11

Cognac: production and aromatic characteristics

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Abstract: This chapter presents the production process and aromatic characteristics of Cognac, the world-famous wine spirit (*eau-de-vie de vin*) produced in the Charentes region of Southwest France. Coming from a delimited geographical area, Cognac has AOC (Appellation of Controlled Origin) certification. Its quality is largely determined by the raw material (grapes) used and the production process, both of which must comply with strict regulations. An olfactometric map of freshly distilled Cognac has been drawn up, bringing together the main aroma compounds generated at succeeding stages of the production process. A Cognac aroma wheel, recently created to raise consumers' awareness of the aromatic richness of Cognac, is also presented here.

Key words: wine spirit, Cognac, production process, aroma, olfactometry.

11.1 Raw materials, production process and major variants

11.1.1 A product with a long history

Grapevines have been grown in Charentes since the end of the first century AD. In the Middle Ages, thanks to the River Charente, the town of Cognac was already famous for its wine trade, a welcome addition to the salt trade, which had been a major source of income since the eleventh century. Wines from the Poitou vineyards, transported in Dutch ships coming to load up with Atlantic coast salt, were much appreciated in the lands lying alongside the North Sea.

In the sixteenth century, the Dutch began distilling the region's wines in order to preserve them better. They came to Cognac to seek out the celebrated wines produced in the Champagne and Borderies vineyards, distilling them back at home in order to preserve them. They named the product obtained 'brandwijn' ('burnt wine') – the origin of the term 'brandy'.

Double distillation made its appearance in the early seventeenth century, enabling the product to travel in the form of a stable wine spirit a great deal more concentrated than wine itself. The first stills were set up in Charente by the Dutch.

Numerous trading companies sprang up which, in the mid-nineteenth century, began dispatching wine spirit in bottles rather than in casks. This new form of trade gave rise to complementary industries such as glassmaking (which went on to develop local expertise in mechanisation of bottle-manufacturing processes), crate and cork manufacture and printing.

Around 1875 *Phylloxera vastatrix*, an insect of the hemiptera order, that attacks vines by sucking the sap from their roots, destroyed most of the Cognac vineyards which, by 1893, only covered some 40 600 hectares, as against 280 000 hectares before the phylloxera plague. As elsewhere in Europe, the Charentes vineyards were reconstituted by the use of American rootstocks. This episode led to the creation of the Comité de la Viticulture in 1888, which went on to become the Station Viticole in 1892, an inter-professional qualitative research body devoted to Cognac.

In the first half of the twentieth century, legislation was drawn up in order to conserve longstanding and unchanging local practices:

- 1909: delimitation of the geographical production area,
- 1936: certification of Cognac as an Appellation d'origine contrôlée (AOC),
- 1938: delimitation of regional appellations.

Historically a product for export, nowadays more than 95% of Cognac is consumed outside France, in over 160 different countries. Currently, around 150 million bottles a year are dispatched to waiting markets. For fans from the Far East, via Europe, to the continent of America, Cognac means top-quality wine spirit emblematic of the French art of living.

11.1.2 Current regulations relating to Cognac

With reference to European Regulation N° 110/2008 (European Union, 2008) on the definition, description, presentation and labelling of spirit drinks, Cognac is a wine spirit. The geographical indication 'Cognac', along with the complementary geographical indications associated with it, are in Annex III of the same regulation. Under French law, Cognac is an AOC, the rules for production of which are more restrictive than those provided for wine spirits by the aforementioned Regulation, and are laid down in Order no. 2009-1146 of 21 September 2009 by the French Ministry of Agriculture Food and Fisheries (2009).

11.1.3 A delimited geographical production area

Temperate maritime climate

The Cognac winegrowing region enjoys a temperate maritime climate, differing little except in coastal areas, which get more sunshine and experience a narrower range of temperatures. Because the ocean is so close by, rain, although heavier in winter, may fall at any time of the year. Periods of drought are few, ensuring the vine a regular water supply. The average annual temperature stands at around

13 °C, with fairly mild winters. Temperatures are high enough to ensure good maturation of grapes to be used for wine spirit production, but not high enough to burn them. The Cognac region's climate was described at the beginning of the twentieth century by Ravaz (1900), and later on by Lafon *et al.* (1964).

A recent study carried out by the BNIC Station Viticole sought to pinpoint recent changes in the Cognac region's climate and assess their impact on vine growing (Boitaud *et al.*, 2010).

