



Module 2

2.4 Post Distillation Modification of Flavour

- 2.4.1 Basic concepts of maturation
- 2.4.2 Principal factors involved in maturation
 - 2.4.3 Properties of oak wood
 - 2.4.4 Cask types and properties
- 2.4.5 General nature of maturation changes
 - 2.4.6 Cask filling
- 2.4.7 Non-matured spirits: gin and vodka

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ABSTRACT

In this Unit of the Diploma in Distilling, 2.4 Post Distillation Modification of Flavour, we will examine post-distillation processing of distilled spirits to alter and improve flavor and aroma.

We will start with an overview of maturation principles (2.4.1 & 2.4.2) before discussing the subtractive and additive roles of wood and barrel ageing (2.4.3 – 2.4.6). Finally, processing in Gin and Vodka production, including the addition of botanicals, is covered in 2.4.7.

LEARNING OUTCOMES

On completion of this section you should be able to:

- 1. Understand the immature characteristics of spirits before removal by maturation.*
- 2. Describe the interactions between spirits and oak casks throughout maturation.*
- 3. Explain botanicals selection for and operation of a gin still.*

PREREQUISITE UNDERSTANDING

Basic scientific knowledge and terminology, Unit 2.1 Distillation.

2.4.1 BASIC CONCEPTS OF MATURATION & 2.4.2 PRINCIPAL FACTORS INVOLVED IN MATURATION

Introduction

Maturation of distilled spirits is the removal during a period of storage of off-notes from raw materials and fermentation, and the development of colour, fragrance, mellowness and complexity of aroma. A specified minimum number of years of maturation in oak casks is a legal requirement for grape brandies, dark rums and whiskies. During that time a complex sequence of reactions removes undesirable flavours and creates desirable flavours in the mature spirit. For Scotch whisky, a minimum of 3 years' maturation is a legal requirement, and Figure 1 shows the typical effect of that maturation on the main flavour congeners, using a malt whisky spirit as an example, although in practice most Scotch malt whiskies would be matured for longer.

	Congener concentration (mg/litre)	
	New spirit	3 years old
Total higher alcohols	2500	2500
Total esters	650	700
Total sugars	0	1500
Total acids	100	200
Total aldehydes	80	50
Tannins	0	500
Also, Ethanol	63 % abv	60 % abv

Figure 1 Maturation changes in a Scotch malt whisky spirit

Only the volatile components of the fermented wash can be present in the new spirit, so the entire amount of non-volatile congeners such as sugars and tannins must develop during maturation. However, the higher alcohols of the spirit remain unchanged by maturation. Changes in acids, aldehydes and esters are greater than the table would suggest, since some compounds originally present are lost or reduced in amount, and partially replaced by different acids, aldehydes and esters. Only partially, since some of these classes of congener derived from raw materials or fermentation persist through maturation to contribute to the characteristic aroma of the product.

About 2% of the volume is lost annually by evaporation from the cask, but the reduction of alcoholic strength during maturation is typical of Scottish conditions. In theory, the smaller molecules of water vapour should evaporate faster than ethanol, and this actually happens in a dry climate, where the spirit increases in alcoholic strength over maturation. However, the damp Scottish atmosphere restricts evaporation of water so a slight dilution occurs. As a result, the changes in flavour congeners are different in Scotland. Hence the clause in the definition of Scotch Whisky: it must be matured in an Excise warehouse in Scotland, thereby specifying the environmental conditions of maturation. The definition also specifies oak casks, of maximum capacity 700 litres (since surface/volume ratio is important) and a minimum maturation period of 3 years. The significance of these factors is discussed below.

Maturation is an expensive process. The principal costs are:

- Loss of capital: the value of the spirit itself, which can not be sold until the end of the maturation period, and in Scotland, the bond lodged with Revenue and Customs. Presumably other countries require a similar financial guarantee.
- Outlay on casks and warehouse buildings; also their maintenance costs.
- Costs of security against leakage, fire and theft.
- The value of the proportion of the product which is unavoidably lost by evaporation
- Costs of general organisation, in particular regular quality checks and record-keeping, but even the initial checks for matching of the spirit to the available stock of casks represents a significant expense.

So it is possible that 5 years of maturation could cost as much as the raw materials and labour and energy costs for initial production of that volume of spirit. Therefore the duration of maturation has to be carefully considered, e.g. on that 5-year estimate,

production of 15-year old whisky would be double the cost of the same volume of 5-year old. Do the contents of a cask have the potential to reach the quality to sell at the inevitably higher price? Another aspect of the cost of maturation is the organisation of stocks for blending. Since the age of a blended Scotch whisky is the age of its youngest component, not the average, it makes commercial sense to blend whiskies of the same age. Unless there is some essential sensory contribution from older whisky, the expense of the additional maturation of 10-year old is wasted on a 5-year old blend.

