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INTEGRATED WINE SERVICES

Study of suitability of 187mL PET bottles for packaging wine in Australia.

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1. Introduction

This report first appeared in abridged form in the Australian and New Zealand Wine Industry Journal, January/February 2009, Vol. 24, No. 1.

PET is an abbreviation for polyethylene terephthalate. It is a type of plastic which can be made into various shaped containers by the process of blow moulding. It has found to be particularly suitable in the beverage industry to pack carbonated and still soft drinks, sports drinks, juice, milk and tea. Many other industries pack with PET containers.

PET has not been widely used in the packaging of wine because PET is semi permeable to oxygen. Recently it has been possible to incorporate an oxygen scavenger in PET during manufacture. The oxygen scavenger is depleted by its contact with oxygen which imposes a shelf life on the container.

The suitability of PET as a container for wine was studied in this report.

Although a wide range of container size, shape and colour are possible with PET it was decided to limit this study to the use of 187mL claret shaped containers. The reasons for this choice include:

1 A supply was available of that size container, complete with oxygen scavenger.

2 The suitability of 187mL bottles for 'single serve' packaging which is the fastest growing segment of beverage container sales.

3 Portavin Melbourne (PVM) was able to handle 187mL glass bottles, albeit that they were burgundy not claret in shape.

Characteristically, single serve PET bottles are portable, lightweight, shatter resistant, strong and re-sealable ensuring their relevance in our increasingly mobile and convenience focused society.

Wine in single serve PET bottles would be particularly suited for consumption in places where large quantities of beverage are required to be served in limited time, such as large entertainment venues. The weight advantage of PET compared to glass suggests it may have application in the service of wine on aircraft and places where freight cost savings might be desirable. Furthermore there may be a safety aspect to favour the use of PET compared to glass in the airline industry and at large entertainment venues.

2. Materials and Methods

Site

The trial was conducted from 4th December 2004 til mid December 2005 at the production facility of Portavin Melbourne (PVM) at 114-118 Talinga Rd., Cheltenham, VIC 3192.

Sample storage

Wine samples were stored at PVM, Cheltenham and Amcor Research and Technology (AR&T), Camberwell. Samples subjected to artificially high oxygen or nitrogen environments were stored in 100L tubs with resealable air-tight lids and were gassed with oxygen or nitrogen twice a week in an effort to keep the atmosphere of the tub as close to 100% gas as possible. The samples stored at ambient conditions were stored in the insulated finished goods warehouse operated by PVM.

Wine

Wine for the trial was supplied by Sirromet winery in Queensland. It was 800L of an unwooded blend of a commercial dry white wine from the 2004 vintage (04CDW). Most of the wine packaged into PET was returned to Sirromet for sale. A small amount of the packaged wine was retained by PVM for the trial. All of the wine packaged into glass was retained for the trial.

Wine Preparation

Wine arrived at PVM in 4x200L plastic drums. On the morning of bottling, the contents of the drums were pumped to a 1,000L tank. SO_2 and DO_2 were adjusted to 43ppm free and <0.7ppm respectively. Wine was sterile filtered at bottling. In an effort to minimise any dilution effects from water with the small batch handled, wine was recirculated via the filter system for 20 mins prior bottling and the first 60L in the filler was drained back to the bottling tank. Dissolved oxygen was maintained at 0.7ppm in the tank all that time.

Bottling Machinery

An MBF synchrofill (commissioned in January 2003) owned and operated by Portavin Melbourne was used to fill the glass and PET bottles for the trial. Machine output capacity was 4,500 bph however the trial was conducted at a fraction of that output due to the short run of glass (200) bottles and the fact PET bottles were not compatible with the change parts designed for burgundy shape bottles. Bottles delivered in cartons were fed by hand onto a depaletising table. Bottling followed the SOP of PVM. Bottles were singlised, rinsed, N2 sparged, filled and screw capped and packed unlabelled into 24x187mL plain cardboard cartons. A top load of 120kg was applied to the screw cap during application. The seal was BVP rather than BVS which is now commonly used in the wine industry.

Bottles

PET

Plastic Bottles used in the trial were supplied by Amcor PET Technologies, Footscay, Victoria. Details of the PET bottle include:

- Antique green colour
- Claret shape
- 48mm wide x 163mm high
- Weight was 31gm
- Fill volume at 16mm ullage was 197mL @ 20°C; nominally called 187mL
- Date of manufacture was 1st and 2nd December 2004.
- 4,000 were supplied.
- The oxygen scavenger Amfresh™ was added during manufacture at a concentration of 2%. Amfresh™ is one of a variety of oxygen scavengers which derive from a parent group of compounds known as Amosorb™.

GLASS

Glass bottles used in the trial were manufactured by ACI and supplied by PVM, details of the bottle appear below:

- Colour was classic green
- Burgundy shape
- 53mm wide x 170mm high
- Weight was 153gm
- Fill volume at 16mm ullage was 187mL @ 20°C
- code 20290
- 217 were supplied.

From a commercial perspective in Australia, the availability of PET is quite limited and their price is currently about 30-50% more than glass 187mL bottles. More competitive pricing for PET would be expected when PET can be purchased in large volume.

Other Materials

Screw caps were 25x42 manufactured by Auscap and supplied by PVM.
Cartons (24x187mL) were manufactured by Amcor and supplied by PVM
Plain pallets and stretchwrap were supplied by PVM.

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Plain pallets and stretchwrap were supplied by PVM.

