) could penetrate the liner and react with the aluminium (Barokes, 2006; Sacks, 2021). The resulting formation of H_2S gas can cause blistering which then allows other wine components access to the metal surface (Sacks, 2021). Further work is required to better understand the diffusion mechanism.

The main issue?

The exact mechanism responsible for the failure of the protective coating will depend on many factors such as the coating composition, coating application, wine chemical composition and handling and storage conditions.

The research team led by Prof Gavin Sacks from Cornell University is investigating these mechanisms. To date, their findings have shown considerable variation in H_2S production from one can to the next (the same coating and the same wine). This would suggest variation in micro imperfections from one can to the next. On the other hand, their studies have also shown that the variation from liner to liner or wine to wine is significantly higher when compared to the variation observed between cans. Other than that, studies investigating coating imperfections using electrochemical impedance spectroscopy (EIS) have shown that there is no correlation between initial EIS measurements and eventual H_2S production. Therefore, even though micro imperfections can have a significant effect, it seems that liner composition as well as wine composition are the major factors responsible for liner failure (Sacks, 2021).

Coating composition and interaction

The frequency in coating problems may be increasing due to recent shifts away from BPA-containing epoxy coatings to new and safer, but possibly less effective types of liners (Maslov Bandić & Sacks, 2019). However, more recent generations of liners are reported to have improved performance (Allison *et al.*, 2020; Scrimgeour, 2021).

The polymer coating itself contains a variety of compounds which can possibly interact (react/absorb) with wine components. Wine compounds can be absorbed by the coating (a process called "scalping"), thereby affecting the sensory composition of the product. Typically, the compounds of greatest concern during scalping are non-polar flavours and odorants, which can be absorbed into non-polar polymer packaging materials (Allison *et al.*, 2020). The scalping effect of the internal coating on canned wine has not been studied (Allison *et al.*, 2020), however, scalping has been shown to have a significant effect on hop constituents in canned beer (Wietstock, Glattfelder, Garbe, *et al.*, 2016) as well as other beverages such as spiked seltzers and sodas (Sacks, 2021).

Some coating substrates can also be extracted by wine (typically aggravated by the presence of alcohol). However, the leaching of compounds from the lacquer is not a common occurrence and can be considered negligible provided the correct coating composition and application are used during manufacturing (Peinke *et al.*, 2020; Du Randt, 2020).

Wine compounds can be absorbed by the coating (a process called "scalping"), thereby affecting the sensory composition of the product.

Some coatings may contain surfactants (for example a defoaming agent when canning beer) or residual lubricant from the manufacturing process. This can initiate chemical reactions in the beverage, resulting in a change in surface tension. This is only an issue in cases where the coating composition and application was not optimal for the beverage in question.

The interaction between wine and coating can also have detrimental effects on the barrier integrity through liquid absorption. This is especially prevalent in cases where the coating was not cured completely or if the coating has low moisture or alcohol resistance. Extended storage of the filled pack at high temperatures can also lead to the coating absorbing the liquid, causing the polymer to swell. This will result in adhesion loss and reduction of barrier efficiency. These issues can be avoided by selecting the correct lacquer, ensuring proper application and curing, and maintaining appropriate handling and storage conditions.

Temperature effects

Temperature is a major factor that affects the rate of chemical reactions. In a canned wine the reaction between wine components and either aluminium or the coating will be accelerated at elevated temperatures (Barokes, 2006; Sacks, 2021). Higher temperatures also favour the dissolution of weakly bound SO_2-adducts in wine as well as increase the proportion of SO_2 in the molecular form which, in turn, can influence the efficiency of the internal coating (Sacks, 2021).

Nampak Bevcan's lacquer systems can handle pasteurisation parameters of temperatures above 60°C for an extended time. Even so, high temperatures during transport and storage should be avoided, mainly to preserve wine quality and limit any wine-packaging interactions (such as corrosion). Routine pack tests conducted by Nampak Research & Development to evaluate wine-packaging interaction and to determine the shelf life of a canned wine is conducted at 37°C. The results should provide a good indication of the suitability of the coating and packaging for the specific product. A maximum storage temperature of 20°C is recommended for best pack performance (Peinke *et al.*, 2020), but lower temperatures can be used for better preservation of the product and to minimise/delay any beverage-packaging interactions.

Pack exterior and handling

The can body is coated with an over varnish which helps improve mobility and handling during manufacturing and filling while contributing to protection from external corrosion and scuffing (Peinke *et al.*, 2020; Du Randt, 2020). The can base (Figure 1) is not coated with any resin except for the rim of the base (the ringed section in direct contact with a flat surface when in upright position). This rim is coated with a UV-coating to improve mobility and prevent corrosion. Therefore, the section of the exterior of the can most susceptible to corrosion is the base of the can. Leaking packs pose a risk as the wine can contaminate surrounding cans, increasing the risk of corrosion of especially the can base.

The stacking and packaging of filled cans should be carefully considered (Peinke *et al.*, 2020; Du Randt, 2020). The use of good quality pallets that provide an even base and do not have any protruding nails are essential. The use of a bottom layer pad and separation sheets between layers (which does not have to be between every layer) of cans and secondary packaging, such as cardboard trays, can also help distribute the weight and prevent supply chain damage. Stretch wrapping of pallets prevent movement of cans during transport and it is important to ensure that the packs are completely dry due to potential corrosion problems when liquid is trapped between the aluminium can and the wrap. Any exterior surface in contact with wine needs to be rinsed with clean water and be allowed to dry completely. Stock should be regularly inspected and any wet or leaking cans/packs should be removed from pallets immediately.