2.4.3 PROPERTIES OF OAK WOOD & 2.4.4 CASK TYPES AND PROPERTIES

Strong, durable, non-porous oak has been the preferred wood for storage of preserved food and drink for hundreds of years. Now, with the availability of other methods of packaging and storage, maturation of alcoholic beverages is a rare surviving commercial use of oak casks, for which several types of oak (genus *Quercus*) are in common use. White oak, *Q. alba*, is available in greatest amount, largely because of its forest habitat. Competition for sunlight with other trees encourages tall straight unbranched trunks, yielding the greatest amount of useable wood per tree. The principal source is U.S.A., hence its common name American oak. Several types of oak grow in Europe, particularly the species *Q. robur*, *Q. pedunculata* and *Q. petraea*. However, nomenclature of the genus *Quercus* is still uncertain and these may not all be valid specific names, e.g. the shape and small size of *Q. petraea* may be due to its stony hillside habitat in the Limousin region of France. In practice cooperage oak is known simply as either American, Spanish, Limousin, or another French type Tronçais, which is mainly used for wine. Northern European types, particularly English and Memel, are not normally used for maturation of spirits, but have been used in the past in casks for other purposes. Not only the shapes of the trees differ; there are significant differences in wood chemical structure which affect maturation of spirits, and which will be

mentioned in the context of the specific congeners.

Oak is a strong hardwood, and its structure prevents leakage of liquids. In a growing tree only an outer ring of wood just below the bark carries sap to the higher levels of the tree. In the inner zone, the heart wood, tyloses develop in, and block, the sap vessels and the grain of the wood. Therefore well constructed oak casks are impervious to liquids, but can not completely prevent slow loss of water and alcohol vapour, or inward diffusion of atmospheric oxygen, both of which fortuitously enhance the progress of maturation.

Figure 2 shows the sequence of sawing an oak tree for cask staves. The useable length of trunk of an American oak will be many times the length of a single cask stave, but with the shorter and more branched European oaks, only 1 - 2 stave lengths are likely. Obviously this affects availability and cost of wood of cooperage quality.

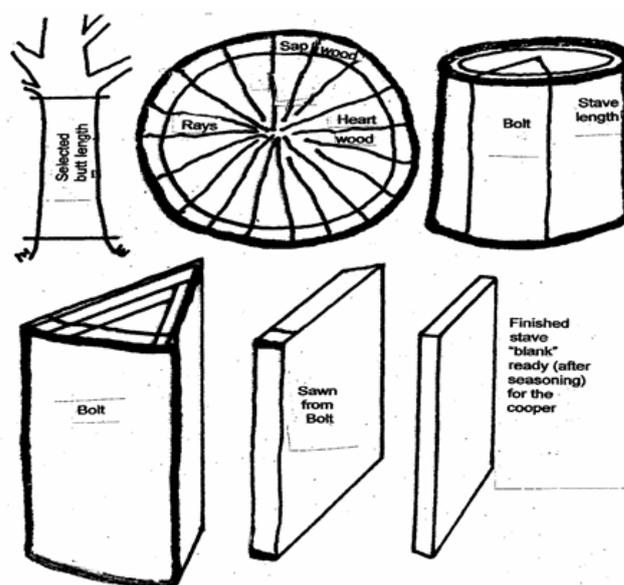


Figure 2 Preparation of oak for cooperage.

Precise sawing is essential to prevent leakage. The staves are cut from a "bolt" of triangular cross-section so that the medullary rays which run radially in the trunk are in the same plane as the cut. If a ray runs across the stave, that creates a leak. Oak must be seasoned before

use in cooperage. For traditional outdoor seasoning, planks are laid in rows with each level of the stack at right angles to the next, to allow air to circulate. Traditional seasoning continues for 1 – 2 years so it was inevitable that rapid oven treatments were introduced. However, slow decomposition changes in the wood over long slow open-air seasoning, too slight to affect structural strength, release tannins which contribute to the maturation process. The heating required to bend the cask staves (the curvature of traditional casks is essential for manual rolling and steering when filled).also causes some chemical degradation of structural components, again providing possible congeners of maturation.

Figure 3 illustrates the process of cask construction. Glue or metal nails can not be used, so the planks of the cask ends are secured by wooden pegs. However, external steel bands can be used to hold the curved staves since liquid spirit can not come in contact with the metal round the outside of the cask. An important stage of manufacture of new casks, but not shown in Figure 3, is the charring of the internal surface of the body of the cask, or at least a milder "toasting" which does not actually char the wood. Heating generates compounds which contribute to maturation, as explained in the section on wood chemistry.

Commonest sizes of cask for whisky maturation are the Standard American Barrel (190 litres) and the Hogshead (250 litres) but the traditional Butt and Puncheon (both 500 litres but of different shape) are also still in use. For economy of transport, used American barrels are dismantled for export to Scotland, and the staves are normally re-assembled as 250 litre casks. The finished cask can be tested by adding a few litres of water, pressurising with air and rolling the cask around to check for leaks. Another important activity of the cooperage is the "rejuvenation" of the inner surface of used casks by scraping off the previous char layer and re-charring. This can be repeated several times over the "life" of the cask since only about 2 mm has to be removed.

Chemistry of oak wood and its heat-degradation products

The structural strength of oak wood is conferred by cellulose and lignin which constitute approximately 50% and 25% respectively of the wood. The other 25% is accounted for by a variety of materials, the most important of which are listed in Figure 4. Although the amount of cellulose, hemicellulose and lignin is approximately constant, the amounts of some minor components vary between types of oak, e.g. Spanish oak has a higher content of extractable tannins than American.