Line and staff time

Line and staff time were supplied by PVM.

Production Order

The machinery was first set for 187mL glass production which was followed immediately by the PET production. Bottling started at 0930 on Sat 4 December 2004 and finished at 1225 a total of 2 hours and 55 minutes. Glass and PET production was noted on the carton and the treatments were stretch wrapped and stored separately on plain pallets.

Laboratory analysis

The majority of analysis was performed by PVM with some early analysis confirmed at Amcor Research and Training.

1. The following equipment was used to conduct the laboratory analysis;

Free and total sulphur dioxide	SO_2 Still - Rankine apparatus
pH and Titratable acidity	Metrohm 719S Titrino
Turbidity	HACH 2100P Turbidity Meter
Alcohol	Alcolyser MEP Instruments Anton Paar
Dissolved oxygen	TPS AQUA DO_2
Torque	Securepak bottle torque metre, model D/3171

2. Methods for conducting the above analysis were followed from Iland, et al (2000), and Portavin's standard laboratory procedures.
3. At each sample interval 5 replicate bottles were analysed individually. The 5 results for each sample interval and each treatment were subject to statistical analysis to assess significance.

Sensory Assessment

1. The following equipment and people were used to conduct the sensory assessment:
   - XL5 wine tasting glasses.
   - Sensory assessment panels were comprised from the staff of Portavin Melbourne who had various levels of wine tasting experience and knowledge. This was considered an advantage for this trial because the cross section of tasters was more likely to resemble the mix of consumers for 187mL product.
2. The following sensory assessment was conducted throughout the trial period;
   a) Prior the 12 month interval;
   In an effort to conserve wine sample blind tastings were conducted (rather than triangle tests) in which samples were given to panelists in a random order in a randomly numbered glass. Each panelist was asked to make notes on each wine, and record preferences. Wine sample for sensory assessment of each treatment at each interval was obtained by blending 2 bottles. This ensured enough sample for the panellists and that the same wine was being assessed without any effect from bottle variation.

   b) For the 12 month interval;
   Twelve (12) panelists participated in the sensory assessment, in which the wine samples from Glass and PET were compared using a modified triangle test. They were presented with a set of three samples in a random order. Panelists had a second attempt, latter in the day, using the same samples presented in a different order.

   As well as identifying the odd sample, they were asked to determine which samples they liked and which ones they disliked. Notes on colour, nose and palate could be made.

   Wine sample for sensory assessment at this interval was obtained by blending 6 bottles. This ensured enough sample for the panellists and that the same wine was being assessed without any effect from bottle variation.

Statistical analysis

1. Laboratory analysis – the results were analysed with the statistical tool pack in Microsoft Excel, using the ANOVA – single factor function.
2. Sensory assessment – the results were statistically analysed by use of the Statistical Chart 2: triangle test, probability of x or more correct judgments in n trials (one-tailed, p=1/3), page 80 of Poste, et al (1991).

3. Results

The results are dealt with in several sections as they relate to:

- Wine Quality - statistically significant.
- Incidental to Wine Quality – statistically significant.

In this report, sulphur dioxide, dissolved oxygen and titratable acidity are abbreviated as SO_2, DO_2 and TA respectively.

WINE QUALITY - STATISTICAL SIGNIFICANT RESULTS

Free and Total Sulphur Dioxide (SO2)

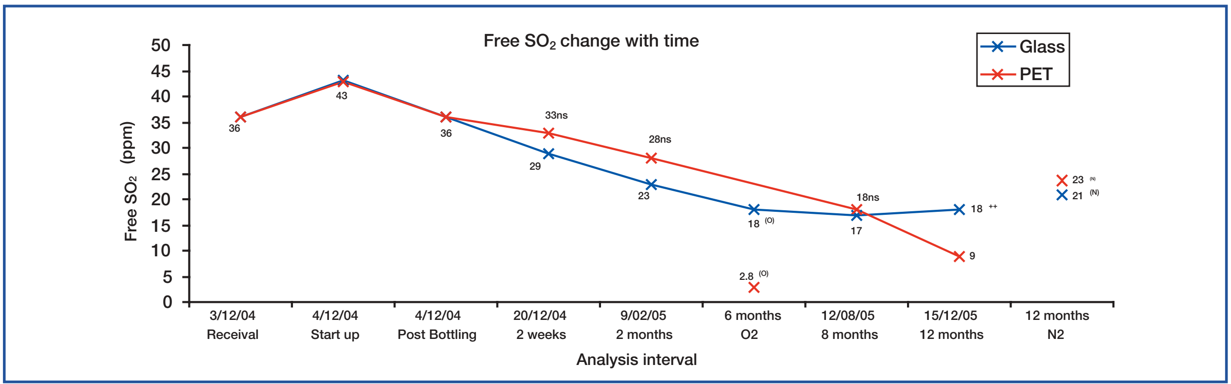

Figure 1: The change with time of Free SO_2 concentration of wine stored in glass and PET bottles. ++Statistically significant to 99% Confidence. (N) and (O) indicate that the measurements were taken on wine after the filled bottles were stored in either a nitrogen or oxygen enriched environment (≈100%).

