Malt Maniacs E-pistle #2011-06

By Matthew Fergusson-Stewart, Singapore

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CHILL FILTRATION AND CLOUD FORMATION IN WHISKY

This is a discussion on the chill filtration of whisky. It's not a discussion on whether or not whisky ***should*** be chill filtered, nor a discussion on whether water and ice should be added to whisky. I do have opinions on both of these issues, but they are just opinions, and there's a pretty good chance that you have your own. I don't want to start a fight on such a passion-fuelled topic! This is a discussion on what chill filtration is, why it is done, why some whisky goes cloudy, and an investigation into an associated phenomenon.

What is Chill Filtration?

Chill filtration has applications in several beverage categories and in many industrial processes. When it comes to whisky, chill filtration involves chilling matured whisky to between -10^{0}C and +4^{0}C Celsius, then filtering by adsorption (not absorption), which is the adhesion of dissolved particles to a surface. In the case of whisky, these particles are things like fatty acids and proteins.

The whisky is chilled, as this helps to precipitate (clump together) the particles so that they can be easily filtered from the liquid. Not every distillery chill filters in the same way, and in the winter months, some distilleries even chill filter at the high end of the range (3^{0}C to 4^{0}C), without actually chilling the whisky first. Temperatures around zero are typical, with the higher temperatures being less effective in removing all the fatty acids and proteins than lower temperatures.

Why Do Distilleries Chill Filter?

Not all distilleries chill filter their whiskies and many that do, still have non-chill filtered releases in their range. Regardless on your views of chill filtration, it is fair to say that there is a passionate and growing demand for non-chill filtered whiskies. So if most distilleries spend money to chill filter most of their whiskies when a growing group of people are demanding that they don't, there must be some advantages to chill filtration to the distillery, right? There are.

In essence, whisky is a mixture of ethanol, water and just a little bit of other stuff that contributes to the colour, aroma, mouth-feel and flavour. That 'other stuff' includes a host of different chemicals including esters, ketones, congeners, aldehydes, phenols, tannins and many more. A typical commercial whisky is approximately 40% alcohol (principally ethanol), 59% water and 1% other stuff. But here's the rub. Everything organic contains something called lipids, which are also known as fatty acids or fats. Some of the lipid content of the barley used to make whisky persists all the way through gristing, steeping, fermentation, distillation and maturation, and is found in the resulting whisky. They certainly aren't a problem in terms of health or calories, and their contribution to flavour and aroma is part of that argument I don't want to get into, except to say, plenty of people love to drink whiskies with the lipids left in.

When whisky is above 46% alcohol at room temperature, there is no issue with lipids. But if you add enough water, if you chill the whisky or if you do both of these by adding ice to your whisky, something significant happens; the whisky goes cloudy. This does not mean the whisky has gone bad or doesn't taste as good, it just means that it loses the classic bright golden shine that is associated with whisky. People who aren't familiar with this phenomenon could be excused for thinking they have an inferior or flawed whisky if it goes cloudy when they add ice. In short, lipids are removed through chill filtration for almost purely aesthetic reasons. Whether chill filtering noticeably changes the flavour or mouth-feel, is a subject of much debate. You can easily do some cloud formation experiments yourself with a bottle of non-chill filtered whisky, preferably with an alcohol percentage between 46 and 50% ABV.

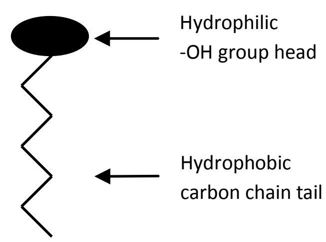
> **Experiment 1:** Pour some of the whisky into a glass and add twice as much pure water. You should see the whisky go cloudy fairly quickly.
>
> **Experiment 2:** Put the bottle of whisky in your freezer. After a few hours of cooling, you will see that the entire bottle of whisky has gone cloudy, even without dilution. Leave the bottle at room temperature and the cloudy haze will slowly disappear, with no negative effects.
>
> **Experiment 3:** While your whisky is still cloudy from the freezer in Experiment 2, pour some of it through a coffee filter paper to replicate the chill filtration process, and then seal it in a smaller bottle to prevent oxidation. Once the bottle and the chill filtered sample have both returned to room temperature, you can do your own taste comparison.