Many of the compounds contributing to maturation are generated, or at least their production is initiated, by toasting or charring of the wood. Because of the physical structure of oak wood, spirit can penetrate only about 4 mm. Since the thermal gradient associated with charring the internal surface affects only the first 2 mm of wood, in the 4 mm layer in contact with liquid spirit there is a range from unheated to intensely charred wood, providing a range of heat-degradation products from different temperatures. Charring has the physical effect of increasing the surface area, and the capacity for absorption of sulphur compounds on the

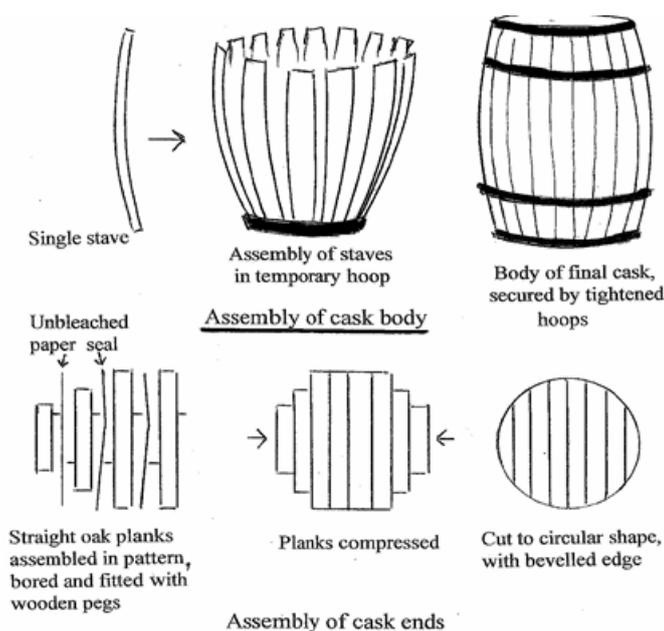


Figure 3 Construction of casks

activated carbon. Charring also forms caramel and other strongly coloured products which are extracted into the spirit. The less intense heating immediately beneath the charred layer produces degradation products of cellulose, hemicellulose, lignin and tannins which are essential for maturation. But even in the unheated layer the ethanol-lignin complex which is formed by contact with spirit

Figure 8 Typical repeating unit of hemicellulose

releases the maturation congeners derived from lignin.

Polymer	%	Function	Contribution to maturation
Cellulose	50	Structural	Sweetness (glucose, cellobiose)
Lignin	25	Structural	Ethanol-lignin, lignin degradation products
Hemicellulose	10	Cell gum	Sweetness (glucose, arabinose, etc) Various heterocyclics by thermal degradation of pentoses
Tannins	10	Antimicrobial defence?	Ellagic, gallic acids, flavonoids, also glucose
Miscellaneous compounds	5	Various	Lactones, sterols, terpenes, aliphatic acids and methyl esters, hydrocarbons, etc

Figure 4 Typical analysis of oak wood

Heat-degradation of cellulose and hemicellulose produces a range of simple sugars. Cellulose is a linear polymer of β 1-4 linked glucose units, hemicellulose (cell gum) is more complex Figure 8.

Glucose and cellobiose from cellulose, and the combination of glucose and the range of pentoses derived from hemicellulose, contribute sweetness and caramel colour to the maturing spirit. Various heterocyclics, e.g. furans, are also formed by pyrolysis of glucose and pentoses and extracted into the spirit, but subsequently degraded to less objectionable congeners.

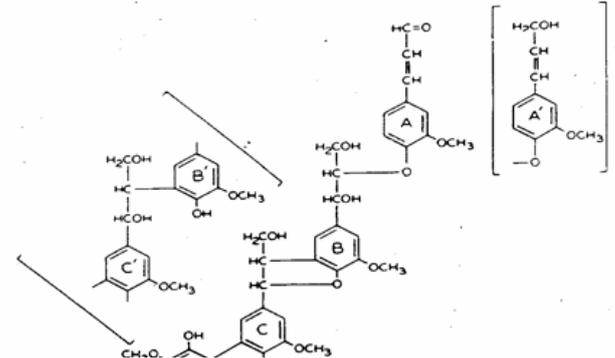
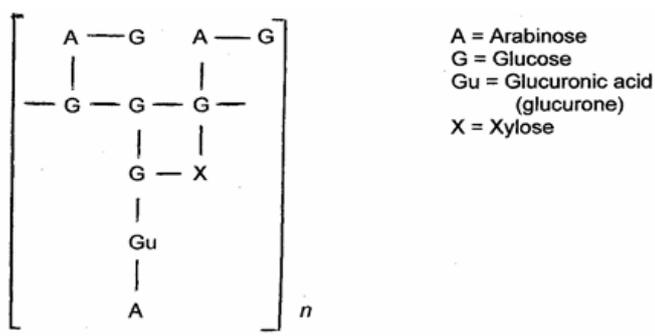


Figure 7 Aromatic aldehydes (mg/litre) produced by toasting or charring oak chips

