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.