Closures for Wine Bottles: Issues and Challenges

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Introduction
The closure is an essential part of a beverage container. Its function is to complement the container in confining and protecting the product during storage and distribution, and to allow easy access after purchase. There is no doubt that the traditional preference for cork as a closure for wine is because of its inert nature, its impermeability to liquids, its flexibility and its extraordinary resilience. What is probably not known is that, despite its permeability to gases, cork is able to provide an effective barrier when it is compressed in the neck of a wine bottle and in contact with the wine. The ability of the container to exclude oxygen and retain volatile components of wine (especially carbon dioxide, CO₂) is essential for the preservation of wine quality.

The sealing of wine bottles with corks is a well-established empirical technology, but in recent decades there have been some problems in adapting it to changes in industrial and commercial conditions. The use of cork stoppers has always involved some irreconcilable criteria (Figure 1), and these have been aggravated during the gradual change from rural craft to competitive business enterprise. This change has brought about increased mechanisation and speed of packaging operations, changes in cost structures, the dilution of skills, greater transport distances, and heightened consumer expectations.

The permeability and cellular construction of cork renders it susceptible to the entry of volatile materials, which may then be retained and later transferred to the wine. This has always been a problem, and spoilage of wine and beer by corks has been reported by W o llidge (1676) and H enderson (ca. 1800). The measures developed by cork suppliers (prolonged exposure to ‘the elements’ after harvesting, and during boiling, sorting and washing) have kept the problem largely, but not completely, under control. The traditional ritual of smelling the cork after extraction, and the alleged readiness of wine retailers to replace unsatisfactory bottles of wine, reflect the longstanding acceptance of cork’s lack of reliability. Although there is a widespread perception that the incidence of cork taint has increased over the last 20 years or so, there is little documented evidence to support this view. It is probable that any increase in the incidence of cork taint would be magnified by an attendant increase in the awareness of the problem.

Despite their imperfections, cork stoppers have played an indispensable role in the evolution of wine styles and, in doing so, established the standard for sealing wine bottles. Earlier misunderstandings about the reasons for the effectiveness of cork stoppers as closures for wine bottles endowed cork with a certain mystique, and also impeded the development of alternative closures. Although the cork paradox has been resolved, and practical alternatives to sealing with cork stoppers have been demonstrated, wine consumers are understandably reluctant to abandon a closure which has been linked so closely, and for so long, with quality wine.

Aspects of cork performance
Zero defects
One of the current problems facing the wine industry is the need to cater at the retail level for single-bottle purchasers. These purchasers are not sympathetic to the concept of ‘average lot quality’. The preferred goal of zero defects can only be approached asymptotically and requires a strategy of ‘control at source’, which means that the primary sources of defects must be identified and documented control measures applied at the site of their origin. It is also important to remain aware that even seemingly random defects have causes.

Dealing with inherent defects would normally be the responsibility of the cork supplier, but where these defects only become apparent after the corks have been used, a close liaison between the supplier and the user is required; that is, a cooperative rather than adversarial approach is needed to relate the performance of corks to their source. Many of the problems with corks result from the way in which they are used by the wine bottler. Once again, the solution lies in having an intimate knowledge of the processes, and being able to control potential problems at their source.

Sealing
Wine bottles leak when their internal pressure is greater than the sealing pressure exerted by the closure. Although the escape of fluid reduces the excess internal pressure, there will be additional intermittent leakage over a period of time with fluctuations in temperature, and the gradual decline in resilience of the cork. Little data exist regarding sealing pressures of wine bottles sealed with corks, but pressures of 1–3 atmospheres have been measured shortly after corking, and 1 atmosphere or less after a period of one or more years.

The mechanical properties of cork are difficult to define precisely, not just because of its macroscopic heterogeneity, but also because stiffness and strain dissipation depend on the size and moisture content of the individual cell walls. Furthermore, stoppers made from a single piece of cork are not isotropic in the axial plane (Figure 2) and, after insertion into a cylindrical bore, the sealing pressure is determined by the force exerted against the glass by the softest region of the cork. This is usually at the largest growth ring, particularly when it passes close to the centre of the cork.

Even if the sealing pressure is very low, for leakage to occur the pressure in the bottle must be greater than atmospheric pressure. Significant pressure increases can be produced temporarily by expansion of the wine caused by an increase in temperature, but it is more common for the main contribution to leakage to be a result of the direct effect of headspace pressure.
If the headspace pressure is greater than the sealing pressure of some circumstances, such as long compression stroke, small reducing the pressure above the wine just before the cork 

produced at corking, and the adverse effect that this pressure can have indirectly on the sealing ability of the cork.