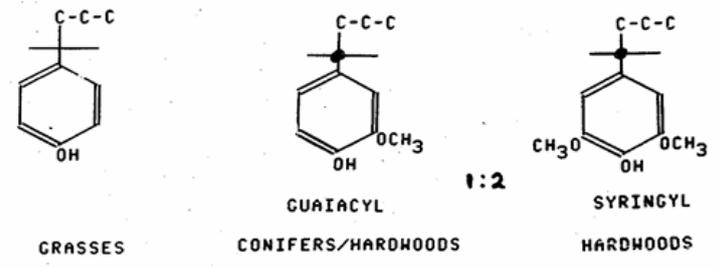
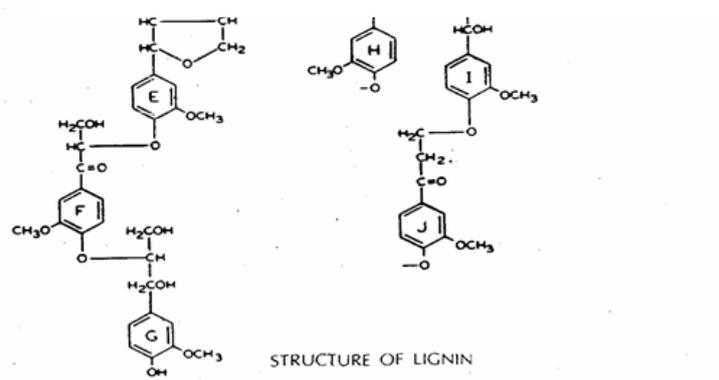


Figure 6 Structure of lignin and its guaiacyl and syringyl sub-units

1	Lignin + ethanol	>	Coniferyl alcohol, sinapic alcohol
2	Coniferyl alcohol + O ₂	>	Coniferaldehyde
	Sinapic alcohol + O ₂	>	Sinapaldehyde
3	Coniferaldehyde + O ₂	>	Vanillin
	Sinapaldehyde + O ₂	>	Syringaldehyde

Figure 5 Formation of aromatic aldehydes during maturation in oak

Product	Toasted temperature °C			Charred
	100	150	200	
Guaiacyl congeners:				
Coniferaldehyde	trace	4.3	24.0	4.8
Vanillin	1.1	3.8	13.5	2.8
Vanillic acid	-	1.8	6.1	1.1
Syringyl congeners:				
Sinapaldehyde	trace	6.5	60.0	9.0
Syringaldehyde	0.1	3.8	32.0	9.2

However, the contribution of lignin degradation products is much more significant. Lignin is a complex phenolic polymer; hardwood lignins such as oak contain both guaiacyl (mono-methoxy) and syringyl (di-methoxy) units, in approximately 1:2 ratio, providing a complex range of congeners. Unit A (top right) separated from the complete structure by the successive effects of heat treatment (pyrolysis) and extraction by ethanol of the spirit (ethanolysis) would form coniferaldehyde.

The equivalent syringyl structure with two methoxy groups is sinapaldehyde. Figure 6 is a summary of these reactions, and subsequent oxidation reactions. More detail, with chemical formulae, is provided in the Progress of Maturation section of this chapter. Typical yields of these and related compounds from different intensities of experimental heat treatment and subsequent ethanolysis are shown in Figure 5.

The reduction in these compounds by the unspecified high temperature of charring is not as important as may appear at first glance. In charring a cask, all temperatures in Figure 5 would be reached at some point in the 2-mm thermal gradient referred to above. However, although toasting at 200°C gives a good yield of flavour compounds, only charring provides the surface layer of activated carbon that absorbs unwanted congeners. Note that heating only to 100°C yields little flavour, and all cask wood must be heated to about 100°C to bend the staves to the correct shape. More intense heating, “toasting” at least, is generally regarded as necessary for spirit maturation for degradation of wood polymers and destruction of unpleasant wood aromas. Actual charring is often preferred, and is a legal requirement for Kentucky Bourbon whiskey..

Heat degradation of tannins also produces a wide range of non-volatile astringent and flavoured compounds. Oak tannins are phenolic glycoside polymers of which the

principal degradation products are ellagic and gallic acids, flavonoids, and glucose. Figure 9 illustrates these three important tannins, but there are others which also contribute to mature flavour. Tannins of the different types of cooperage oak differ in several respects, e.g. of the total tannin in Spanish oak, 10% can be extracted into the 65% alcohol typical of spirit maturation, but only 3% from American. Also the gallotannin/ellagitannin ratio varies between American and Spanish oaks.