Appellation area delimited into 'crus'

In the mid-nineteenth century, Henri Coquand (1811–1881) made a study of the Cognac region's geology (Coquand, 1858). With the help of a taster, he classified the different areas according to the quality of the wine spirits that their soils could produce. Around 1860, their work resulted in the demarcation of different 'crus' (growing areas) and served as a basis for the Order of 13 January 1938 delimiting the crus. Geographical denominations, complementary to the Cognac appellation, still make use of their historical names: Grande Champagne, Petite Champagne, Fine Champagne, Borderies, Fins Bois and Bons Bois, to which must be added Bois Ordinaires or Bois à Terroir (Fig. 11.1).

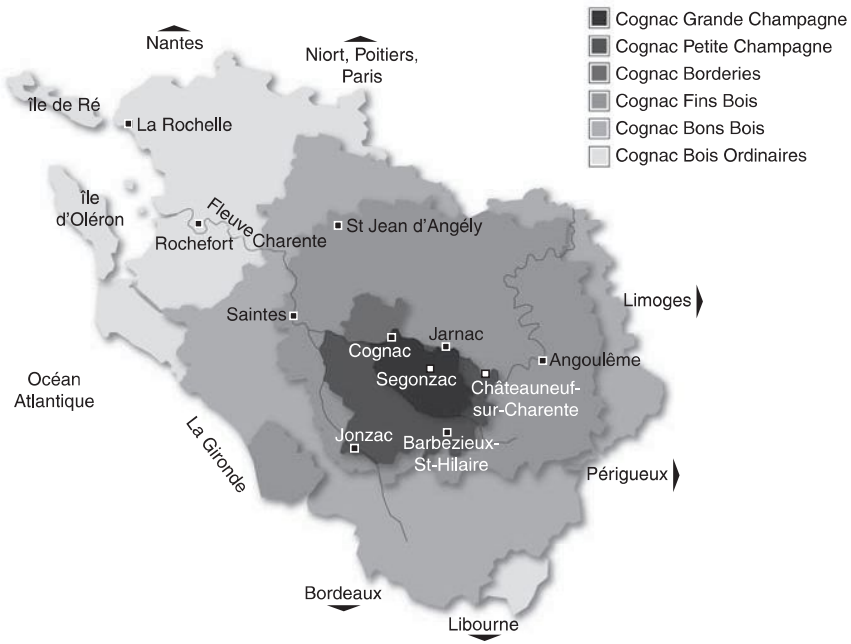

Fig. 11.1 A delimited production area divided into six crus (© BNIC).

According to the work carried out at the time, the dominant characteristics of soils typical of each denomination are as follows:

- Grande and Petite Champagne: thin argilo-calcareous soils over soft chalky Cretaceous limestone,
- Borderies: sandy clay soils containing flint nodules resulting from limestone decarbonation,
- Fins Bois: largely covered by 'groies', thin, stony red argilo-calcareous soils, from Jurassic limestone,
- The Bois (Bons Bois, Bois Ordinaires and Bois à Terroirs): sandy soils in coastal areas, certain valleys and over the entire southern part of the winegrowing area. The sand comes from erosion of the Central Massif.

Dumot *et al.* (1993) give a detailed description of the main types of soil to be found in the Cognac area, which has become a reference in the field.

Wine spirits obtained from the stills are marked by very considerable analytic and organoleptic diversity, largely due to their origin. Such diversity necessitates implementation of different ageing techniques of variable duration.

Grande Champagne produces wine spirits of remarkable finesse, characterised by great distinction and a long finish, and with a predominantly floral bouquet. Its wine spirits are slow to mature, and require long ageing in oak casks in order to reach full maturity.

Petite Champagne wine spirits have mostly the same characteristics as those from Grande Champagne, without, however, the latter's extreme finesse.

The Borderies produce smooth, rounded wine spirits with a strong bouquet and characterised by an aroma of violets. They have a reputation for reaching optimal quality after shorter maturation than those from the Champagne areas.

Fins Bois produce supple, rounded wine spirits that age quite rapidly and whose fruity bouquet is reminiscent of pressed grapes. Bons Bois produce wine spirits with fruity aromas that age rapidly.

Regulations provide for the indication of the cru (Grande Champagne, Petite Champagne or Borderies, for example) on the label. In such cases, the blend must be 'single cru' – in other words, all the products in the blend must come only from the area mentioned on the label. The term Fine Champagne designates a blend of Grande Champagne and Petite Champagne, with at least 50% from Grande Champagne.