Headspace pressure at corking is generated by compression of the gas above the surface of the wine when the cork is driven into the neck of the bottle (Figure 3). Although vacuum corks are designed to circumvent this problem by reducing the pressure above the wine just before the cork enters the bottle, excessive pressure can still be generated in some circumstances, such as long compression stroke, small headspace volume and inadequate vacuum (see Equation 1 of Figure 3). It is not possible to say just where the compression stroke of a vacuum cork begins, or what pressure exists at the beginning of the compression stroke. This is because the vacuum line is blocked by the cork at the start of insertion, and the escape of compressed gas cannot begin until its pressure exceeds atmospheric pressure. Corkers without vacuum always generate pressure, although this pressure will decrease quickly and substantially if the headspace has been flushed with CO₂. Equations 1 and 2 give only a crude estimate of headspace pressure at corking. Their main purpose is to show the relative significance of the variables.

Pressure produced at corking can be dissipated in several different ways (Figure 4), as listed:

1. Venting
If the headspace pressure is greater than the sealing pressure of the cork, excess pressure will be vented as gas if the bottle remains upright, or as liquid if the base of the cork is covered by the wine. In both cases, the residual pressure will still be in the region of the concurrent seal pressure (1-3 atmospheres). This process can begin while the cork is being inserted.

2. Permeation
If the pressure is greater than the pressure of the gas in the cork cells (approximately 1 atmosphere), and the base of the cork is in contact with the headspace, some of the headspace gas will permeate into the cork until the partial pressures of all gases present are equalised.

3. Dissolution of CO₂
Carbon dioxide is quite soluble in wine, and can dissolve in a matter of minutes. If CO₂ is the only gas in the wine and headspace, the final pressure will be less than atmospheric pressure.

4. Dissolution of air
Some of the headspace air will dissolve in the wine, and this will lead to a gradual reduction in headspace pressure. If the wine is already saturated with nitrogen gas, as some wines are, the reduction in pressure will be less, and due mainly to reaction of the oxygen with constituents of the wine. The final pressure attained will depend on the total amounts of nitrogen and carbon dioxide in the bottle, and on the wine and headspace volumes according to the equation:

\[ p = \frac{V_c}{(L.b_c + h)} + \frac{V_n}{(L.b_n + h)} \]

where
- \( p \) = total pressure
- \( V_c \) = volume of carbon dioxide
- \( V_n \) = volume of nitrogen
- \( L \) = volume of wine
- \( h \) = headspace volume
- \( b_c \) = absorption coefficient of carbon dioxide
  (approximately 0.7 at 20°C)
- \( b_n \) = absorption coefficient of nitrogen
  (approximately 0.014 at 20°C)
A though the partial pressures of carbon dioxide and nitrogen in the wine may be individually less than atmospheric pressure, their combined pressure may be significantly greater.

If, immediately after corks were stored with wine covering the base of the cork, there will be no permeation or venting of gas from the headspace (Figure 4). Some wine may be forced past the cork, but more importantly, the uptake of vapour by the cork will be accelerated by the initial hydraulic pressure, particularly if that pressure is sufficient to force the cork away from the glass and expose a greater area of the cork surface to the liquid. This increase in the condensation of vapour in the cork cells causes a more rapid decline in the resilience and sealing qualities of the cork (Jung et al. 1993).

It is virtually impossible to guarantee that there will be no excessive corking pressure in every bottle, because of the difficulty of removing air completely, and of variation in corks, bottle bores and the performance of corking machines (maintenance of vacuum, and gradual enlargement of the outlet of the compression chamber by wear). Thus, it is desirable that corked bottles remain upright for as long as practicable. Depending on the nature and quantity of gas in the bottle, pressure equilibration can be reached in a matter of minutes (CO₂), or 7–10 days (air). Upright storage for longer than several weeks after corks do not cause oxidation, but will allow sufficient loss of CO₂ to dull the taste of the wine. During storage and distribution, expansion of the wine caused by increases in temperature will aggravate the problem, particularly when the wine is in contact with the cork. The increase in pressure may not always cause leakage, but will tend to accelerate the uptake of vapour by the cork. An increase in volume (relative to bottle capacity) of 2–3 mL can reasonably be expected with an increase in temperature of 10°C. This figure may exceed 5 mL with larger increases in temperature. Estimates of the expected increase in pressure are complicated by differences in the amounts of CO₂ and N₂ in the bottle and the changes in their solubility with changes in temperature. As a rough guide, it can be assumed that the maximum increase in pressure will be by a factor equal to the ratio of the original headspace volume to the new headspace volume. That is:

\[ p_2 = p_1 \frac{h_1}{h_2} \]

where
- \( p \) = absolute pressure
- \( h \) = headspace volume

Moody (1982) has proposed a nomogram for estimating the headspace pressure of bottled liquids in relation to temperature. As in the equation above, this nomogram is based on the assumption that the headspace gas is not soluble in the liquid. Naturally, in a headspace larger than the volume of the liquid expansion, there will be virtually no increase in pressure in the absence of nitrogen or air.

Pressures produced by corking, dissolved gases, and increases in temperature are smaller when the headspace volume is larger. However, the headspace volume is constrained by the volume of the bottle and by the perceived need to restrict oxygen content in the headspace.

**Cork taint**

Spoilage by taint is a constant threat to the food and beverage industries, and its avoidance requires constant scrutiny of the raw materials, premises, ingredients, contact materials, packaging, transport and storage conditions. Despite a high level of vigilance, taint problems do occur from time to time because of some unusual combination of circumstances, or indirect pathways which are not detected during routine inspections (Whitfield 1983). This has probably been well known to winemakers for several millennia. Peynaud (1980) has devoted some 2000 words to descriptions of his experiences of these occurrences.

Corks have persistently been implicated as a source of unpleasant odours in bottled wines, although until recently there has been little direct evidence. The circumstantial evidence is that the taint appears only in some of the bottles of wine after corking, and that the taint can be detected on the cork when it is extracted from the bottle. In the last decade, highly sensitive analytical techniques have enabled the presence of minute amounts of odorous compounds in corks and wines to be linked to the appearance of cork taint.

New glass bottles, after washing and flushing with sulphur dioxide (SO₂), sometimes contain mould mycelia adhering to the interior. Although not visible to the naked eye, they often cause filling problems when bottling sparkling wines. The author has experience with specific microbial techniques which have demonstrated the location and viability of these moulds.

Corks are sometimes falsely incriminated in the appearance of off odours in bottled wine. The two most common examples are:

1. Certain styles of white wine (notably those containing the varieties Riesling, Traminer or Muscat Gordo Blanco) occasionally develop sulphide-like odours under strongly reducing conditions, brought about by a combination of factors including ample free SO₂, presence of ascorbic acid, anaerobic filling, hermetic sealing, exposure to sunlight or fluorescent lights, and clear bottles. The cork is often regarded as the prime suspect because the odour usually appears only in some of the bottles after sealing, such as those in the top layers exposed to light, or those bottles with no oxygen absorption. However, the problem is much more common when impermeable metal closures are used.

2. The atmosphere and materials in wine cellars can become pervaded with foreign odours (microbial, solvent, fumigant), which can be passed on to the wine. Their presence in the wine is not detected on the premises because of the persistent background odour. When the odour is detected away from cellars in the bottled wine, it creates the impression that the odour has appeared after bottling and corking, with suspicion directed mainly at the cork.

It is now generally accepted that the most significant cause of 'corkiness' is the presence in the cork of extraordinarily small quantities (much less than 1 µg/cork) of 2,4,6-trichloroanisole (TCA), some of which is expelled into the bottled wine after corks. The primary source of chloroanisoles is the microbial methylation of chlorophenols, but the mechanisms by which corks acquire this taint are not clear. As chlorophenols (below a certain pH) and chloroanisoles are volatile in steam, it would be reasonable to expect that there would be little in the way of contaminated material immediately after the boiling process, one of the first steps in the manufacture of cork stoppers. Certainly, significant amounts of TCA and other chloroanisoles are displaced quite readily from the contaminated corks after bottling, after soaking in liquids, or after contact with water vapour. Prolonged boiling followed by a 'good airing' is a common domestic remedy for the removal of odours from household materials.