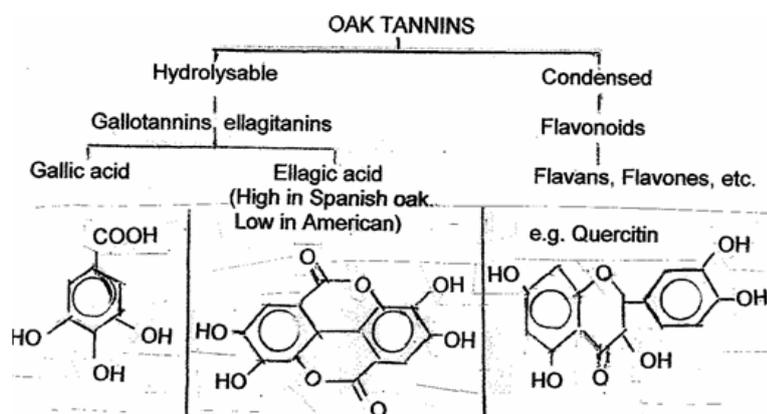


Figure 9 Principal tannins of oak wood

2.4.5 GENERAL NATURE OF MATURATION CHANGES & 2.4.6 CASK FILLING

Progress of maturation

Before filling into casks, spirit from continuous distillation must be diluted to about 65% abv. Spirit from pot stills is normally of the correct strength for maturation, although the stronger product of triple distillation requires reduction. For Kentucky Bourbon whiskey, there is a legal requirement for precisely 62.5% abv (125 US proof) at filling. Otherwise, if there is a standard filling strength, that is the distillery’s choice. The range of congeners extracted from the wood varies with alcohol concentration, e.g. more of the water-soluble congeners such as glycerol and sugars at lower concentration, and more of the ethanol-soluble (e.g. lactones, etc) at higher. With filling strengths above about 75% abv, wood lipids and unpleasant harsh flavours are

increasingly extracted into the spirit, so the usual filling strength is 63 – 70%.

The introduction and removal of congeners over the course of maturation are termed additive and subtractive reactions respectively, but it can be useful to subdivide these terms, e.g. to distinguish between additive and productive reactions. Additive refers to the extraction into the spirit of compounds which were already present in the wood of the cask at the time of filling; productive is the development of new compounds over the course of maturation by reactions within the bulk of the spirit, or between the spirit and the cask surface and/or oxygen. Oxygen is initially dissolved in the spirit by the turbulence of filling, and subsequently there is a slow diffusion of air through the wood of the cask. Probably the most important example of productive maturation is the sequence of oxidation and esterification reactions of lignin degradation products (Figure 11).

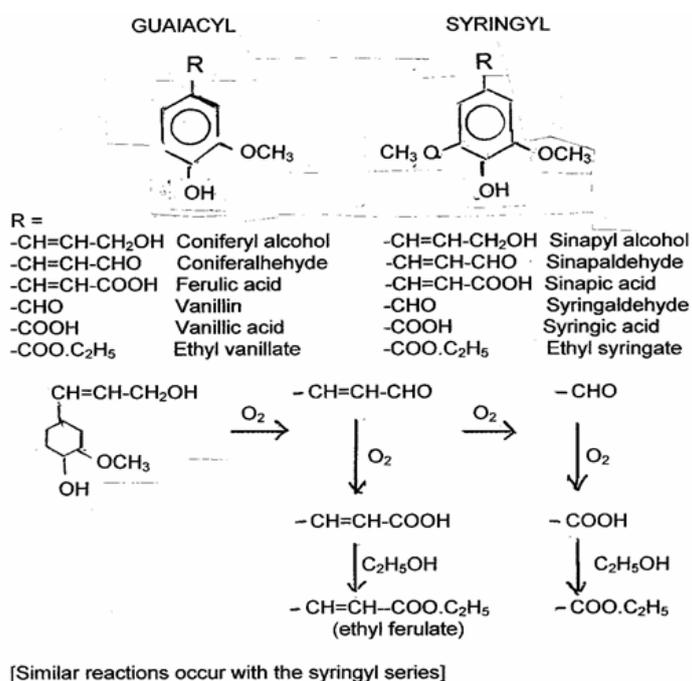


Figure 11 "Productive" oxidation and esterification reactions of lignin degradation products

Similarly, reductive and subtractive reactions can be distinguished. Subtractive implies physical removal, either by absorption to the activated carbon of the char layer, or by

evaporation through the wood of the cask, e.g. acetaldehyde and dimethyl sulphide. However, some of the acetaldehyde could be oxidised to acetic acid, an example of a reductive effect: where a congener is removed from the spirit, or at least reduced in amount, by chemical removal: conversion to a less pungent or more pleasantly flavoured compound. Important examples of each are listed in Figure 10.

Type	Activity	Chemical compounds
Additive	Extraction of flavour Congeners from wood	Sugars, aromatic aldehydes, lactones, polyphenols, etc
Productive	Creation of new congeners by reactions in the spirit or at surface of cask	Acetals (by oxidation reactions) Esters (of ethanol + various acids) Quinones (hydrolysis of tannins)
Subtractive	Evaporation and absorption to char layer	Acetaldehyde, dimethyl sulphide, polysulphides (but see Fig. 8) (Malt whisky: various N and S heterocyclics from malt)
Reductive	Conversion of undesirable congener to less strongly flavoured	Acrolein (very pungent) to acrylic acid

Figure 10 Examples of flavour changes during maturation in oak wood

Note that the progress of maturation is not linear: changes occur rapidly at first and slow down over subsequent years (Figure 12). It is fortunate that in general it is the undesirable congeners which are removed by maturation, but some desirable compounds may also be reduced in amount and regular sensory analysis is required.