The ridge at the top of the can is prone to collecting dust/dirt and water. The presence of water and air can accelerate corrosion and it is important to ensure the can end remains clean and dry, especially when filling is done in the summer months when condensation is more of a problem.

The seaming of the interlocking parts of the can body and can end should be flawless and any sealing issues, damage or pack failures should be reported and investigated to prevent loss of product.

Compatibility testing

Wine suitability for canning

Screening and compatibility tests are important in confirming the suitability of wine for packaging in aluminium cans. Nampak Research & Development maintains that the wine in question should first meet specific requirements (based on the chemical analyses) before compatibility tests can be conducted. Any product not conforming to the basic chemical requirements (see Part 2) will not be recommended for canning. If, however, the wine is deemed suitable according to the certificate of analyses, the wine can be packaged whereafter pack performance and wine quality are evaluated over a period of four months. Packs are stored at 37°C to accelerate the ageing process and to enhance wine-packaging interactions (if any). If the wine quality and package integrity are acceptable after the storage period, then packaging for commercial sale can commence.

Shelf life tests

Nampak Research & Development retains a number of samples for each unique product that is packaged. The physical condition of the retained packs is inspected and chemical and sensory analyses conducted for any signs of degradation and decline in product quality. These tests are conducted in three-month intervals and results made available to the client. In total, samples are kept for 12 months at 21°C after which a recommendation regarding the shelf life is issued. This recommendation is based on the performance of the pack, but the recommended shelf life should not be interpreted as a set expiration date and products may maintain the required quality standards past the 12-month period.

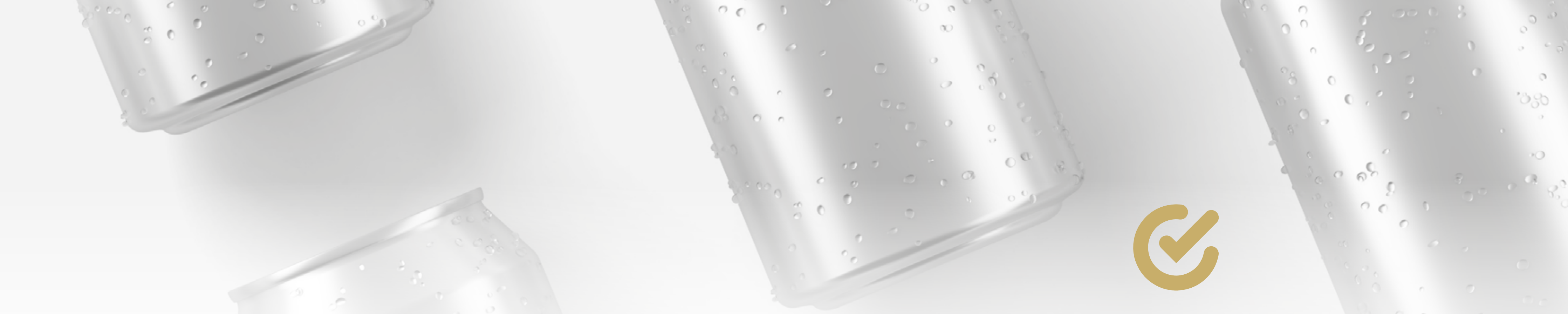
Producers should retain their own set of samples to help identify problems should they occur. This will also assist in determining a suitable shelf life for the specific product (note that your minimum acceptable quality thresholds might differ from those of Nampak Bevcan). Tracking the sensory development of the wine over time will provide valuable insights into the effect of the packaging on wine sensory composition.

Record keeping

Proper record-keeping is critical to ensure consistency and simplify troubleshooting if problems should occur. Pallet cards and certificates of conformance accompanying the aluminium packaging will allow traceability, while other details which should be documented include:

Pre-packaging:

- Pallet cards and packaging details.
- Wine analyses and sensory evaluation notes.
- The concentration of dissolved gasses in the tank before canning.



On the day of packaging (during filling and sealing operations):

- Filling conditions, line speed, purge, headspace flush, lot number/date.
- Can pressure and concentration of dissolved gasses in the sealed can.
- Sensory evaluation notes. Also record any observations during the opening of the newly sealed can.
- Double seam evaluation (seam and end teardown).
- Filling date (as for all non-glass containers, the indication of a filling date is compulsory, which particulars may, as is customary with cans, be indicated on the bottom of the can) (“Wine in cans”, 2019).

Post-packaging:

- Storage conditions, handling, time, temperature.
- Wine analyses and sensory evaluation notes.
- Investigation of the internal condition (blisters, stains, cracking). Internal coating integrity and under-film attack/corrosion checked against the manufacturer’s standards.

Conclusion

The chosen packaging supplier must be able to provide information regarding the suitability of the can (especially the internal coating) for the packaging of the intended wine (including information on conducted shelf-life studies). This is especially important as newer and cheaper products entering the market may not be suitable for “hard-to-hold” products such as wine and could damage the reputation of the growing industry.

The pack should be tested for its compatibility with wine (preferably in partnership with the can provider) before packaging and recommendations from your aluminium packaging vendor should be considered to minimise the risk of packaging failure. The support from the vendor’s research and development team is critical to ensure product integrity; not only to protect the brand, but also the growing canned wine industry.

Ensuring that the can structure and composition meet specific requirements and making the wine “can friendly” will increase the likelihood of a successful match. The producer should try to compensate for a degree of liner failure by limiting the concentration of corrosive compounds present in wine (see Part 2).