11.1.4 Encepagement and vineyard management

Wines destined for elaboration of wine spirits come exclusively from the following grape varieties:

- Colombard B, Folle Blanche B, Montils B, Ugni Blanc B and Semillon B,
- Folignan B, up to 10% of the regional grape varieties.

There are around 75 000 hectares of vineyards devoted to Cognac production. Encepagement is the term used to describe the grape varieties planted within a

vineyard. Ugni Blanc is the most commonly planted variety and accounts for almost 98% of vines in the Cognac area. Its rise in Cognac vineyards began following the phylloxera crisis, about a century ago (Ravaz, 1900). A variety originating in Italy, where it is known as 'Trebbiano Toscano', the Cognac region is its northern limit for ripening. In the mid-twentieth century, it became the first variety for Cognac production, due to its qualities with regard to productivity (its average yield in the Cognac region is between 120 and 130 hectolitres per hectare), late budding, and production of an acidic wine, low in alcohol content, that is particularly suited to production of quality wine spirits. In 2003, the Bureau National Interprofessionnel du Cognac undertook a major research programme in order to preserve the variety's genetic diversity (Dumot *et al.*, 2010).

Rules concerning vineyard management also define planting density, distance between rows, pruning, number of buds per hectare, percentage of missing plants, and minimum age of vines.

The management method used by the vine grower enables reinforcement of the required characteristics of high acidity and low alcohol content. Such maturation objectives are specific to wines meant for distillation. High acidity helps wine preservation through the winter months up to distillation, and low alcohol content enables greater concentration of the wines' aromas in the spirits.

Maximum annual production expressed in pure alcohol per hectare is fixed each year by inter-ministerial order.

11.1.5 An adapted vinification technique

Harvesting of grapes is currently largely mechanised in the Cognac area. Ensuring the grapes' integrity during the transfer and must-extraction stages is very important for the final quality of the spirits obtained. For this reason, the use of centrifugal pumps with pallets is prohibited for grape transfer. Grapes are pressed immediately after harvesting in traditional horizontal-plate presses or pneumatic presses. Continuous presses with Archimedes screws are prohibited. The musts are immediately transferred into vats for fermentation.

Alcoholic fermentation management is a key factor in ensuring the success of winemaking. The process produces ethanol as well as a large part of the wine's – and therefore spirit's – volatile compounds.

Studies on Cognac region yeasts were carried out from the 1970s (Park, 1974; Ribes, 1986) in order to provide producers with strains specifically adapted to distillation wines. In the 1990s, a programme bearing on characterisation and selection of yeast strains naturally present in the Cognac vineyards (Roulland *et al.*, 1995; Versavaud *et al.*, 1995) was carried out. The BNIC defined specifications for selecting the best adapted yeast strains. Six strains currently meet these specifications and are mostly used in the region (Fig. 11.2). In order to increase diversity in production of aromatic compounds, use of several different strains in the same winery is recommended (Ferrari *et al.*, 2010).

Use of sulphur dioxide is not authorised during the fermentation of distillation wines. Addition of sulphur dioxide leads to increased production of aldehydes,

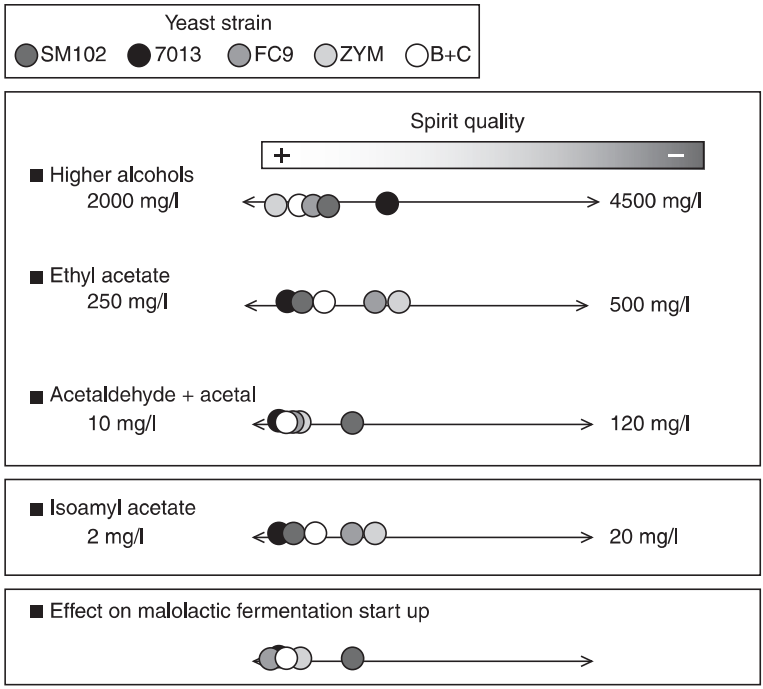

Fig. 11.2 Characteristics of the main yeast strains used in the Cognac area.