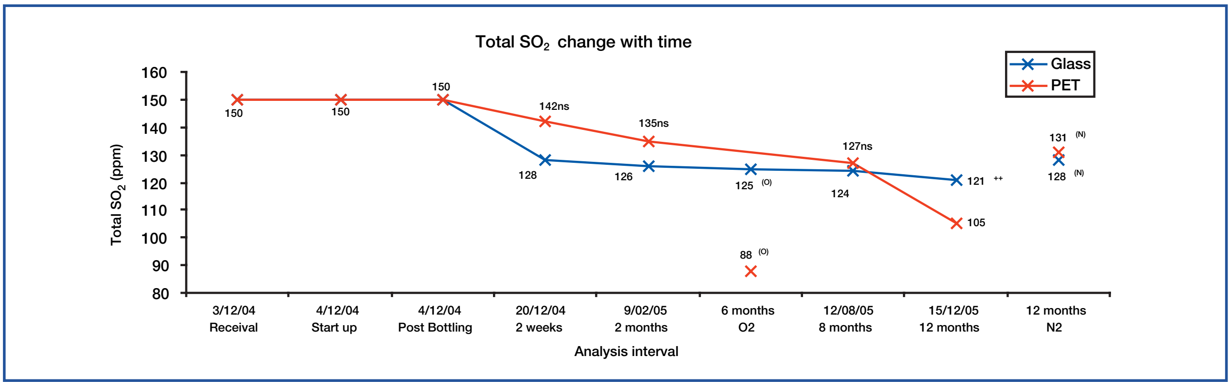

Figure 2: The change with time of Total SO_2 concentration of wine stored in glass and PET bottles. ++Statistically significant to 99% confidence. (N) and (O) indicate that the measurements were taken on wine after the filled bottles were stored in either a nitrogen or oxygen enriched environment (≈100%).

Ambient Conditions The free SO_2 and total SO_2 data for the trial is shown in figures 1 and 2, respectively. Initially, the concentration of free and total SO_2 is identical in both containers. As the trial progressed the drop in the concentration of free and total sulphur dioxide was more pronounced with wine in the glass bottles, than the PET, until 8 months. After that time, both the SO_2 levels in the PET bottles declined rapidly to a level lower than that of wine in glass.

Nitrogen Atmosphere The trends in the data at 12 months show that free and total SO_2 levels were highest in PET (N2) and lowest in Glass (air). The relevance of this observation is discussed in terms of the presence of Amfresh™ and seal of the screw cap.

Oxygen Atmosphere Wine in PET bottles which were kept in a 100% oxygen atmosphere declined to <5ppm by the 6 month sample interval. Levels of free SO_2 as low as 5ppm are not considered adequate for the preservation of wine. These wines were described in sensory terms as brown and tired (data not shown). In contrast, the level of free and total SO_2 of wine in glass bottles were similar, or marginally lower, when compared with the glass treatment under ambient conditions. This is discussed in terms of the hermetic quality of the screw cap – glass seal.

Dissolved Oxygen (DO_2)

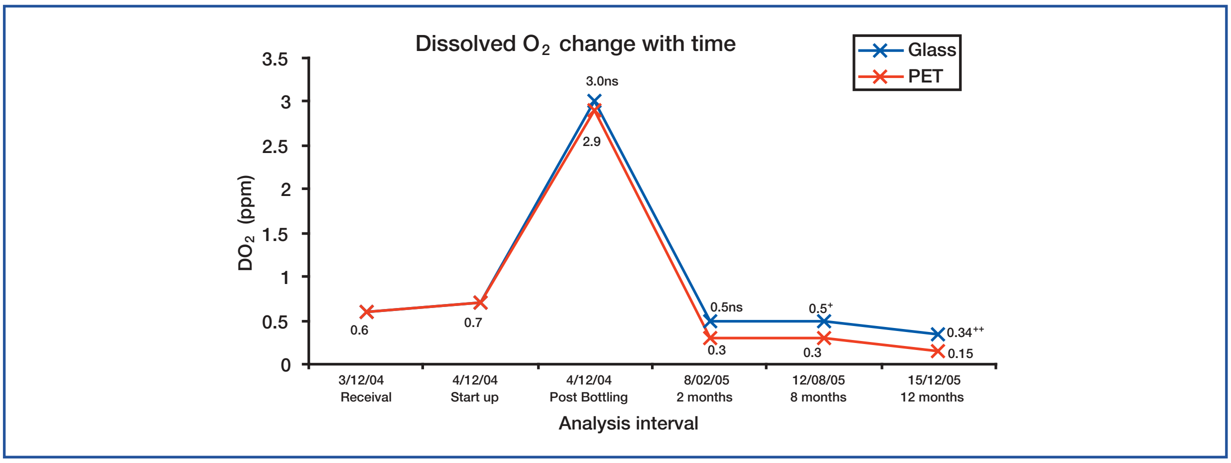

Figure 3: The change with time of Dissolved Oxygen (DO_2) concentration of wine stored in glass and PET bottles. +Statistically significant to 95% confidence. ++Statistically significant to 99% confidence.

The dissolved oxygen (DO_2) data for the trial is shown in figure 3. Initially, the concentration of dissolved oxygen in wine is identical in both container types. During bottling the concentration of DO_2 in both treatments peaked at about 3.0 ppm; a level considered high by industry standards. In some respects it was serendipitous that both treatments commenced the trial with, effectively, the same level of DO_2. As the trial progressed, a drop in the concentration of dissolved oxygen occurred in both treatments. The drop was always more pronounced in wine in the PET bottles compared with glass such that at 12 months the confidence level for this result was 99%. The lower level of DO_2 in wine in PET bottles compared to glass is discussed with the behaviour of SO_2 and the role of Amfresh™ (the oxygen scavenger) in the PET bottle.