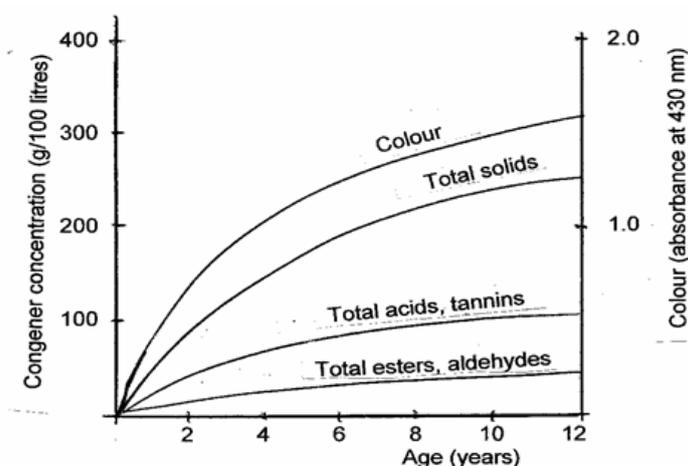


Figure 12 Increase in colour and congeners during maturation

However, complete removal of some of the undesirable compounds may only be achieved by unacceptably long maturation. An important example of this problem is the slow removal of dimethyl polysulphides. Dimethyl sulphide is lost rapidly, mainly by evaporation, but absorption to char also occurs. Unfortunately the more pungent di- and tri-sulphides decline slowly: Figure 13 shows excessive DMTS even after 12 years. So DMTS is an example of an unacceptable congener which may be impossible to control by maturation alone. If “high” DMTS (i.e. high in the parts per billion range which gives off-flavour) is detected in a batch of new spirit, re-distillation will give the copper of the still a second chance to remove the offending congener. Once aware of the problem, increased removal of foreshots/heads during spirit distillation, bringing the initial DMTS content down to a more manageable level, is a more efficient solution for subsequent distillations.

be rejuvenation or disposal. So, matching the spirit to the cask is important. Sensory assessment will determine how much maturation is required (i.e. sensory changes, rather than time) and new, refill or rejuvenated casks are chosen accordingly. Re-use of casks from other alcoholic beverages (e.g. sherry, port and Madeira wines) is also a possibility for whisky maturation. However, whether to use such casks, and if so for what proportion of the total maturation time, is so dependent on the preferences of individual blenders as to be beyond the scope of this chapter.

Compared with brandy and rum maturation, where only strongly-flavoured pot-distilled spirits would normally receive any significant maturation, the choice of cask is especially important in whisky maturation. All whisky spirit, ranging from lightly-flavoured grain to malt spirit with the phenolic aroma of peat smoke, requires at least 3 years of maturation, requiring a range of casks of different potential for maturation changes.. With a newly charred cask, the increase in additive and productive congeners may overwhelm the lightly-flavoured spirit. Figure 2.7.9 is a simple sketch of the problem. The horizontal lines represent the congeners conferring the basic character of two whiskies and the rising lines the development of maturation flavour. So, a new cask is acceptable for malt whisky of strong flavour character, whereas a “lighter” spirit would be overwhelmed by the maturation flavours developing even over only 3 years in that cask. A refill cask would be sufficient.

Although not included in Figure 16, the converse also applies: with their higher level of undesirable congeners at time 0, some malt whiskies could not be satisfactorily matured in the weaker refill cask.

To complete this section, Figure 15 summarises the principal reactions associated with maturation of spirits. Note that the char itself (insoluble carbon) does not provide colour, which comes mainly from heated hemicellulose and lignin.

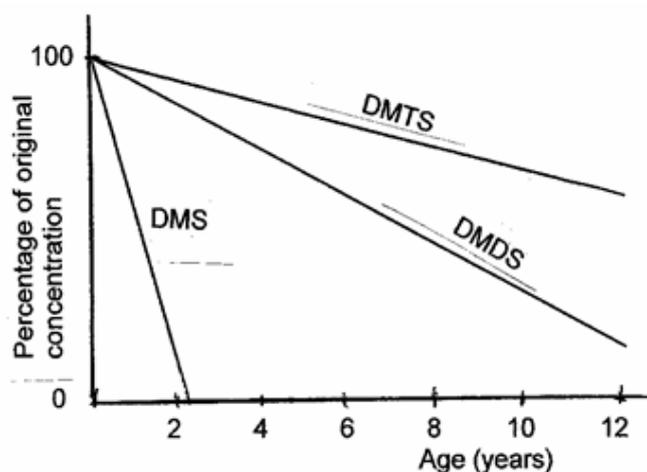
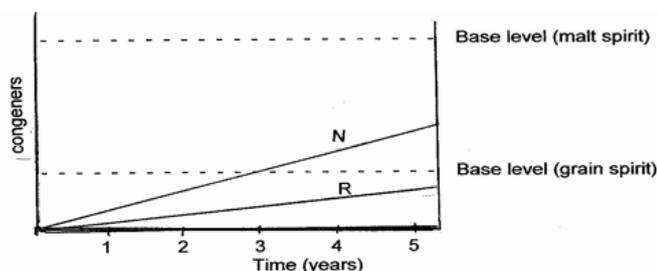


Figure 13 Loss of sulphur compounds during maturation

(DMS = Dimethyl sulphide; DMDS = Dimethyl disulphide, DMTS = Dimethyl trisulphide)