It's worth noting that just as each whisky has different levels of esters, aldehydes or phenols, they can also have different levels of lipids, and some will exhibit this behaviour more strongly than others. For an incredibly stark example of the same principle, try the same experiments with some Greek Ouzo, which goes from clear to opaque white. Absinthe also gives a very strong result.

So Why Does it go Cloudy?

The appearance and disappearance of cloudiness in whisky comes down to the properties of lipids, the properties of the water-ethanol mix, temperature, and something called micelles.

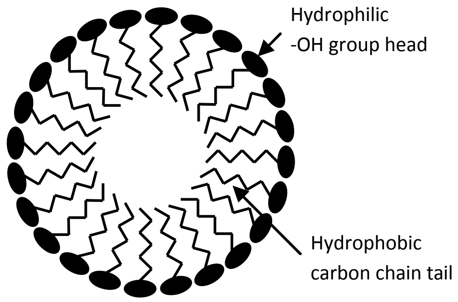
Diagram 1 - Representation of a Lipid



The lipids in whisky are basically fats, and like most fats they have a hydrophilic (water loving) 'head' characterised by an electrically charged -OH group, and a hydrophobic (water hating) 'tail' characterised by one or more long carbon chains **(see Diagram 1).** It is the dominance of these long hydrophobic carbon chains that prevent oil (oil being fat that is liquid at room temperature) from mixing with water. Ethanol, on the other hand is a slightly stranger character. It also has a hydrophilic -OH group at one end and a carbon chain at the other, but the carbon chain is very short. The charged -OH group is therefore able to dominate the short carbon chain, allowing it to mix easily with water. In contrast, alcohols with longer carbon chains than ethanol, like hexanol, do not mix readily with water. Fortuitously, the short carbon chain of ethanol is still sufficiently friendly with the long carbon chains of lipids to allow them to mix together as well. So, in a mixture of water, ethanol and lipids, ethanol is like that guy at the party who makes sure everyone gets along well together. And, let's face it, almost every party benefits from ethanol!

But if a party doesn't have a sufficient number of socially capable people who are able to bring your wife's friends and your work colleagues into the same conservations, the party will break down into cliques. The same thing happens in whisky. If the ethanol drops sufficiently, there will no longer be enough of it to keep the oil and water mixed and they will separate. This starts to happen when the ethanol drops below the magic number of 46% ABV at room temperature. At lower temperatures, the party mood is dampened, and the oil and water will separate even with higher concentrations of ethanol. This is what happens when distilleries chill filter, and it is also what happened in the freezer experiment above.

Diagram 2 - Representation of a Micelle



As the lipids and the water stop mixing, the lipids form something called micelles. A micelle is basically a spherical clump of lipid molecules, where the hydrophobic carbon chain 'tails' all point in to the centre, away from the water, while the hydrophilic 'heads' all point outwards towards the surrounding water **(see Diagram 2)**. Though these clumps of lipid molecules are still tiny, when there are millions of them scattering light in the same glass, the result is a cloudy suspension of solid particles in a liquid, known as a colloid. Incidentally, the cell walls in a human body are constructed in an almost identical way. Animal cell walls have an outer layer of lipid molecules, with the hydrophilic heads pointing outwards, and a reversed inner layer, with hydrophilic heads pointing into the cell. The hydrophobic tails of the molecules in each layer point to each other between the layers. Quite bizarrely, non-chill filtered whisky and cell biology have much in common. Maybe that's why whisky makes me feel so good?

Does This Always Happen?

Some whisky lovers believe that if a whisky is bottled at say 43%, it **MUST** be chill filtered. Others will even go so far as to say that chill filtered whisky is an inferior product, not worth drinking. I disagree on both counts but I will only address the former, the latter being somewhat more subjective.

All non-chill filtered whisky has some level of lipids, and lipids will always contribute to cloudiness when the ethanol content is low enough. However, as mentioned above, not all whiskies have the same lipid levels, and cloudiness does not appear en-mass when whisky first drops just below 46%. The length of the hydrophobic carbon tail (or tails) varies between different lipids, and it is the length of this carbon tail that determines their solubility in ethanol. Longer carbon tails make lipids less soluble, and these lipids form micelles just below 46% ethanol. Others need the ethanol concentration to drop further.

> **Experiment 4:** Take a non-chill filtered whisky and add just a little bit of water at a time, allowing time for the micelles to form between each addition. You will see that gradually more water brings out gradually more cloudiness, until you reach a maximum.