Organoleptic changes to wine based on container type

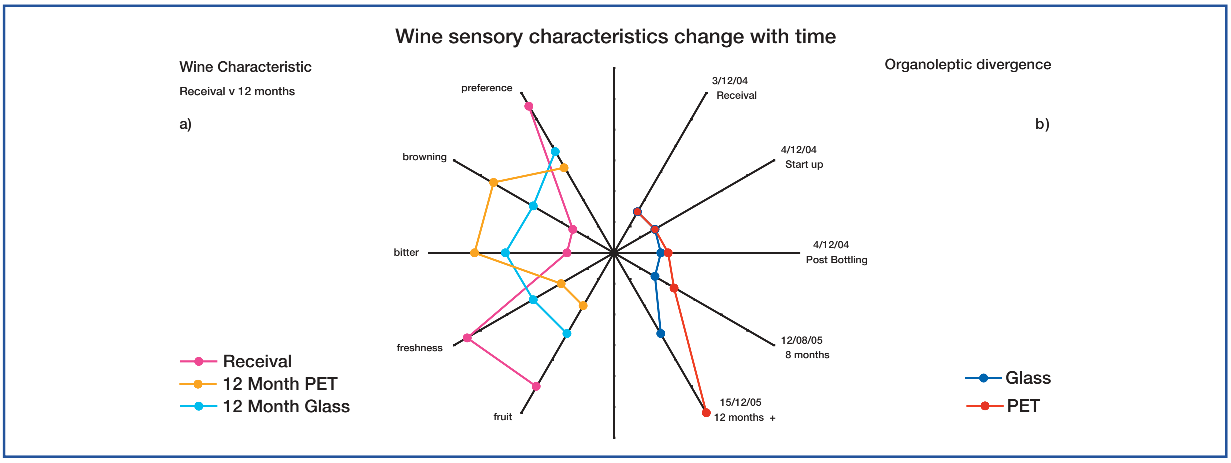

Figure 4: a) The change in Wine Characteristics of wine at receival compared with wine stored for 12 months in glass and PET. b) The organoleptic divergence of wine stored in glass and PET bottles with time. +Statistically significant to 95% confidence.

DATA PRESENTATION

It can be difficult to graphically present subjective results such as wine flavour and other wine attributes.

Figure 4 is an attempt to pictorially present such data and the way to read it is as follows:

- black lines (spokes) of the 'wagon wheel' or 'flavour wheel' are the wine attribute examined.
- a value on the black line close to the centre of the diagram is a 'low' result and a value furthest away from the centre is a 'high' result.
- example, Figure 4a Wine Characteristics (LHS) BROWNING receival sample was least brown and 12 month PET was most brown with glass showing some browning.
- example, Figure 4b Organoleptic Divergence (RHS) 8 MONTHS wine in PET was trending to be more divergent from that packed in glass, although the result was not statistically significant. In other words some tasters could begin to detect differences in the taste of the wine but it was not significant (+) until 12 months from bottling.

INTERPRETATION

The change over 12 months in taste of the wine in glass and PET is presented as Organoleptic divergence in Figure 4b. Organoleptic divergence of wine in each treatment was similar at post bottling. There was evidence of a trend at 8 months that PET was different from glass, however only some experienced tasters could consistently detect a difference – the majority of tasters were unable to reliably detect differences between the treatments at 8 months from bottling. At 12 month sample interval, wine in PET and glass were readily identifiable by most tasters as determined by triangle testing (significance of 95%). Despite that level of significance, there was no consensus with the tasters as to the preference for wine in PET or glass.

The change over 12 months in certain wine attributes of the wine stored in glass and PET is presented as Wine Characteristics in Figure 4a.

Very small, if any, differences in wine characteristics existed between treatments at 8 months (data not shown; sample size was too small for significant results). In contrast, at 12 months, wine in PET was showing more age or development because it was less full and fresh and more bitter and brown, compared to wine in glass. Both treatments exhibited aged characteristics compared to the wine when received. Also demonstrated in this figure is an indication of the number of people who preferred each treatment. It is interesting to observe that wine in PET and glass containers have almost equal numbers liking each, with only 56% of tasters preferring the Glass container (Figure 4a, 'preference').

INCIDENTAL to WINE QUALITY – STATISTICALLY SIGNIFICANT RESULTS

Attributes of opening torque, alcohol concentration, titratable acidity and turbidity are considered.