Sponholz and Muno (1993) examined 400 samples of nominally sound Portuguese cork bark from eight regions. A fer the
boiling process, they found some chlorophenols (1–33 ng/g) in all the aqueous samples of finished stoppers. After washing in hypochlorite, all of the 40 samples analysed contained trichlorophenol (19–301 ng/g). Although Zehnder et al. (1984) demonstrated the microbial conversion of 2,4,6-trichlorophenol to TCA in non-sterile corks from damp storage (100% relative humidity), production of TCA in corks has not been recorded under routine commercial conditions.

The main problem lies in the seemingly perverse ability of cork to absorb, immobilise and then later release sufficient contaminant to spoil the wine. The most likely mechanism is one whereby the molecules of the contaminant permeate the cell structure of the cork and are trapped at the cell wall, either by a process of physical adsorption or by dissolution in the waxy layers. The consequent reduction in vapour pressure makes it less likely that a cork tainted in this way will be detected by casual inspection. However, when the cork is inserted in the neck of a bottle, the increase in pressure in the cork cells and the permeation of vapour into the cork increase the vapour pressure of adsorbed materials and cause their permeation into the wine.

A cork stopper has a void volume of 80–90% and an internal surface area of 2–3 m². That sorption/desorption processes take place can be deduced from water vapour adsorption isotherms (Lee et al. 1984), from the ability of cork to absorb other volatile materials, the way that the sorption of phenol is modified by the presence of moisture in the cork, and the way that water vapour will displace volatile materials which have been absorbed by the cork (Casey 1991; see also Figure 5).

Mazzoleni et al. (1993) used a ‘purge and trap’ technique (helium at 60°C) and detected a total of 107 different volatile compounds from samples of raw cork and finished stoppers. The samples showed qualitative differences between provenances, and between the raw cork and the finished stoppers. Stoppers that had been removed from bottles of wine showed the presence of volatile compounds which were not detected in the raw cork. A different range of volatile compounds was obtained when samples of finished stoppers were extracted with aqueous ethanol. Interestingly, these included tributyl phosphate and a number of phthalate esters (commercial plasticisers), probably picked up from the packaging materials. These results demonstrate the ability of cork to retain volatile materials, and the changes in the nature of these materials with changes in environmental conditions.

**Frequency of cork taint**

Accurate data on the frequency and distribution of cork taint could provide valuable clues to its causes. An apparent increase in frequency in the last decades has been attributed to the increased general use of chlorine-based and organochlorine compounds, political and commercial changes in Portugal, the use by wine bottlers of treated (coated) stoppers, and to supply/demand problems in the cork industry. These views are, however, mostly anecdotal or speculative.

Valade et al. (1993) recorded the number of still and sparkling wines which were rejected for cork taint in approximately ten select restaurants in France, and also for Champagne sealed with different batches of corks. The latter were tasted by technical personnel in the Comité Interprofessionnel du Vin de Champagne (CIVC) (Table 1). C. antagrel and Viidal (1990) estimated the incidence of cork-tainted Cognac to be in the region of 0.001%. This figure cannot be compared with those obtained with wine because of the much higher threshold for TCA in Cognac of 0.6 μgL. Six tainted samples contained 1–20 μg TCA/L.

Baldwin (1993) recorded the percentage of wines rejected by judging panels because of corkiness at four Austrlian wine shows in 1992 (Table 1). He noted that the significantly lower rates for red and fortified wines probably indicated that a further 1–2% of these wines were contaminated with a concentration lower than the recognition threshold level (subliminal contamination, at which the character of the wine is altered without any recognisable corkiness).

The author has had direct experience with the inadvertent use of three large batches of tainted corks. One batch (identified as A in Table 1) was used to seal a number of different red and white wines. Approximately 20–40% of these wines were later found to be tainted, and analysis by gas chromatography/mass spectrometry showed the presence of TCA in samples of the affected wines and their corks. No other chloroanisoles were detected. The wines were tasted by a variety of trained, untrained, expert, non-expert and naive panels. Contamination rates varied between panels and wines, with red wines initially showing a lower rate of contamination. As the panels became more experienced, these differences decreased. Many of the wines were badly contaminated, containing several hundred ng TCA/L.

