How Wine Barrels Work

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Introduction

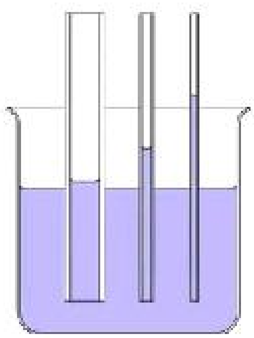
Barrels are more than just expensive liquid-tight containers that give Oak flavour to wines. They soak-up and evaporate wine (or parts of it), breathe, flex, filter oxygen out of the air, aid wine maturation and sometimes cause wine spoilage.

An understanding of the physics and chemistry operating in Wine Barrels, is important not just to promote better winemaking practice, but is vital to the successful application of �barrel-replacement� technologies, such as micro-oxygenation, permeable-bag maturation [4] and the appropriate use of Oak additives, such as staves and chips.

In this article, we explore basic �barrel physics�, discuss what oxygen sources and addition rates best mature wine and relate traditional barrel usage to underlying physical principles.

Finally some interesting and low-cost experiments are discussed that could cut evaporative loss (where desired) remove the need for regular barrel topping and increase awareness as to the �correct� way of oxygenating wine.

Concept 1: Oak Porosity - the Capillary Effect



Surface tension �lifts� fluid higher in finer capillaries.

Photo-micro graph. Oak has through-capillaries, is micro-porous to gases.

Capillary action, which arises from the surface tension property of liquids, has enough �power� to work against significant pressure and height.

A lamp wick, for example, can soak up quite a high �column� of fuel against gravity, from the tank in which one end is immersed.

The Oak wood in a wine barrel contains a fine, porous micro-structure which in the tree, helps supply the nutrients that allow it to grow.

These capillaries, like blotting paper, suck the liquid components of wine (water and ethanol primarily) through the barrel wall, out to the barrel surface where they evaporate, typically at a rate of 300-600 ml/week in a barrique, depending on the relative humidity in the barrel store.

The power of this capillary action is enough to force a vacuum within a stoppered, tight barrel.

Concept 2: Oak Porosity - Gas Exchange

An incorrect, but typical reference in a respected winemaking text [1] states: �The existence of vacuum in the barrel is proof that air is not able to diffuse into a wet full barrel, which means that oxidation of the wine through the barrel walls is not significant [2]�.

In fact, the porosity of Oak runs �both ways�, allowing outside air (~20% Oxygen, 80% Nitrogen) to be sucked into the barrel by increasing vacuum until equilibrium is reached [3] between the rate of evaporative loss and the rate of incoming air. At equilibrium, barrel vacuum stabilizes at about -0.12 atm. in a �tight� barrel.

However, micro-leaks between the staves and in grain faults within the wood add to the natural porosity of the wood. Each barrel thus behaves differently and finds its� own equilibrium vacuum.

Many barrels are �loose� enough not to draw a vacuum at all and French Oak (Q. sessillis, Q. robur) is generally more porous than American Oak (Q. alba).

As the oxygen component of head-space air is continuously consumed by the wine, the equilibrium gas make-up in the head-space is low in O_2 (~ 5%) and high in CO_2 [3]. However all incoming air still contributes its 20% O_2 to wine oxidation.

Concept 3: Deflection - Ullage � DO_2 Surface Gradient

As soon as the barrel is stoppered, after initial filling or topping-off, capillary evaporation commences and a vacuum begins to develop. This increasing negative pressure applies inwards force to the ends and staves. As a result, these deflect inwards [3], decreasing the barrel�s internal volume.

The resulting volume reduction prevents any significant barrel head space (ullage) from forming until after vacuum equilibrium is reached. This typically takes about three weeks.

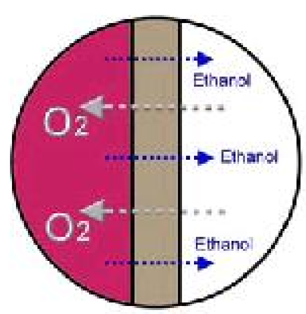
After that time, all ongoing liquid volume lost by evaporation is replaced by the same volume of air (at the reduced internal pressure).

Any free liquid surface in a barrel allows incoming air-oxygen to dissolve into wine at a high rate, in direct proportion to the free surface area. This area increases quickly initially because of the double-curved shape of the barrel at its bilge.

As oxygen is dissolved into wine, it is continuously consumed so that the bulk DO_2 content of wine remains zero. However a concentration gradient exists near the surface. The surface layers of the wine remain oxygen rich and this encourages the growth of various aerobic organisms, such as Acetobacter. This region is not effectively protected by SO_2 which is also depleted there, by oxidation to sulphates.

Unless acetaldehyde character is required (i.e. flor sherry), it is thus necessary to top-up at no longer than 3-4 week intervals. The more often topping is done the better, especially with �loose� or leaking barrels.

Concept 4: Oak - A two-way Osmotic Membrane



Oakstaves are membran e-permeable to molecular gas exchange

As well as being micro-porous to liquid and air, wet Oak staves in a barrel form a semi-permeable membrane, allowing gas molecules to permeate through in both directions by osmosis.

In any osmotic membrane, the rate of molecular transfer of a gas is dependent on the membrane permeability and the partial pressure difference of the particular gas component across the membrane.