Torque

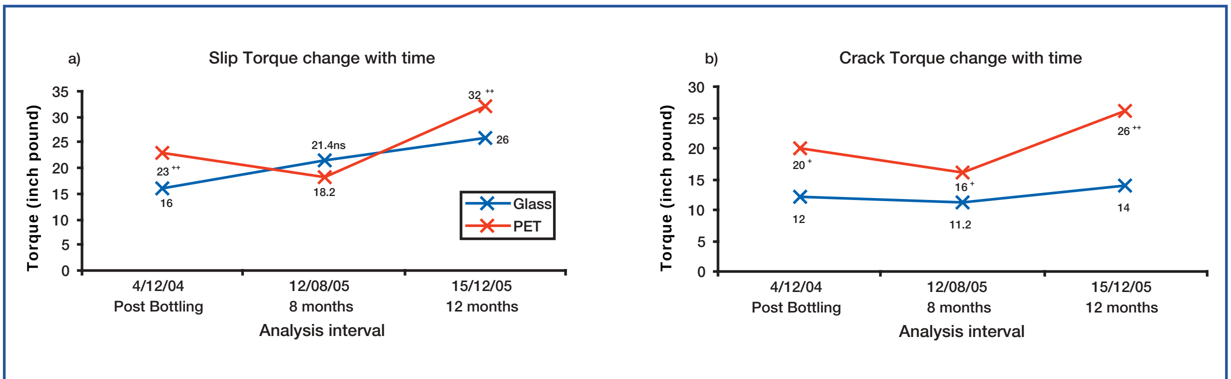

Figure 5: Changes with time of a) slip (seal) opening torque and b) crack (pilfer proof) opening torque of glass and PET bottles filled with wine. + Statistically significant to 95% confidence. --++ Statistically significant to 99% confidence.

As observed in figure 5, torques related to opening the bottle (slip) and breaking the pilfer-proof bridge (crack) are significantly higher with the PET bottles, than glass, at all sample intervals with the exception of seal torque at 8 months. This observation was considered incidental to the any effects on wine quality since all torques were adequate and within specification of each of the manufacturers (Amcor PET bottle; Auscap screw cap). Thus no influence was expected from torque characteristics. One reason for why the PET torque might be higher than for screw caps on glass is that the anti-scuff coating on glass ensures a more slippery surface on which the screw cap can work during opening.

The results of analysis of % alcohol, titratable acidity and turbidity for the trial are presented in figures 6, 7 and 8 respectively below:

Alcohol

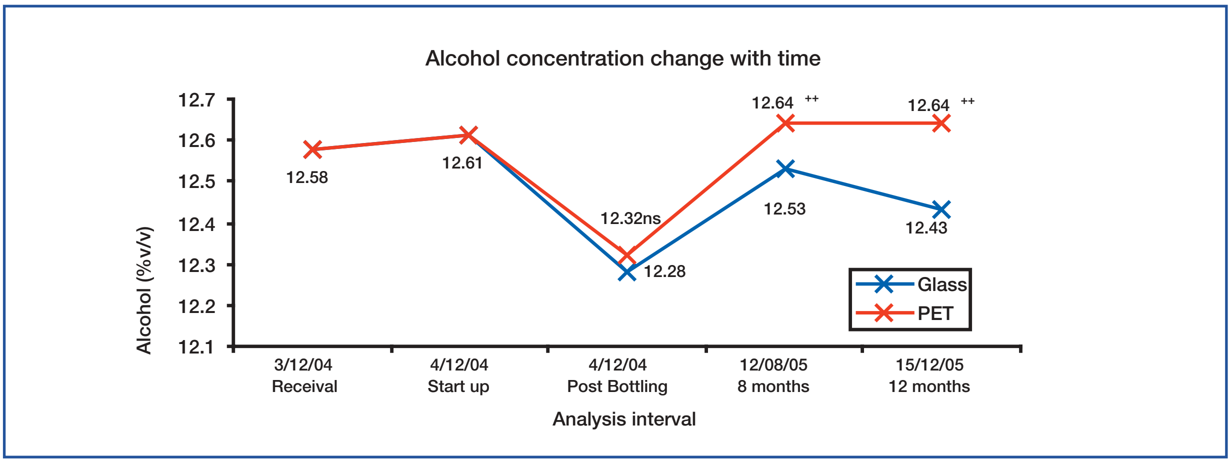

Figure 6: The change with time of Alcohol (%v/v) concentration of wine stored in glass and PET. ++ Statistically significant to 99% confidence.

Titratable Acidity

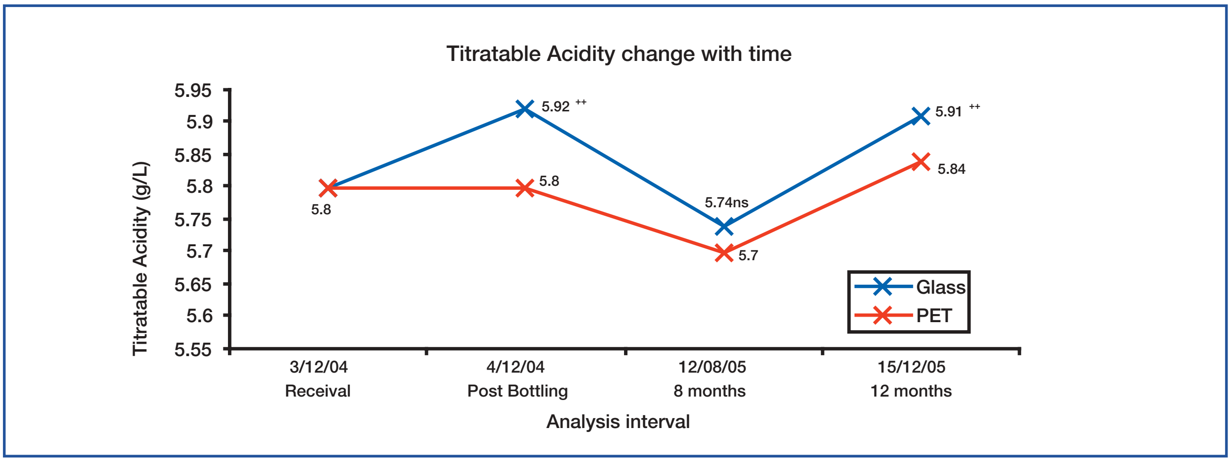

Figure 7: The change with time of Titratable Acidity (TA) of wine stored in glass and PET. ++ Statistically significant to 99% confidence.