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PART 2

Risk factors to consider when producing wine for a can

Aluminium in wine: Increases during *the storage of canned wine*

Aluminium content as a benchmark for exposure

The concentration of aluminium in canned wine is often used as a benchmark to indicate direct contact between the wine and the aluminium layer of the can wall. Aluminium increases over time would suggest that direct contact and interaction is taking place. However, the aluminium can is not the only source of aluminium in wine. The initial concentration of the metal in wine depends on how and

The initial concentration of the metal in wine depends on how and where the wines were made.

where the wines were made. Typically, Australian red wines have an aluminium concentration of 100-300 µg/L (Scrimgeour, 2021), while the aluminium content in South African wines has been reported to range between 200-700 µg/L (Peinke, Julius, Themba, *et al.*, 2020). White wines typically have a slightly higher content compared to red wines due to the use of bentonite clay (which contains low concentrations of aluminium) during the winemaking process.

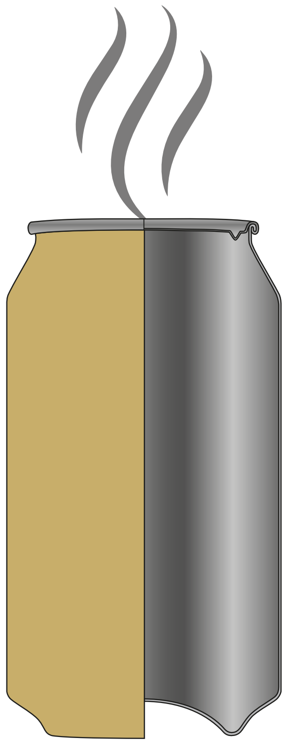
Aluminium increases during storage of canned wine

Researchers from The Australian Wine Research Institute (AWRI) (Scrimgeour, 2019, 2020) studied 16 different commercial canned wine products during storage (all packaged at a similar time). The aluminium concentration in the canned wine was measured soon after packaging, after which the products were stored for five months under typical cellar conditions and measured again for aluminium content. Results showed a significant increase in aluminium concentration post-packaging with wines reaching up to 1250 µg/L aluminium (Scrimgeour, Hirlam, Bey, *et al.*, 2020). This would suggest that there is migration of aluminium into the product. Scanning electron microscopy and subsequent X-ray analysis highlighted that there was evidence of pitting on the inner surface of the can body and lid, potentially allowing direct migration of aluminium into the wine (Scrimgeour *et al.*, 2020). However, some of the products showed only marginal increases suggesting more effective barrier protection activity.

The increase in aluminium concentration in canned beverages is not a problem unique to wine products. Benchmarking of other canned beverages indicated that aluminium concentration increases can occur in other drinks, such as cider and kombucha products (Scrimgeour *et al.*, 2020). It is however particularly problematic for canned wines as the wine's interaction with the aluminium packaging (see Part 1) is an additional factor to consider when compared to wine packaged in glass (Scrimgeour *et al.*, 2020).

> *It is important to determine the aluminium concentration in the wine before packaging.*

When conducting shelf life and compatability tests, it is important to determine the aluminium concentration in the wine before packaging (and perhaps directly after filling) to determine if the aluminium concentration in the packaged wine increased during storage. Nampak Research & Development aims to have aluminium pick up of less than 1 mg/L when stored for 12 months at 21°C (Peinke *et al.*, 2020). The AWRI advises that the increase in aluminium content in wine that is stored in a can for three months in the upright position at 30°C, to be minimal and preferably less than 10% of the original concentration (Scrimgeour, 2021).



The development of *reductive aroma*

Together with corrosion issues (see Part 1), the development of reductive aroma is one of the main problems that occur in canned wines. Reductive aroma in wine usually originates from the formation and/or release of hydrogen sulphide (H_2S), which has a distinct odour described as "rotten egg" and "vegetal" if present at higher concentrations. Low concentrations of H_2S might suppress the fruit character of wine resulting in disappointed consumers. The development of reductive aromas in canned wine post-packaging can occur anywhere from a few weeks to a few months.

Mechanisms for the formation of H_2S post-packaging

The formation of the reductive aroma in the post-packaging phase of canned wine can occur via three main mechanisms:

1. Interaction of SO_2 with aluminium metal.
2. Release of H_2S from metal-bound complexes present in the wine.
3. Degradation of polysulfanes (Bekker, Kreitman, Jeffery, *et al.*, 2018) .

The interaction of SO_2 with the aluminium metal is probably the main cause of H_2S formation in canned wine. SO_2 is reduced in the presence of aluminium under acidic conditions leading to the formation of H_2S (Trela, 2019) (Figure 4). It is important to note the formation of H_2S is due to the reaction between SO_2 and the aluminium metal and not dissolved aluminium ions in the wine.

$$2Al_{(s)} + SO_{2(aq)} + 6H^{+}_{(aq)} \longrightarrow 2Al^{3+}_{(aq)} + H_2S_{(g)} + 2H_2O$$

Figure 4. The reaction of aluminium with sulphur dioxide to produce hydrogen sulphide.

For this reaction to take place, SO_2 must be in direct contact with the aluminium metal. Proposed mechanisms for this exposure include coating imperfections, coating degradation and/or diffusion of wine components through the coating (see Part 1). The exact pathway is unclear and will likely be unique for each situation as it depends on many factors.

> *The interaction of SO_2 with the aluminium metal is probably the main cause of H_2S formation in canned wine.*

The release of H_2S from metal-bound complexes as well as polysulfanes is not specific to canned wine and can occur in any type of packaging. The relative importance of these two pathways in the accumulation of H_2S in canned wine is unclear (Sacks, 2021). In general, the release and accumulation of H_2S have been found to be directly related to the amount of metals (especially copper) present in the wine and also depends on factors such as pH, the presence of reducing agents (such as SO_2 and ascorbic acid) (Bekker *et al.*, 2018) and the presence of oxygen. The accumulation of H_2S is typically exacerbated by an oxygen-deprived environment. In bottled wine, oxygen ingress through the closure might mitigate some of the H_2S accumulation. But in the anoxic environment inside a sealed aluminium can (assuming low oxygen concentration at the time of sealing), the formation of H_2S via these mechanisms can be significant.