The magical 46% is not a switch that flicks cloudiness on and off; it simply marks one end of the micelle forming range as each lipid has its own critical micelle concentration. There are a number of non-chill filtered whiskies bottled at 43%. This is low enough for micelle formation to begin, but sometimes for it to be less than obvious. Nonetheless, putting one of these whiskies side by side with a chill filtered whisky of similar colour often reveals that the 43% non-chill filtered whisky is not as bright and shiny, a fact that may not be obvious when it is observed alone. Alcohol strength alone is usually not sufficient to determine whether a whisky is, or is not, chill filtered.

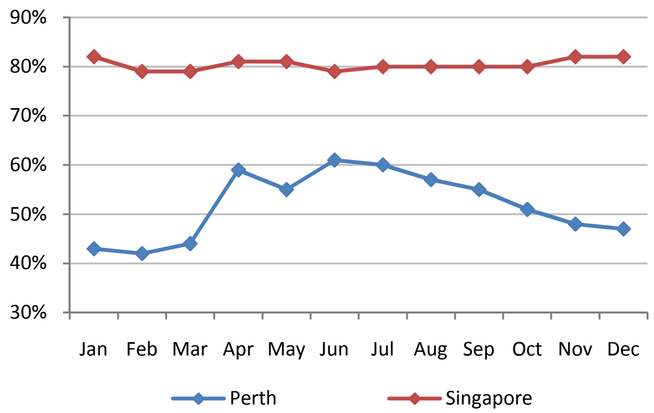
Spontaneous Cloud Formation

That's not the end of the story for cloudiness in whisky, as there is another notable effect that can occur as the result of another property of ethanol. I had the pleasure of growing up in the city of Perth, which is where I also developed my love for Single Malt Whisky. Not in Scotland, but in the other Perth, in Western Australia. Living in Perth, I was very partial to single cask, non-chill filtered whiskies, as I still am now that I live in Singapore. My reason for mentioning these locations will soon become clear. It wasn't until I moved to Singapore that I noticed a strange new phenomenon in my non-chill filtered whiskies – spontaneous cloudiness.

Punctuality is not a trait for which Singaporeans are famed. Once, while running a tasting of cask-strength, non-chill filtered whiskies, I spent some time waiting for guests to arrive. By the time they all sat down and we got around to tasting the drams, some of them had started to turn cloudy. I have observed this in Singapore several times since, but I never saw it in Perth.

I consulted a few people, looking for an explanation. I received a couple of great suggestions, but they did not hold up against further investigation. The first was oxidation in the glass, but cloudiness did not seem to coincide with the appearance of notes associated with oxidation, nor could I identify any specific oxidation reactions that would induce cloudiness in whisky. Higher evaporation of ethanol than water in accordance with Raoult's Law on vapour pressure* was another suggestion, but some very careful measurements indicated that evaporation of ethanol could not have been sufficient to drop the ABV below 46% in the time elapsed. In fact, the volume had marginally increased! Those anomalous measurements and that this phenomenon is prevalent in Singapore but not Perth, led to another hypothesis.

Chart 1 - Average Monthly Relative Humidity of Singapore and Perth



While Perth and Singapore are both known for hot weather, Perth is famed for a very dry heat while Singapore is renowned for intense humidity **(see Chart 1)**. Could the whisky be somehow taking atmospheric water vapour from Singapore's humid air? Further investigation revealed another relevant property of ethanol. Due to its molecular structure, particularly that –OH group we discussed earlier, ethanol exhibits a force known as 'hydrogen bonding'. This means that ethanol is hygroscopic, which in turn means that it readily absorbs water vapour from air. BINGO! While ethanol certainly evaporates from a glass faster than water, providing a contribution to the curious observation of spontaneous cloudiness, the whisky simultaneously pulls water molecules in from the atmosphere, and it does so more quickly in humid Singapore than dry Perth.

With falling ethanol content and rising water content, a cask-strength, non-chill filtered dram in Singapore can quickly drop below 46% ABV and become cloudy, without a detectable loss of volume. No doubt this would eventually happen in Perth as well; I just never left it in the glass long enough!

***For a great explanation of Raoult's Law, see E-pistle #2011-03 by Nabil Mailloux, "Reverse Angel's Share".**

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