Turbidity

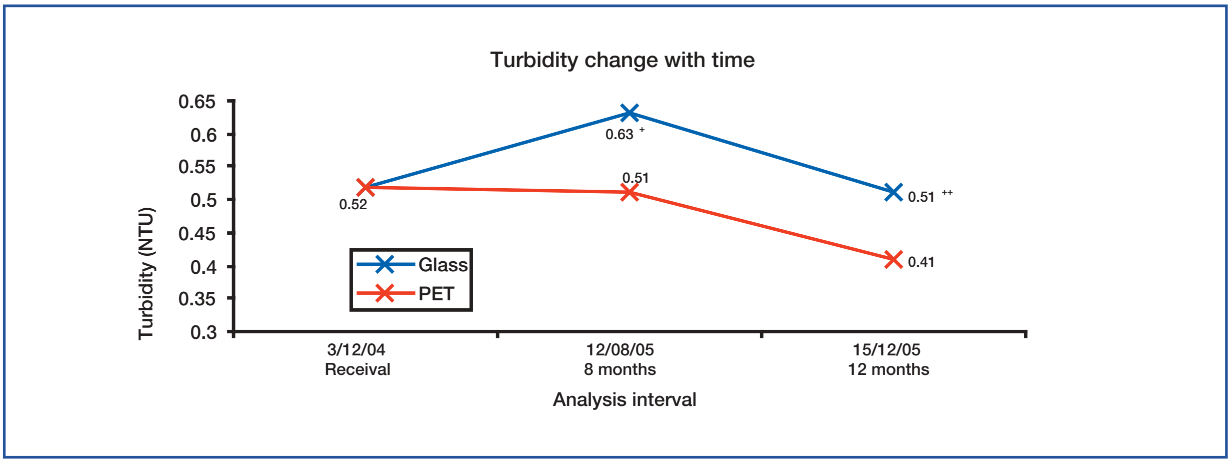

Figure 8: The change with time of Turbidity (NTU) of wine stored in glass and PET. + Statistically significant to 95% confidence. ++ Statistically significant to 99% confidence.

It was interesting to note that, from post bottling analysis and for the duration of the trial, alcohol concentration was higher, and levels of titratable acidity and turbidity were less in wine in PET compared to glass. These observations were statistically significant to 99% confidence at the 12 month sample interval. The most likely explanation for alcohol% to be less in the glass treatment was that it was the only bottle which could be handled into the rinser and it is residual rinse water which diluted slightly but significantly the wine in that treatment. Whether this fact had any bearing on the titratable acidity and turbidity is unclear.

The pH was measured at all sample intervals throughout the trial. The results, however, indicate that there was no significant difference between the two treatments (Data not shown).

The vacuity of the Amcor PET 187mL bottle was found to be approx 200mL at the same fill height (ullage) of the ACI glass187mL bottle. The PET bottles were supplied by Amcor who have taken steps since the beginning of the trial to remove volume and redesign the claret bottle to 187mL fill volume.

4. Discussion

Free and total SO_2, Dissolved Oxygen (DO_2) and Amfresh™.

The results show that for most of the trial, till 8 months from bottling, a trend was observed that levels of free and total SO_2 were higher in wine in PET than glass. Conversely, there was a trend observed that levels of DO_2 were lower in wine in PET than in glass. These trends may indicate a dual role of Amfresh™ acting to scavenge oxygen from the environment outside the bottle (air) and the environment inside the bottle (wine). These trends were not supported by statistical significance, so it may take a trial with larger number of replicates at each interval to explore this suggestion further. This trial showed that up to 8 months from bottling PET and glass perform equally well as a suitable container for wine, a result which was supported by sensory assessment

It was not until the 12 month sample interval that the trend in level of SO_2 was reversed - and it decreased rapidly in the PET treatment. A rapid decrease in the level of free and total SO_2 in wine is evidence of oxidation since SO_2 readily combines chemically, via many intermediaries, with oxygen (Stelzer 2005). The most likely reason for the rapid drop in the level of free SO_2 is that it ultimately reacted with oxygen which permeated the PET bottle. It was concluded that between 8 and 12 months the Amfresh™ was exhausted which permitted oxygen to permeate the PET bottle. This agreed with the expectation from Amcor, prior to the start of the project, that 2% Amfresh™ might confer atleast a 6 month shelf life for the product. These observations and deductions are supported by organoleptic characteristics obtained by sensory assessment at 12 months which showed that wine in PET had become significantly more 'developed' than wine in glass. Interestingly, this had not resulted a clear preference of the tasters for wine in PET or glass. For storage longer than 12 months, glass was the preferred container given the analytical data. Perhaps the most practical way an increase could be achieved in the preservation of wine in PET would be to increase the proportion of Amfresh™ used in manufacture of PET.

Interestingly, the level of DO_2 stayed at low levels in the PET bottles at the 12 month interval after the apparent exhaustion of the oxygen scavenger. DO_2 might, more reasonably, be expected to rise directly with the permeation of oxygen into the wine in PET. The most likely explanation given by the authors for this observation is that the oxygen which permeated the PET bottle, did so at the same rate as the oxygen reacted with SO_2 and other constituents in the wine such that the newly introduced oxygen had no net effect on the pool of dissolved oxygen in the wine. This could occur until critically low levels were reached of free SO_2 in the wine, whereupon there may be observed an increase in DO_2.