H_2S increases during the storage of canned wine

In the AWRI study where 16 different commercial canned wine products were monitored over time, about half of the products tested generated significant concentrations of H_2S during the five-month storage period. An informal sensory evaluation of several of the tested products also reported the presence of reductive sensory attributes including "rotten egg", "sulphurous", "vegetal", "rubbery", "garlic" and "onion" aromas (Scrimgeour *et al.*, 2020) and were declared as "faulty" by the AWRI technical quality panel.

For some of these wines, an increase in H_2S concentration was already observed after one month, while in other wines H_2S only increased significantly after three months' storage. It should be noted that the source of the H_2S may not have been solely from the reaction between SO_2 and aluminium and the alternative mechanism of H_2S formation should also be considered. However, in the AWRI study many of the cans tested showed evidence of corrosion on the interior surfaces, which suggests direct contact between SO_2 and aluminium.

The remainder of the sample set did not show any significant increases in H_2S concentration. Likely, the internal coating in these samples was more efficiently applied and/or the wine's risk factors (such as SO_2 content) were lower.

> *Sulphur dioxide is an important antimicrobial, antioxidant and binding agent in wine, and is added to preserve and maximise the shelf life of the product.*

Sulphur dioxide

The role of sulphur dioxide in canned wine

The contribution of SO_2 to faults in canned wine is primarily due to the formation of H_2S when it reacts with aluminium (Figure 4). The formation of H_2S gas could, in turn, result in blistering and further exposure between the wine components and the aluminium (Sacks, 2021). The possible mechanisms responsible for the initial exposure are discussed in Part 1.

The AWRI tested the aluminium content of a wine canned with either "low" free SO_2 (30 - 35 mg/L) or "high" free SO_2 (53 - 59 mg/L) content (Scrimgeour, 2020). Results showed that the wines with the higher free SO_2 content had a higher aluminium concentration after storage compared to wines with lower free SO_2 concentration. This would suggest that the corrosion of the aluminium is facilitated and accelerated by SO_2, allowing aluminium increases in the wine.

The role of the different forms of SO_2 (molecular vs bisulphite) in the packaging failure of canned wine is unclear. However, what is clear is that free SO_2 plays an integral role in canned wine issues. The exact effect of bound SO_2 is still under investigation, however, Prof Gavin Sacks from Cornell University indicated that their studies have shown little evidence that bound SO_2 has any effect (Sacks, 2021).

Limiting the use of SO_2

Sulphur dioxide is an important antimicrobial, antioxidant and binding agent in wine, and is added to preserve and maximise the shelf life of the product. However, the interaction of SO_2 with aluminium can have detrimental effects. Thus, the most important approach in making wine for a can is to minimise the use of SO_2. Winemakers should thus carefully manage all other aspects of the winemaking process to achieve stability in order to limit the necessity for additional SO_2.

In terms of SO_2 limits in wine, the lowest possible concentration is recommended to reduce the risk of corrosion and H_2S formation (Wilkes, 2021). The compatibility of the sulphur-containing wine and the aluminium packaging depends on the type and quality of the packaging used and the wine composition. Nampak Research & Development recommends that the molecular SO_2 concentration falls within the range of 0.4 - 0.8 mg/L, however, products containing up to 1.0 mg/L molecular SO_2 have successfully passed the shelf life test using Nampak Bevcan products. Table 1 shows typical chemical analysis recommendations for canned wine. It is recommended to consult with your can manufacturer and filling service provider for specific limits and recommendations.

TABLE 1. Typical wine analyses recommendations

Parameter	Threshold
Alcohol	< 18.5 % v/v
pH	**Note:** Note the influence of pH on molecular SO_2 content
Residual sugar	< 5 g/L **Note:** Consider treating with additional antimicrobial agent if the RS is > 4 g/L
Free SO_2	< 35 mg/L **Note:** Use free SO_2 parameter in combination with molecular SO_2 value
Molecular SO_2	< 0.8 mg/L
Copper	< 0.1 mg/L
Iron	< 1.0 mg/L
Chlorides	< 190 mg/L
Aluminium	Pick up < 10% **Note:** Measure before canning and track over time
Dissolved oxygen	white < 0.5 mg/L rosé < 0.5 mg/L red < 1.0 mg/L
Total package oxygen	< 2 mg/L

("Canned Packaging", 2019; "How to get your wine into cans", 2020; Peinke *et al.*, 2020; Scrimgeour, 2020).

Disclaimer: The above recommendations are generic and the author's interpretation of current available data and knowledge on this topic. Please refer to your can manufacturer and filling service provider for specific limits or recommendations as wine composition and packaging specifications might differ.

Even though the exact role of the different forms of SO_2 (molecular vs bisuphite) in canned wine issues is still unknown, research would suggest that the molecular form could be problematic and can be used as a guideline. Researchers from Enartis have observed more problems in wines with lower pH and higher SO_2 content (Karasek, 2020). However, the exact contribution of the individual factors (high SO_2 alone and low pH alone), as opposed to the combined effect of high SO_2 concentration in a low pH environment (resulting in a higher molecular SO_2 content), requires further investigation.