Two other batches of corks (B and C in Table 1) were used to seal bottles of a number of different red and white wines. Before using the corks, ten samples, each consisting of six corks, had been taken from each batch and subjected to sensory assessment using a neutral dry white wine as the test medium. No taint was detected. Afer each batch of corks was used, however, taint was detected in some of the bottled wines. Samples of these wines were assessed for cork taint by trained assessors in panels of five to seven, using a scale from 0–4, where 0 corresponds to ‘nil’ taint, 1 corresponds to a ‘perceivable but not recognisable difference’, 2 to a ‘weak’ taint, 3 to a ‘distinct’ taint, and 4 to a ‘strong’ taint. Wines scoring an average of greater than or equal to 2.0 were classed as ‘corky’. Although batches B and C showed relatively low proportions of clearly ‘corky’ wines (3.7% and 6%, respectively), the corks from the ‘non-corky’ bottles were, when sniffed after extraction, obviously tainted, while the wines were perceived to be ‘different’. That is, they were not obviously

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**Figure 5. Sorption and desorption of chloroform vapour by cork**

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Table 1. Summary of cork taint data

<table>
<thead>
<tr>
<th>Wine type</th>
<th>Cork batch</th>
<th>Sample number</th>
<th>Proportion tainted (%)</th>
<th>Tasters</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still</td>
<td></td>
<td>16000</td>
<td>0.5</td>
<td>Restaurant patrons</td>
<td>Valade et al. (1993)</td>
</tr>
<tr>
<td>Champagne</td>
<td>#1</td>
<td>1700</td>
<td>0.4</td>
<td></td>
<td>CIVC technical personnel</td>
</tr>
<tr>
<td>Cognac</td>
<td>#2</td>
<td>1625</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>#3</td>
<td>1392</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4462</td>
<td>6.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rejected</td>
<td>1000000(^1)</td>
<td>0.001</td>
<td>W ine show panels</td>
<td>Baldwin (1993)</td>
</tr>
<tr>
<td>Dry white</td>
<td></td>
<td>807</td>
<td>3.5</td>
<td>Expert, trained &amp; naive panels</td>
<td>Unpublished data</td>
</tr>
<tr>
<td>Dry red</td>
<td></td>
<td>734</td>
<td>1.2</td>
<td>Trained panels</td>
<td></td>
</tr>
<tr>
<td>Fortified</td>
<td></td>
<td>135</td>
<td>1.5</td>
<td>Trained panels</td>
<td></td>
</tr>
<tr>
<td>Still</td>
<td>A</td>
<td>&gt; 2000</td>
<td>20-40</td>
<td>Trained panels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>463</td>
<td>3.7(^2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>316</td>
<td>6.0(^2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Estimate.
2. Virtually all non-tainted bottles exhibited some alteration of character when compared with the original wines, and all extracted corks exhibited a perceptible taint.

Batch A: sporadic contamination

Batch B & C: fluctuation around threshold levels

\[ R = \text{Recognition Threshold} \]
\[ D = \text{Detection Threshold} \]

Figure 6. Two hypothetical patterns of TCA contamination of corks.

'corky', but 20-40% were judged to have an atypical character, and virtually all lacked fruit character when compared with the original wine.

The same test was applied to samples of the corks by consultants, who concluded that corks from batch B (10 samples each consisting of 10 corks) were 'sound and not affected by corkiness' and that the proportion contaminated in batch C (15 lots of 5 corks) was 6%. Figure 6 is a hypothetical depiction of the difference between two patterns of contamination (A versus B and C).

It is difficult to draw firm conclusions from such limited data. It is clear that the contamination is often related to the cork batch, suggesting an intermittent specific cause rather than a permanent, fluctuating pervasion. There is no indication as to why only some of the wines sealed with a particular batch of corks are affected.

Depending on the source of the contamination, some possibilities are:

- in situ microbial activity;
- permeation from an external source; and/or
- contaminated coating materials.

Sporadic occurrence may be caused by:

- different rates of in situ microbial infection or activity;
- blending of corks from different sources;
- differential exposure to an external source of contamination;
- differences in sorptive/desorptive capacity of individual stoppers (and consequent difference in water activity at the same nominal moisture content); and/or
- fluctuation of taint concentration around threshold levels.

The perception of risk is notoriously subjective, and it is easy for individuals to dismiss occurrences of cork taint of less than several percent as isolated, random events. Taking into account what is considered by the author to be a lack of awareness of the nature of the problem and the probability of subliminal contamination, the problem of 'corkiness' in the past has probably been underestimated. Winemakers who have to bear the burden of accumulated complaints have never been happy about these defects, but, because 'corky' wines are not detected until after they reach the consumer, it can often be difficult to establish a firm link to the materials or processes. However, when the proportion of affected bottles exceeds 5-10%, there is a good chance that the problem will become evident soon after bottling; it is then possible to track down the source. For this reason, it is safe to assume that higher rates of 'corkiness' have occurred only in recent decades, and that they are the result of a change in the processing, handling or distribution of cork and cork stoppers. It is important that the nature of this change or changes be identified.