Further evidence of the role of Amfresh™ as an oxygen scavenger in this trial was gained by comparison with bottles kept in 100% nitrogen and oxygen atmospheres.

1. 100% NITROGEN ATMOSPHERE

In a 100% nitrogen atmosphere, wine in PET had higher levels of free SO_2 at 12 months compared to wine in glass bottles (Figure 1, no statistical treatment because of small sample size). This was taken as further indication that the oxygen scavenger had lowered the DO_2 in the wine of the PET bottle to a level where consumption of free and total SO_2 was minimal. In the absence of air on the outside of the bottle, Amfresh™ would scavenge oxygen dissolved in the wine.

2. 100% OXYGEN ATMOSPHERE

PET bottles stored in a 100% oxygen atmosphere succumbed within several months to the effects of oxidation, and were totally oxidized at 6 months, as measured by levels of SO_2 (Figure 1) and inspection of wine colour and taste. The oxygen concentration which enveloped this treatment was more than 5 times what is usual in air, so it is understandable that the wine oxidised quicker than in air. The exact time wine became oxidised was not elucidated in this trial but was before 6 months from bottling. Glass bottles stored in a 100% oxygen atmosphere had wine which tended to show a lower concentration of free SO2 at 6 months than similar wine stored at ambient conditions (Figure 1). While no result was measured at 6months for glass stored in 100% nitrogen, by comparison with the later result at 12 months it would appear likely that atleast 3ppm free SO2 could be lost between 100% nitrogen and oxygen treatments. This difference is small but may offer an answer why wine may be observed to age or 'develop' when sealed under screw cap. The authors suggest that the seal between the screw cap (with aluminium PP liner in this trial) and glass bottle is not totally hermetic. Under these conditions any oxygen which enters the bottle may react with free SO2 and other wine constituents (Stelzer 2005) thereby oxidizing the wine to a small degree which wine consumers may observe as aging or 'development'. These changes in wine quality were not considered detrimental to the wine in this trial.

At present wine packaged into 187mL glass containers does not have a shelf life ascribed to it. Depending on the end user, a shelf-life ascribed to wine in 187mL glass sealed with screw cap may be justified. It was not considered that this trial ran long enough to indicate what that shelf-life might be.

Shelf life of 187mL production in PET and glass

There are 2 aspects of shelf life which need to be understood in the use of PET bottles for wine packaging.

1. The first concerns the shelf life considerations of the empty bottle. As mentioned in the introduction, PET is permeable to air, and hence oxygen. In that state a 187mL PET bottle is totally unsuitable as a container in which to store wine. The addition of an oxygen scavenger at bottle manufacture confers protection from the transfer of oxygen across the wall of the bottle. Thus the oxygen scavenger in the bottle begins to react with atmospheric oxygen as soon as the bottle is blow moulded. Since air has more oxygen in it than wine, depletion of the oxygen scavenger in the empty bottle could be very rapid due to the air inside and outside the bottle.

This trial did not investigate the shelf life of the empty bottle, though did minimize any effect it might have had by bottling several days after bottle manufacture. In order that wine packed into PET, manufactured with Amfresh™, has maximum protection from oxidation, the bottle needs to be manufactured as close as possible to the date of filling.

2. The second aspect of shelf life in the use of PET bottles for wine packaging concerns the rate at which oxygen combines with the scavenger after bottling is complete. While the Amfresh™ in this trial was still active, the wine in PET appeared to be equally protected from oxidation compared to the wine in glass. It was not until the Amfresh™ was exhausted that PET failed as a suitable container for wine. The results of this trial showed that the oxygen scavenger Amfresh™ conferred a shelf life of between 8 and 12 months when the bottle was filled immediately after bottle manufacture. With reference to the divergence shown after 8 months in free and total SO_2 concentrations in PET and glass treatments (Figure 1 and 2, respectively), the authors suggest the shelf life of wine in PET from this trial is most likely to be 8 or 9 months from bottling.

One strategy to maximize the shelf life of wine bottled into PET Amfresh™ containers would be to store the empty bottles in a 100% nitrogen atmosphere until bottling day. An extension to this approach could be to store the packaged wine in an atmosphere of inert gas for as long as possible after bottling. Another method may be to chill the packaged wine since this is believed to retard the shelf-life decay rate by the packed wine (David Carew, Amcor PET Technologies (2005), personal communication). These procedures add cost and may be an extreme, and therefore unnecessary, precaution when it is remembered that wine packed into 187mL containers is for rapid consumption and not intended for bottle maturation. From this background a bottle with 2% Amfresh™ may be considered more than adequate for use in the single serve market when considered that Amcor regarded the trial a success in the single serve market if a shelf life in excess of 6 months could be demonstrated.

Bottle Handling

The challenges were considerable to handle the 187mL PET bottle on a bottling line designed for glass bottles from 187mL to 1.5L. The challenges to overcome could be summarized in 2 main categories:

1. stability of the bottle due its ultra light weight (31gm vs 153gm for glass) and narrow diameter (49mm vs 53mm for glass).
2. scratching and scuffing of the soft surface of the PET bottle relative to glass.

Significant changes shall be required to the line designed for glass bottles in order to handle 187mL PET bottles efficiently.