Copper

The role of copper in H_2S increases

Copper is often added as a remedial treatment to remove H_2S and other reductive aromas in wine during the winemaking process and sometimes immediately before bottling. It is widely accepted that copper reacts with H_2S forming an insoluble complex that can be removed from the wine by racking and/or filtration. However, studies have shown that these complexes remain dissolved in the wine and do not precipitate (Clark, Grant-Preece, Cleghorn, *et al.*, 2015).

> *Copper chemistry and the role of copper in wine have recently been the focus of studies and several publications have shown the complex mechanisms involved.*

The implication is that H_2S can be released from these complexes at a later stage resulting in the formation of reductive aroma (Clark *et al.*, 2015). This release is especially troublesome in an anoxic environment as is the case with canned wine.

Copper chemistry and the role of copper in wine have recently been the focus of studies and several publications have shown the complex mechanisms involved (Franco-Luesma & Ferreira, 2016). While these mechanisms will not be discussed here, it is important to understand that copper in wine can be detrimental to the wine's shelf life due to, among others, its role in H_2S formation and accumulation during storage in an oxygen-deprived environment (Scrimgeour *et al.*, 2020). Therefore, the use of copper should be avoided as far as possible. By preventing the formation of H_2S during and after fermentation, the need for copper can be mitigated. Factors such as optimal juice turbidity, yeast nutrition, appropriate fermentation temperatures and choosing a yeast strain with low nutrient requirements, can be used to ensure a healthy fermentation with low H_2S production.

Copper removal

In the event that H_2S accumulation was unavoidable, the use of copper to bind the H_2S could be considered with caution. However, removing the remaining copper and copper complexes from the wine after treatment is important to prevent the delayed release of H_2S at a later stage. Studies have shown that the onset of H_2S formation can be delayed if the copper concentration is decreased, even when aluminium (metal) is present (Scrimgeour *et al*., 2020). Cross-linked polymers such as polyvinylimidazole/polyvinylpyrrolidone (PVI/PVP) can be effectively used to scavenge heavy metals in wine. Commercial products supplied by Enartis, Claril HM and Stabyl MET, were put to the test to investigate the efficiency in removing residual copper from 38 wines (Hirlam, Scrimgeour & Wilkes, 2019). Treating the wines with Stabyl MET (PVI/PVP) resulted in an average 50% decrease in copper concentration. Claril HM (PVI/PVP in combination with chitosan) removed slightly more copper (59%).

The role of copper in aluminium corrosion

Other than the contribution to H_2S release, trace elements, such as copper and chloride, are known to facilitate the electrochemical reaction between the beverage and aluminium (when exposed) (Sacks, 2021; Vargel, 2004). Aluminium pickup in the wine was less when the copper was previously removed using PVI/PVP (Scrimgeour, 2020). Most wines have a copper concentration less than 0.2 mg/L which is also within Enartis' recommendation ("Canned Packaging", 2019). Nampak Bevcan recommends that the copper concentration of any beverage should not exceed 0.05 mg/L and considers copper concentrations higher than 0.1 mg/L as potentially problematic (Table 1) (Peinke *et al*., 2020).

> *Packaging wine in a low oxygen environment is critical to prevent excessive oxygen in the sealed product and to ensure maximum shelf life.*

Oxygen

The role of oxygen in the canned wine environment

Too much oxygen in wine can be detrimental, resulting in the disappearance of fresh and fruity aromas and the formation of oxidation-related aromas described as “green apple skin” and “sherry” (Coetzee & Du Toit, 2015; Coetzee, Van Wyngaard, Šuklje, *et al.*, 2016). Packaging wine in a low oxygen environment is critical to prevent excessive oxygen in the sealed product and to ensure maximum shelf life, both from a packaging as well as a wine quality perspective.

Oxygen transmission

When packaging wine in glass, the presence of oxygen is carefully monitored and the oxygen transmission rate of the closure is considered. Aluminium cans have the lowest oxygen ingress of all wine packaging (much lower than glass bottles sealed with a screw cap) and the double seam (Figure 3) seals hermetically. The oxygen ingress into a sealed can is considered to be negligible (around 0.1 mg O_2/L per year) (Allison, Sacks, Maslov Bandić, *et al.*, 2020; Crouchiere, 2020), therefore the total package oxygen (TPO) of the sealed product is an indication of the last oxygen exposure of the wine until the can is opened for consumption. The TPO is the sum of the dissolved oxygen in the wine and the gaseous oxygen present in the headspace.

Dissolved oxygen

Before packaging, the dissolved oxygen concentration of the wine in the tank should also be low. Sparging wine with nitrogen and/or carbon dioxide (using a dispersion stone) can remove dissolved oxygen with minor to no sensory alteration (be sure to keep an eye on carbon dioxide levels) (Walls, 2020). Enartis recommends a dissolved oxygen concentration of less than 0.5 mg/L for white and rosé wines and 1.0 mg/L for red wine (Table 1) ("Canned Packaging", 2019). Filling using counter-pressure could also help reduce oxygen exposure in which case a TPO of less than 1 mg/L can be obtained (Allison *et al.*, 2020). However, without the use of counter-pressure, the TPO might reach much higher concentrations and realistically TPO concentrations of 1-3 mg/L are observed, depending on the dissolved oxygen concentration in the tank before filling. The source of oxygen pickup should be investigated by both the client and the filling facility and the process optimised to reduce the exposure. In general, a TPO of below 1.3 mg/L is recommended (Riley, 2020).

Headspace

The headspace allows expansion and contraction in the event of temperature and pressure fluctuations and the can is designed so that, if filled to the correct

volume, the headspace is sufficient to avoid problems caused by small fluctuations (Peinke *et al.*, 2020). Proper pressurisation and management of the product's storage temperature is important (Peinke *et al.*, 2020).