A) Internal closures

Aglomereate corks

Although agglomerate cork stoppers are manufactured from cork, their relative homogeneity and uniformity make them...
more akin to an industrial product. Their appearance, density, hardness, and elasticity can be quite different from stoppers made from a single piece of cork, and their use requires some adoption of techniques to ensure optimum performance. Nevertheless, agglomerate stoppers share many of the attributes of natural corks, and are able to provide the full range of performance: good, bad and indifferent. They are certainly not immune to the acquisition of taints, including TCA.

Expanded polymer (EP) stoppers

Producers of synthetic stoppers face the problem of trying to approximate the appearance and palpable properties of cork, as well as creating an effective closure. Their behaviour at insertion and extraction is different because their physical properties differ from those of cork products. Like agglomerate stoppers, the main advantage of EP stoppers is their relative uniformity and homogeneity, while their non-biological origin makes them an unlikely target for microbial activity. Nevertheless, they are still susceptible to the acquisition of taints from external sources because the raw materials (polymers) are notorious for their ability to absorb and desorb odorous volatile materials.

Metal closures

Metal closures seal the bottle by compressing an impermeable gasket material against the glass surface at the outlet. A number of combinations are possible using a threaded, crimped or crown metal cap, plus a laminated wad or plastisol gasket in contact with the top, inner or outer surface of the finish. The most successful combination has been the long-skirted, roll-on, tamper-evident (LSROTE) aluminium cap fitted with a wad which is faced with a layer of tin and a layer of polyvinylidene chloride. More commonly known as Stelvin, it was developed by the French company Le Bouchage M éch anique during the 1960s and ‘70s. Its performance as a closure for white and red wines equaled or excelled that of cork in all experimental trials in Australia (Eric et al. 1976). It was used commercially for a number of years, but only for white wines. Other roll-on closures, using similar wadding materials or various plastisol gaskets, have been used experimentally and commercially as closures for table wines (Rankine et al. 1980).

The use of ROTE closures is a well-established technology in the food and beverage industries, and its successful application to the sealing of table wines depends on the properties of the materials comprising the gasket. The ideal combination of materials must not only be inert and impermeable to gases, but also be able to maintain a degree of resilience during the expected shelf-life of the product. A seal with no pressure generated during application and the relatively large headspace (15 mL) reduces the magnitude of thermally-induced pressure changes, a high sealing pressure per se is not required. However, metal closures remain effective only while some pressure is maintained against the sealing surface. Over a period of time, the energy stored in the compressed gasket is dissipated, and the seal becomes less resistant to pressure differences. Selection of the gasket material is thus very important; its thickness, compressibility and long-term resilience need to be matched to the width of the sealing surface, the application force, and the required shelf-life. The integrity of closures that rely on a sealing wad is vulnerable to a side impact on the wad-retention groove, which can result in a loss of sealing pressure.

Unlike cork stoppers, it is not necessary for the gas-impermeable gasket of a metal closure to remain in contact with the wine for maintenance of a gas barrier. Bottles of wine can be stored and distributed standing up without allowing the entry of oxygen or the loss of carbon dioxide. This simplifies many packaging and warehouse storage problems. Alternatives to cork stoppers are not without problems. The use of cylindrical stoppers involves the same compromises depicted in Figure 1, while differences in material properties require changes in application and removal techniques. Metal closures involve a completely different technology, and are a highly visible and more fundamental break with tradition. Despite their indisputable functional advantages, alternatives to cork stoppers remain ‘mythologically unsound’.

Summary

Changes in the retail market, particularly single bottle purchases, have resulted in a greater emphasis on the performance of cork stoppers. Increases in the demand for corks, together with increases in the size and speed of bottling operations, make it difficult to cater for the special conditions required for optimal sealing. Taint problems (including TCA) are not exclusive to the wine industry, but the permeability and sorptive capacity of cork make it a prime vehicle for the transfer of all sorts of volatile materials to bottled wine. Effective alternatives to cork stoppers are available, but their use may destroy the psychological advantages that bottled wines have over their competitors.

References