5. Conclusion

Tailor made handling parts combined with certain changes to the bottling line would ensure that claret shaped 187mL PET bottles could be properly handled on the production line at PVM. This would take into account the light weight nature, diameter and surface softness of the bottle.

The trial indicated that from a wine quality point of view, the PET container manufactured with 2%Amfresh™ was equal with glass as a 187mL single serve bottle because the wine had:

1. comparable levels of free and total SO_2
2. comparable low levels of dissolved oxygen
3. vinous flavour equal to that from glass
4. no plastic taint, and
5. comparable freshness.

within 8 months of packaging and bottle manufacture. This was discussed in relation to the shelf life of the:

- empty PET bottle
- bottle full of wine

and the apparent ability of Amfresh™ to scavenge oxygen from the:

- air surrounding the bottle, and
- the wine inside the bottle.

Convenience related attributes of PET which promote it in comparison to glass as a single serve container included the fact 187mL PET was:

1. light weight
2. shatter proof
3. same price when used in volume, and
4. a suitable preserver of wine within the shelf-life period.

After 8 months from packaging (or bottle manufacture), a marked decline in quality of wine was observed with the PET container. However there were indications that the glass container was not suitable, indefinitely, as a container for wine since there was a trend showing the wine would deteriorate at some time after 12 months from bottling. This was discussed in terms that the seal between the screw cap and bottle neck was not as hermetic as might be presumed.

The main drawback with use of PET 187mL containers for wine concern the:

1. permeability of PET to air and hence oxygen.
2. unknown consumer reaction to wine in plastic rather than the traditional glass format.
3. the shelf life which exists on the empty bottle and finished goods.

Analytic and taste attributes studied in this trial showed that 187mL PET made with 2%Amfresh™ was a suitable container for wine for the single serve market.

6. Acknowledgements and References

The authors would like to acknowledge the assistance of the following people or companies whose help was invaluable in the conduct of the trial.

Company	Item Supplied	Personnel
Sirromet Winery	Dry white wine	Adam Chapman, Winemaker Mark Barnsdale, Engineer
Amcor PET Technologies	PET bottles manufactured with 2% Amfresh™	Shay McQuade, Project Initiator Mike Spyropoulos, Manager
	storage of O2 and N2 environment samples	
Portavin Melbourne	Glass, screw caps, cartons, line time, pallets and wine preparation	
	Production	Gavin Wade, Production Manager Savas, Head Production Supervisor Line operators
	Laboratory - data collected & collated throughout trial	Rebecca Taylor, Lab Supervisor Bernie Sullivan, previous Wine Technical Services Manager
	Tasting trials	Micheline Parfait, Lab Technician Plus 15 staff members who volunteered for tasting duty
	Dry goods provision	John Ely, Customer Service Manager Tim Ross MRP specialist The PVM Materials team
	Warehouse sample storage	Rob Burke, W&D Manager The PVM Warehouse team

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7. Addendum

POST TRIAL EXPERIENCE

The results of this trial provided sufficient confidence to commence commercial bottlings of wine into 187mL PET with 2% Amfresh™ as the oxygen scavenger. The first commercial bottling occurred in August 2006. Amfresh™ is one of a variety of oxygen scavengers which derive from a parent group of compounds known as Amosorb™.

TEMPERATURE EFFECTS ON EMPTY AND FULL BOTTLES

PET bottles while empty are very susceptible to deformation by heat and great care must be taken with the dispatch, transport and receival of stock of empty bottles. Direct sunlight for 15 minutes in summer on the side of a pallet of empty bottles is sufficient to heat bottles enough to render them unusable. Indirect sunlight or sustained heat, such as a truck parked in the sun for several hours can have similar results.

The temperature effect on packaged stock is largely by way of an increase or decrease in shelf-life decay rate with temperatures above and below 23°C respectively. Storage of finished product in an insulated warehouse is required as a minimum for wine packed in PET, which incidentally is good management practice for wine packaged in glass as well. Any cost of refrigeration to extend shelf-life of packaged stock can often be avoided by judicial planning of the production schedule.

BOTTLE HANDLING ON THE BOTTLING LINE

Once a bottling line designed for glass bottles is configured to handle PET efficiently, it is a constant 'work in progress' to keep to a minimum scuffing of the soft surface of the PET bottle.

SHELF-LIFE OF COMMERCIAL PRODUCTION

Experience with commercial bottling runs have shown shelf-life of wine to be 9 months from bottling date for bottles manufactured with 2% Amosorb™ and filled within 2 weeks of manufacture. This is consistent with that predicted by the trial, which showed that a shelf-life was justified between 8 and 12 months from bottling.

In order to extend the shelf-life of wine packed into PET, 4% Amosorb™ has been added to the PET bottle at manufacture which has enhanced shelf-life by 6 months. This level of Amosorb™ is less than the limit of 5% prescribed for alcoholic beverages in PET by FDA and EU authorities.

EXTRA MARKER FOR SHELF-LIFE

Browning has begun to be assessed by measurement of the wine at absorbance 420nm and red colour at 520nm, rather than simply by organoleptic assessment. Measurement of browning and colour density and hue by this method gives veracity to the assessment of shelf-life.

NEW SCAVENGERS

Amosorb™ was the only commercially available oxygen scavenger with FDA and EU approval when this trial was commenced in 2004. Since that time a lot of research effort has been directed at finding alternative scavengers which extend shelf-life of wine in PET. There is confidence within the PET industry that an improved oxygen scavenger, with less shelf-life limitations, will soon be found and be commercially available.