The large headspace to wine volume ratio in a canned wine product makes canned wine especially susceptible to oxidation if the headspace contains air. The cylindrical shape of the can also means that the surface area of wine in contact with the headspace is up to 20 times greater compared to wine in a conventional glass bottle with a narrowing neck (Barokes, 2006). Thus, the concentration of oxygen needs to be low to reduce the risk of oxidation. Before filling, some fillers will purge the empty aluminium container with carbon dioxide to displace the air and minimise oxygen dissolution, but the effectivity of this technique in isolation (without inerting the headspace after filling) to exlude oxygen in the headspace is questionable (Peinke *et al.*, 2020).

After filling, the headspace is usually inerted using liquid nitrogen. The conversion of the liquid nitrogen into gaseous nitrogen will displace the air and remove oxygen molecules in the headspace. This conversion from liquid nitrogen to gaseous nitrogen also creates the appropriate pressure after which the seaming of the body and the can end takes place. Higher volume fillers (such as for soft drinks and beer) use "undercover" carbon dioxide gassing between filling and seaming to flush the air from the headspace (Peinke *et al.*, 2020). Producers usually do not inert the headspace of carbonated wines due to the presence of carbon dioxide in the beverage. This is done based on the assumption that carbon dioxide will be released from the wine and inert the headspace during filling. The effectiveness of this method is unclear and has resulted in higher TPO measurements and therefore needs further investigation.

> *Too much oxygen will result in oxidation and too little oxygen might result in reduction.*

A study measured the headspace volume in the sealed can and results showed large variation in the fill height of all the products tested (Scrimgeour, 2020). The variation was not only between different products (from different canning facilities), but also between different cans from the same canning line. The filling volume in South Africa is governed by the Trade Metrology Act and fillers should aim for the nominal fill volume and fill as precise and accurate as possible. The filling accuracy and consistency can be monitored by weighing the cans and insufficient pressurisation can be identified by simply testing the can body's flexibility by applying moderate external pressure by hand.

Oxygen management

Considering that the oxygen ingress in the sealed product is negligible, sound oxygen management during the packaging process will mitigate the need for antioxidant protection in the form of free SO_2, hence reducing the risk of reaction with aluminium and corrosion. All of the commercial canned wines tested in the AWRI study (see section Sulphur Dioxide) had an initial free SO_2 concentration of less than 29 mg/L (average 17 mg/L) (Scrimgeour, 2020; Scrimgeour *et al.*, 2020). A decrease in free SO_2 was observed during the first months post-packaging, probably due to a higher TPO leading to oxidation reactions. For some of the packs tested, minimal decrease in SO_2 was reported. This would suggest that the oxygen management before and during packaging of these packs was sound ensuring a low TPO in the sealed product and therefore better preservation of the wine.

In a separate study, the TPO levels of different cans from the same filling line were investigated (Scrimgeour, 2020). Results showed large variability between the cans (from 1 to 3 mg/L TPO), which suggests that oxygen management was not up to standard on that particular canning line. Setting up a testing protocol could help with quality control to ensure consistent oxygen concentration during packaging. A low TPO can be obtained by ensuring the dissolved oxygen in the tank is low, keeping the tanks full and using inert gas as a protective blanket during filling (especially as the volume lowers), minimise movement of the wine, check pumps and valves, and avoid filling at too low temperatures.

Too little oxygen

The effect of excess oxygen on wine quality is well known. However, packaging wine with too little oxygen can also result in unwanted quality changes in the wine. The low oxygen environment can increase the risk of H_2S formation and accumulation and the development of reductive aroma. It was mentioned previously that H_2S can form via three mechanisms in canned wine (see section *Mechanisms for the formation of H_2S post-packaging*). If oxygen is present, it will quickly react (indirect reaction) with the formed H_2S rendering the compound odourless. The complete absence of oxygen in the sealed pack can support the release of H_2S from copper-bound H_2S complexes and polysulfanes and the *de novo* formation of H_2S during the storage of wine.

Total package oxygen

The final TPO after packaging will be a good indication of the amount of oxygen present to prevent H_2S formation. This is a delicate balance as too much oxygen will result in oxidation and too little oxygen might result in reduction. Indeed, anecdotal studies (Wilkes, 2020) have shown that a higher TPO resulted in less H_2S formation over time, however, the shelf life might be reduced due to oxidation. The best strategy would be to avoid having copper in the product before packaging (reducing the risk of H_2S release from copper complexes), thereby minimising the need for oxygen and ensuring that the wine's risk factors are low in order to decrease interaction with the aluminium.

Pinking

Under certain conditions the colour of white wines (some cultivars are more susceptible than others) can adopt a pink hue due to a phenomenon called pinking. This usually occurs when wine was made very reductively and then undergoes a sudden influx of oxygen (Du Toit, Marais, Pretorius, *et al.*, 2006). The use of dry ice, inert gas and ascorbic acid during vinification are all considered as reductive handling and can increase the pinking potential of wine. Exposure to oxygen at a later stage can then potentially cause the wine to turn pink (Simpson, 1977).

Wines may be especially susceptible to pinking during canning as the packaging of smaller volumes usually increases the exposure to oxygen. Even though it is believed that pinking does not affect the aromatic composition of the wine, consumers are intolerant to product deviations. It is advised to test the pinking potential of the wine before canning to ensure product integrity after packaging.

Methods to prevent pinking include:

- Sufficient oxygen management before and during filling.
- Sufficient free SO_2 content.
- Adding an oxygen scavenger, such as ascorbic acid (together with SO_2).
- The removal of the pinking precursors by fining.
- Oxidative winemaking techniques (removal of precursors during wine processing).