The history of the cask is also relevant in this context. A charred new cask, rich in all of the congeners associated with maturation and with a powerful char layer of activated carbon, will carry out the required changes more rapidly and effectively than a cask on its second fill, which is about 50% less efficient. A further 25% (approximately) of “cask virtue” is lost on a third fill, after which the choice must



N = Additive/productive congeners from New cask; R = from Refill cask

Figure 15 Comparison of congener development in newly charred and second refill casks

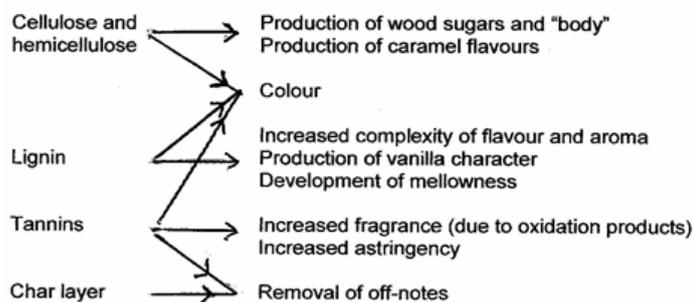


Figure 14 Relationship between wood constituents and flavour changes during maturation

Other congeners

The maturation congeners discussed above are formed by degradation of polymers. Figure 4 also mentioned aliphatic acids and their methyl esters, lactones, sterols, terpenes and hydro-carbons as components of the final 5% of the dry weight of oak wood. These were named because of their contribution to additive maturation by direct extraction from the wood, i.e. without preliminary heat degradation, but there are other compounds present as well. Hydro-carbons, sterols and terpenes have little or no effect on aroma or flavour but, like tannins, could cause haze problems after bottling because of their poorer solubility in 40% ethanol than in the higher strength in the cask.

Two important volatile congeners are “oak lactone” (coconut aroma) and eugenol (clove aroma). Of the isomers of “oak lactone” 3-methyl-4-octalactone (Figure 2.7.11), the trans form has a slightly lower aroma

threshold, about 0.5 mg/litre, as an oak-wood aroma. Its coconut effect is detectable above 1 mg/litre. However, both forms occur together and, extracted into maturing spirit, contribute to the coconut aroma. Oak lactone is another important example of a difference between the main oak types, in this case, American high yield, Spanish low.

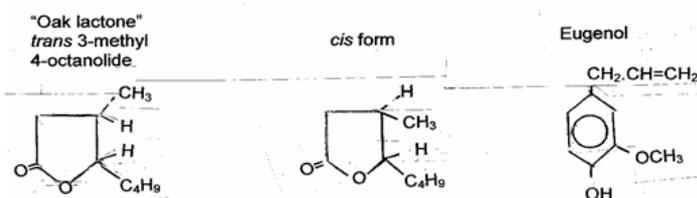


Figure 16 “Oak lactone” and eugenol

Although similar in structure to vanillin, eugenol is not part of the guaiacyl group of lignin degradation products formed by pyrolysis and ethanolysis. It is already present in unheated oak and is extracted directly from the wood.

2.4.7 NON-MATURED SPIRITS: GIN AND VODKA

Neutral spirit feedstock

Gin, vodka and many liqueurs are prepared from neutral spirit obtained by continuous distillation. The usual raw materials for fermentation are grapes, molasses, potatoes or unmalted cereals. The common factor is distillation to a minimum alcoholic strength of 96.0% abv in the European Union (or perhaps slightly different elsewhere) to remove most of the congeners which would impart a distinctive but unwelcome aroma or taste.

The EU specification for neutral spirit for gin and vodka production is shown below. Although an upper limit is not officially specified, diacetyl is also an unacceptable congener. However, the limit for all of these congeners other than methanol is so low that nosing is a more practicable assessment of quality than chemical analysis.

Total acidity (expressed as acetic acid)	1.5 g
Esters (expressed as ethyl acetate)	1.3 g
Aldehydes (expressed as acetaldehyde)	0.5 g
Higher alcohols (expressed as <i>iso</i> -butanol)	0.5 g
Methanol	50 g
Dry extract	1.5 g
Volatile bases containing nitrogen (expressed as N)	0.5 g
Furfural	not detectable

Figure 17. E.U. specification of neutral spirit: maxima expressed as g/100 ml of pure ethanol

These figures are too high for vodka, and also for certain types of gin, hence the requirement for further purification of the spirit by additional column stills and hydro-selective distillation. Although really Module 3 material, a brief outline of the process is relevant here.

Hydro-selective distillation

The principle is explained in the Continuous Distillation unit: at low alcohol concentration, iso-amyl alcohol is more volatile than ethanol, and at high ethanol concentration it is less volatile. Therefore spirit from a 2-column continuous distillation (identified as columns A and B) is diluted to 20% abv with hot water as feed to a third column C, where amyl alcohols and other congeners of similar behaviour (i.e. other higher alcohols) migrate to the **upper** part of the column to be concentrated and drawn off for separation of fusel oil and ethanol. Permanently high-volatile congeners are vented off as heads. Any rising ethanol vapour is refluxed in the downward flow of water, providing a stream of purified 20% alcohol at the base of the column. This is concentrated back to 96% abv in column D, which is similar in most respects to the original rectifier column B. Also, the re-rectifier column D is yet another opportunity to remove any traces of congeners remaining from column C, providing neutral spirit of a high degree of purity. The system is more energy-efficient than this description may suggest, since water continuously circulates at high temperature between columns C and D. To reduce the number of separate stills required, the fusel oil fraction from columns C and D can go to fusel oil still of column B for re-distillation, but **not** if rectifier column B also produces Scotch whisky spirit, since

column D operates above the 94.8% limit.

