Chemistry in a Glass

Creating the Complex Flavour of Whisky

Burns Night is celebrated on 25th January every year. It is a tribute to Robert Burns, the national poet of Scotland, and whisky sits at the heart of the celebrations. Here, we explore the chemistry behind whisky's distinct flavour, texture and aroma.

On Burns Night, Scots all around the world attend a celebratory dinner to honour the poet's birthday and legacy. Haggis is served and glasses of whisky are raised but the "dram" of whisky held in the glass carries more than just warmth. It embodies **centuries of craft and chemistry**. Every flavour, from smoke and spice to vanilla and orchard fruit, is the result of chemical reactions at each stage of whisky's production.

These flavours are not random; they result from a series of processes that have been refined over centuries. From the **selection of grains** to **fermentation**, **distillation**, and **ageing** in casks, each step contributes specific compounds that shape the whisky's aroma, taste, and texture.

THE PROCESS OF WHISKY PRODUCTION

Raw Materials

Whisky's chemical story begins with its raw materials, the very grains famously celebrated by Robert Burns in his ode to Scotch whisky, "John Barleycorn: A Ballad". The choice of grain determines the flavour potential of the spirit before fermentation even begins.

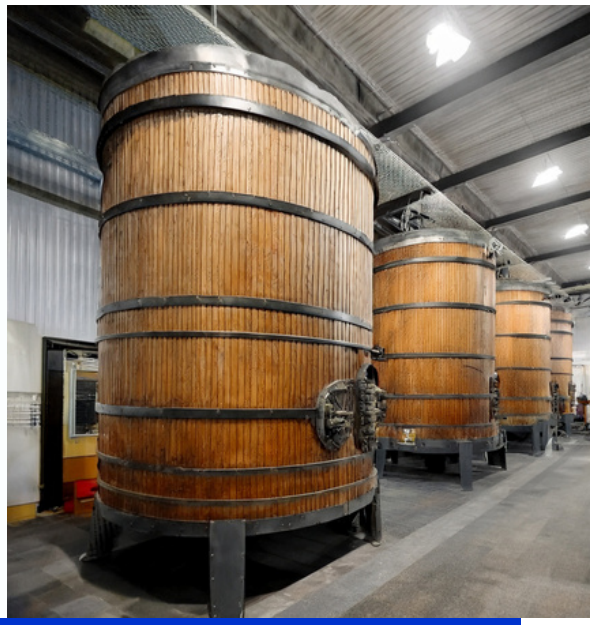
Malt whisky is made from barley, while all other whiskies use corn, rye, or wheat, each of which contains different starches, proteins, and fatty acids that break down into flavour-active compounds during malting and mashing. Corn contributes sweetness and a creamy texture, rye brings spicy and herbaceous notes, whereas both hexanal and furan, found in barley, impart distinct flavours: hexanal adds citrus and grassy notes, while furan contributes nutty caramel nuances.

Malting

The initial step in malt whisky production is malting, where barley grain is first soaked in water to trigger germination. This allows the seeds to sprout and activate enzymes that break down starches into fermentable sugars. The germinated grain (green malt) is then carefully dried to stop the germination process; this preserves these enzymes and develops complex flavours. During drying, heat-driven reactions such as caramelisation occur, creating the whisky's characteristic sweet and toasted notes.

Peat, a partially decomposed plant material commonly harvested from the waterlogged bogs of the Highlands and Scottish Isles, is smouldered beneath the green malt during drying. This deposits phenolic compounds on the barley and gives peated whisky its characteristic smoky and earthy aroma that can persist for decades. The presence of seaweed in Scottish island peat adds subtle salty and briny notes to peated malt whisky, enhancing its smoky, coastal flavour.

Once dried, the malt is crushed and then mixed with hot water to extract sugars into a liquid called "wort", a sugar-rich solution extracted from the crushed malted barley.



Fermentation

The next stage in whisky production is fermentation. During this process, yeast converts sugars in the "wash" (the solution made up of the "wort" and yeast) into ethanol and simultaneously produces "congeners", the compounds that shape the spirit's flavour, aroma, and texture.

Congeners include esters, aldehydes, acids, and alcohols. Different yeast strains produce distinct ester profiles, which, even before distillation, contribute fruity, floral, or spicy notes to the spirit. Short-chain esters such as ethylacetate contribute bright fruity notes reminiscent of green apple, while ethyl lactate adds creamy and buttery nuances. Longer-chain esters such as ethyl palmitate influence "mouthfeel", giving the whisky a waxy or oily texture.

The impact of water on whisky flavour is debated, but the consensus is that trace metals in the water can influence yeast metabolism, affecting the aroma and the taste of the “wash”. It is well established that hard, mineral-rich water tends to promote stronger ester formation, while soft water produces a smoother mouthfeel. Water composition, yeast strain, fermentation temperature, and duration all affect the types and levels of congeners formed, shaping the whisky’s distinctive character.

Distillation

Fermentation is followed by distillation, which separates the fermented wash according to the boiling points of its constituents. The middle fraction, containing ethanol and other desirable flavour compounds, is isolated while the early and late fractions, which contain methanol, harsh aldehydes, and sulphur compounds, are removed.

The copper from which the still (a vessel used to heat and distil the fermented liquid) is made plays a crucial role in whisky production. It binds sulphur compounds, forming copper-sulphur complexes that are removed from the spirit. This process is known as catalytic binding. By removing these unwanted sulphur molecules, copper ensures the resulting whisky smells cleaner and more refined. Additionally, copper promotes oxidation reactions of other trace compounds, further improving the aroma by converting harsh or reactive molecules into more stable, pleasant-smelling ones.

Maturation

Maturation completes whisky’s chemical process. While ageing in casks, the spirit extracts compounds from the wood of the cask.

Oxygen gradually enters the cask, driving slow oxidation that transforms alcohols into aldehydes, acids, and esters. At the same time, natural evaporation concentrates flavours and aromas while reducing harsh alcohols and tannins, resulting in a smoother, more balanced whisky.

The length of ageing is critical, as it allows the spirit to mature and mellows harsh characteristics, although overly-long ageing can result in an excessively woody flavour.

The type of cask also affects the whisky's profile: bourbon barrels made from American oak are the most commonly used, while some whiskies are finished in sherry casks after initial ageing, which adds rich fruity, nutty, and spicy notes to the final spirit.

Oak casks, which are used for almost all whisky production, contribute vanillin, which gives vanilla notes; eugenol, which adds clove-like spice; lactones, which contribute coconut and creamy aromas; and tannins, polyphenols that provide structure and a slight dryness on the palate while helping to balance flavour

Oak variety further shapes the whisky, as European oak produces richer, spicier profiles with higher tannins, whereas American oak contributes sweeter, softer notes enhanced by lactones. Environmental factors such as climate, humidity and altitude affect how the spirit interacts with the wood during ageing.

Summary

Whisky's flavour is shaped by chemistry at every stage. Grain choice determines the initial sugar and protein profile, fermentation produces alcohol and flavour-active congeners, distillation concentrates desirable compounds while removing impurities, and ageing in casks extracts additional flavour compounds.

It is these carefully crafted layers of flavour that make each glass worthy of a toast on Burns Night, carrying the warmth, richness, and spirit of Scotland that Robert Burns so famously celebrated.

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