Chloride

Together with copper, chloride can play a role in the pitting process during corrosion. Some can suppliers recommend that the concentration not exceed 50 mg/L and classify products with a chloride concentration of higher than 50 mg/L as a high-risk product (Crouchiere, 2020). Nampak Bevcan recommends a maximum chloride concentration of 190 mg/L. However, to date, pack tests done by the Nampak Research & Development have shown that South African wines usually contain less than 100 mg/L of chlorides (Peinke *et al.*, 2020). The origin, implications and management of chloride in wine is unclear and information limited, but the wine producer and the canning facility should be aware of the potential risk.

pH

In wine, a low pH is usually preferred due to the decreased risk of oxidation and microbial spoilage at lower pH values. The coating inside the aluminium pack can withstand a very low pH (consider pH 2.5 of Coca-Cola). Therefore, pH alone is probably not a risk factor when canning wine (also depending on the type of coating applied). However, a low pH will result in a higher percentage of molecular SO_2 present in the wine, which could place the product in a high-risk category. The pH should thus be considered in combination with SO_2 concentration.

Carbonation and pressurisation

Sensory contribution

The dissolved carbon dioxide content of wine is important as it can significantly affect the sensory perception of the wine. Too low carbon dioxide concentrations will leave the wine tasting "flat" and "dull", with the ideal concentration depending on wine style. For a canned wine product, maintaining the ideal carbon dioxide concentration is especially important considering that consumers are used to drinking fizzy beverages from aluminium cans. Too low carbon dioxide content in wine might lead to rejection by the consumer and damage the canned wine reputation.

Carbon dioxide and its role in internal pressure of canned wine

Together with the ideal dissolved carbon dioxide concentration, maintaining the ideal pressure inside the sealed pack is critical. The internal pressure will not only preserve the dissolved carbon dioxide levels, but will also lend mechanical strength to the packaging. During the filling of still wines, the pressure within the sealed can is achieved and maintained by dosing a small amount of liquid nitrogen right before seaming. The liquid nitrogen will transform into the gaseous phase and not only provide the needed internal pressure, but also protect the wine from oxygen exposure by inerting the headspace.

Still wines need to be pressurised with enough liquid nitrogen to ensure a minimum of 120 kPa at 20°C (Peinke *et al.*, 2020). The can end is designed to withstand 620 kPa internal pressure (Peinke *et al.*, 2020). However, even though the packaging can handle relatively higher pressures, the filling of highly carbonated wines (especially in combination with residual sugar) leads to excessive foam formation which complicates and delays the canning process (Riley, 2020). The use of counter-pressure during filling might overcome this hurdle, but opening a highly pressurised can can also lead to excessive foam formation and unwanted spillage. Other than that, too high internal pressures might accelerate corrosion (Ferrarini, Amati, Zironi, *et al.*, 1992) and cause sealing problems.

Sparging and filling

Wine can be carbonated to obtain the desired amount of dissolved carbon dioxide. To effectively achieve this, the wine should be placed in a pressurised tank and cooled to 0°C before sparging with carbon dioxide gas. The pressure

that the carbonation tank can handle will most likely be the limiting factor with most tanks only being able to handle 200 kPa. This will equate to approximately 2.8 - 3.0 volumes of carbon dioxide (approximately 5.5 – 5.9 g/L carbon dioxide). The filling process can then proceed while maintaining a low temperature to retain as much carbon dioxide as possible. However, a loss of 0.1 – 0.2 volumes of carbon dioxide is usually observed from tank to can. Setting the filler to operate at a lower filling speed will help to reduce foam formation and preserve the dissolved carbon dioxide content.

Limitations

An increase in carbon dioxide will lead to an increase in internal pressure and the wine classification might change from a still wine to a perlé wine (maximum 300 kPa in the final container) ("LIQUOR PRODUCTS ACT 60 OF 1989 REGULATIONS", n.d.). Even when using carbonation tanks with a higher pressure capacity, Bevcan Nampak recommends that carbonated wines not be carbonated in excess of 4.0 volumes of carbon dioxide (approximately 7.8 g/L carbon dioxide) which is still less than most sparkling wines packaged in glass bottles (Peinke *et al.*, 2020). Other than that, higher carbon dioxide content will have tax implications.

Filling temperature

Temperature can also affect the internal pressure and ideally, the still wine and the aluminium packaging should be at the same temperature during filling (preferably around 15°C) to ensure that the packs are uniformly pressurised. Filling at a lower temperature will help retain dissolved carbon dioxide while

A temporary cloudy appearance may also occur after decanting due to the release of gas bubbles in the pressurised wine.

increasing the risk of oxygen dissolution. Fillers need to determine the optimum filling temperature based on its ability to retain carbon dioxide and prevent oxygen dissolution.

Initial bubble formation and/or cloudy appearance

Some wineries and consumers have reported the formation of bubbles on the interface between the inner surface of the wine glass (when the wine is decanted from the can) and the wine. Even though the formation of these bubbles does not affect the sensory properties of the wine, some consumers may find it unacceptable. Naturally, consumers drinking the wine directly from the opaque aluminium can will not observe this bubble formation.

Tests have shown that bubbles manifest more frequently when the headspace was filled with a mixture of carbon dioxide and nitrogen compared to nitrogen alone (Barokes, 2006) and it is probably due to the decreased pressure in the beverage from the time of opening (similar to when decanting a carbonated soft drink). A temporary cloudy appearance may also occur after decanting due to the release of gas bubbles in the pressurised wine. The cloudy appearance usually disappears within a few seconds after opening/decanting.