Vodka

Even so, to meet the standards for high quality vodka, the re-distilled spirit treated with activated charcoal. Some vodka brands first require yet another re-distillation. Usually spirit is diluted for charcoal treatment, perhaps only to 80% abv, but carbon-filtration may take place even at bottling strength. The carbon treatment is one of the following: (a) filtration through carbon-impregnated filter sheets, as many times as necessary for the desired quality, (b) mixing with powdered charcoal, which is then removed by filtration (a messy process, therefore not often used), or (c) passage through a series of columns of granular charcoal. Good quality charcoal is required, and (b) and (c) must be replaced at regular intervals or reactivated by steam treatment (**N.B.** danger of spontaneous ignition of charcoal at 100°C exposed to air).

“Mouthfeel” is an important characteristic of many drinks, and particularly so with the essentially flavourless vodka. To provide that sensation, trace amounts of mineral salts (e.g. Ca and Na), sugars or sugar alcohols may be added below their flavour threshold. However, natural congeners from fermentation are also present in small quantities that are impossible to remove completely, e.g. acetaldehyde, diacetyl and methanol. Their presence can prove, e.g. in a case of disputed authenticity, that the vodka is not a synthetic mixture of ethanol and water but is of natural origin. Also, various flavoured vodkas exist, prepared by infusion with plant material, not distillation as for gin or many liqueurs.

Gin

The English word gin comes from Dutch *genever* (juniper), the obligatory flavouring of both the Dutch and English (London and Plymouth) versions. An important distinction is that Dutch gin uses EU standard grain neutral spirit, to preserve some grain flavour,

but the London style of “dry gin” (which can be distilled anywhere, provided the flavour is typical) requires a feedstock of re-distilled neutral spirit from hydro-selective distillation. Since London gin is the type produced in greatest quantity world-wide, these notes deal specifically with its production, but other gins differ only in minor details.

The various plant materials for flavouring are collectively known as botanicals. The flavour of juniper must predominate, but that does not prohibit a less strongly flavoured component being added in greater amount. The ingredients vary between brands, but the most commonly used, in addition to juniper berries, are believed to be coriander seeds, citrus peel (lemon, sweet orange or bitter orange), angelica root and cinnamon bark. All contain aromatic essential oils which are extracted by the distillation process, according to the relative amounts of the botanicals, the alcohol charge of the still (% abv and volume), geometry of the still (affecting reflux) and the cut points. Juniper berries are dried for storage after harvest, so quality assessment is based on (a) aroma of essential oil, (b) the extractable yield of essential oil, (c) appearance and size and (d) moisture content. Similar criteria apply to the other botanicals.

A gin still usually has a taller neck to increase reflux but is operated in the same way as the spirit still of rum or whisky distillation, except for the higher starting % abv (usually in the 50 – 60% range) and the addition of botanicals. For the latter, there are various possibilities: (a) botanicals added loose to the spirit in the still, (b) added in a fabric or metal mesh bag for easier removal (giving a slightly decreased yield) or (c) on a perforated tray above the charge of spirit in the still, so that extraction is by alcohol vapour alone. Adding botanicals for (a) or (b) to the spirit in the still 12 – 24 h for extraction before the start of distillation increases the total yield of essential oils. The only certainly about (c) is a different aroma profile from (a) and (b); but the total yield of volatile oils is usually lower.

As in rum and whisky distillations, the first distillate (heads) is collected for recycling, then the gin fraction is collected down to the predetermined % abv of the cut point, often 40%. The remaining alcohol is collected in the tails fraction. However, recycling of heads and tails is **not** done in the next run of the gin still, since repeated distillation of botanical essential oils would create unacceptable flavours and aromas. Instead, the gin feints are returned to the continuous distillation system that produced the pure spirit feedstock, for removal of the remaining flavour, and concentration back to 96% spirit. Smaller distilleries have the choice of re-distilling their own feints in a single-column still similar that for Armagnac brandy or selling back to the original supplier for purification.

Other production methods for gin

Not all gin is produced as above. A product of similar aroma can be produced by blending pure neutral spirit with gin concentrate, e.g. a concentrated gin from a 3-fold greater charge of botanicals. Despite loss of the desirable title “distilled gin”, the advantage is that a standard flavour concentrate is provided for different bottling plants. However it is probably impossible to produce exactly the same aroma by the two methods. Although the two should be of the similar quality, triple strength gin diluted in neutral spirit is unlikely to be identical with the product from standard distillation.

Gin flavourings (gin essences) are highly concentrated products from specialised flavour companies. Some are specific essential oils produced by distillation of plant material with ethyl alcohol, but solvent extraction in liquid ethyl alcohol, liquid CO₂ or other solvent is also used for production of essences for “compounded gin”. Again, there are advantages for producing a standard product world-wide, but with the loss of the title “distilled gin”.