Sterility

As with the production of all wines, the microbial stability of the product is important. Microbial spoilage of wine after packaging can cause significant quality issues and dramatically reduce shelf life. Wines with residual sugar and low alcohol are more susceptible to microbial spoilage and these wines need to be sterile filtered before bottling.

Sanitation protocol

A strict sanitation protocol should be implemented at the canning facility to ensure clean equipment. Sanitising products containing peracetic acid (peroxyacetic acid), a mixture of acetic acid and hydrogen peroxide, can be used to sanitise canning equipment (Riley, 2020). Peracetic acid has a broad microbicidal capacity and rapid, on-contact efficacy under a range of conditions (it has, however, been reported to be less effective against certain spoilage yeasts (Phillips, 2014)). It can be used to sanitise a range of surfaces and equipment, including tanks, pumps, lines and filters (Orth, 1998), and it is non-corrosive to stainless steel at diluted concentrations and during shorter contact times. Moreover, it is a non-chlorinated cleaning agent, reducing the risk of chlorine contamination.

Over time peracetic acid decomposes to acetic acid and water and a 30 minute waiting period should be applied before contact with the wine. Alternatively, the equipment can be rinsed with clean, non-chlorinated water after sanitation. The cleanliness of the equipment should be tested using a procedure that involves swabbing a small surface area and inserting the swab into a luminometer that measures the presence of adenosine triphosphate (ATP), a molecule that functions as the universal energy driver present in every cell.

The use of chlorine-containing cleaning products to clean canning equipment should be avoided, and if used, the equipment should be rinsed thoroughly with clean, non-chlorinated water before any contact with wine (Stokes & Barics, 2013). Filtered, non-chlorinated water should also be used for the rinsing of cans before filling.

Antimicrobial agents

Packaging a clean product using clean equipment will lower the need for antimicrobial protection in the form of SO_2. For low alcohol wines, the addition of antimicrobial agents such as sorbic acid, velcorin and chitosan can be considered to prevent microbial spoilage. These antimicrobial agents are often added using an automatic doser during filling (Riley, 2020). However, some of these additives can have an adverse effect on the sensory composition of wine and the compatibility of these additives with the internal coating should be confirmed with the can provider.

> *A strict sanitation protocol should be implemented at the canning facility to ensure clean equipment.*

Ageing and wine styles

Ageing wine in a can

Ageing wines in cans is not advised due to the higher risk of internal coating and pack failure over time. In general, the maximum shelf life of canned wine is 12 months. However, the wine composition, the packaging composition, and the filling and storage conditions, will eventually determine if the product shelf life can be realised or even exceeded. A preservative such as SO_2, which is not well suited for this type of packaging, is important to prevent oxidation and/or delay natural chemical hydrolyses during ageing.

Smaller volumes more frequently

The oxidation risk of ageing a low SO_2 product in an aluminium can is too great and it is advised to package high-risk products in smaller batches more frequently

> *The global wine industry will have to conduct consumer research to identify the best wine styles.*

as opposed to packaging in bulk and storing the product in the can for an extended period of time. By canning smaller volumes of wine more frequently, the risk of oxidation, microbial spoilage, and the occurrence of off odours and corrosion is minimised. Adopting this strategy is recommended for all wine styles. Other than that, canned products are generally consumed relatively quickly and the convenience of this type of packaging is one of the advantages contributing to the growing popularity of canned wine.

Wine styles

Consumers are used to drinking cold carbonated beverages out of cans and the most popular wine categories seemingly best suited for this type of consumption are the fresher, fruit-driven wine styles such as white, rosé, sparkling, off-dry, and lighter-styled red wines. On the other hand, the global wine industry will have to conduct consumer research to identify the best wine styles and aromatic profiles for wine in cans keeping in mind that consumers are drinking canned wine differently than they do bottled wine. The options are (almost) limitless and even wines needing some aeration (such as the more robust red wines) can be decanted from the can into a glass to allow aeration before consumption.

Conclusion

As for the production of all beverages, the aim is to achieve a quality product with integrity, stability and longevity. The challenges posed by aluminium cans can all be overcome, preserving the product's intended appearance, aroma and taste. Considering that aluminium packaging already faces challenges from many consumers, it is critical to ensure not only that the product's integrity is maintained, but also that the quality of the product is on par, to begin with. To mitigate against highlighted risks, winemakers and brand owners wanting to can wine should partner with a canning company that have invested in their quality control processes and protocols and have proven best practices including: pre-packaging liquid handling, oxygen control and sanitation protocols. Canning a sub-standard quality wine will only cause damage to the canned wine image of which many producers have worked tirelessly to elevate.

The risk factors such as SO_2, copper and oxygen will be minimal in a well-made and carefully packaged wine. Therefore, the intention of canning should be clear from the start of the winemaking process to ensure the risk factors are kept to a minimum. It is recommended that wines be analysed well ahead of packaging to allow sufficient time for any final adjustments. Problems usually occur when a *1* high-risk product is packaged in *2* an environment where the conditions are not well controlled. However, due to the complexity of the wine matrix, no guarantees can be offered and even a low-risk product may develop problems. This is true for all packaging and closure types. As internal coating technology evolves, this should become less of an issue for canned wines.

Once the wine is made, producers need to work collaboratively with suppliers and service providers to make sure the product and the packaging are compatible. The winemaker should also understand the technical aspects of the canning process and ensure that the canning facility has adequate quality control measures in place. Collecting data from canned wine producers, can manufacturers, and service providers will also help to understand the process and how to manage the risks for a specific type of wine. Constructive collaboration between all parties, as well as communication and consultation between different canned wine producers, will ensure the quality of the canned wines is held to a high standard, thereby protecting not only the canned wine industry, but also the global wine industry.

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