which would affect the quality of the spirits (Cantagrel *et al.*, 1998). Because of this, so as to minimise wine-preservation risks, the date limit for distillation of wines for Cognac production is set at 31 March of the year following harvesting.

11.1.6 A traditional method of distillation

Distillation of Cognac is determined by:

- The distillation principle implemented: discontinuous distillation or double distillation, also known as '*à repasse*',
- The type of still used: the so-called 'Charentais' still, whose shape, material (copper), capacity and heating method have been defined since 1936 and are primordial determining factors for wine spirit quality (Fig. 11.3).

This is because:

- The shape of the apparatus contributes to selection of volatile substances,
- Heating by a naked flame generates synthesis of complementary aromas, due to the contact between the wine and the surface of the boiler (cooking phenomenon),

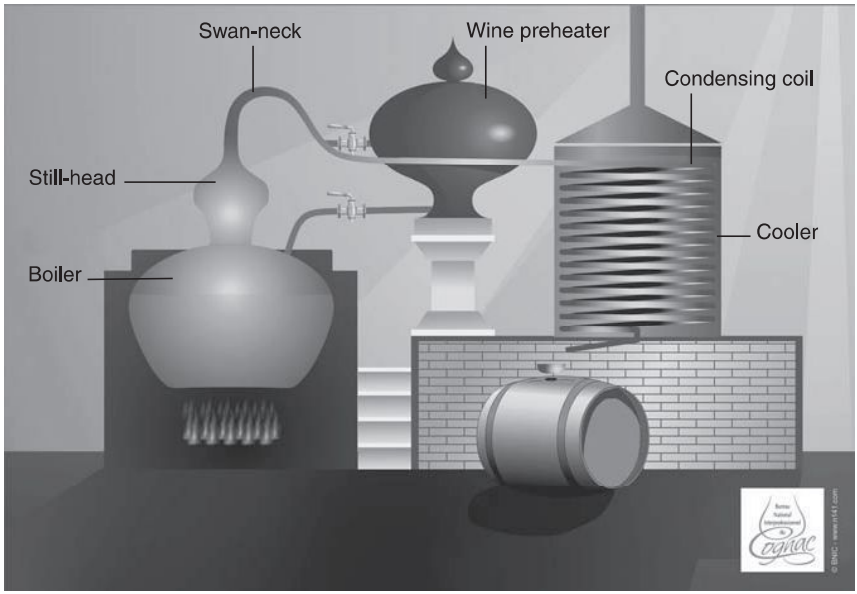

Fig. 11.3 The Charentais still: main components (© BNIC).

- Still components in contact with the wine, vapours and distillates are made entirely of copper, because of the metal's physical properties (malleability and good heat conductivity) and its chemical reactivity with different wine constituents.

For each distillation, this type of still requires the carrying out of a highly delicate operation: the 'coupe' (cutting). This consists of dividing up the distillate according to its proof and composition in terms of volatile substances, into the 'heart' (which will become Cognac) and the parts to be recycled in following distillations ('heads', 'seconds' and 'tails'). Depending on wine quality and their qualitative objectives, distillers judge the right moment for cutting along with methods of recycling. Distillation of Cognac therefore remains a manual operation whose success very much depends upon the distiller's skills.

There are two possible variations to the distillation process for Cognac wine spirits: one concerns the type of wine used in the still, and the other concerns methods of recycling during distillation.

- The distiller can distil either a clear decanted wine or a wine with its lees, i.e. containing the yeasts resulting from alcoholic fermentation. In this case, the distillate acquires a specific aromatic profile, due to higher content of long- and medium-chain fatty acid esters. This type of product is generally matured in casks over longer periods.
- The other variant concerns the distillation method itself, specifically the recycling of the different parts. During the second distillation, the distiller has

the choice of recycling the seconds either in a wine or in a 'brouillis' (first distillate). The choice calls for different parameters, such as the proof of the wines, seconds and brouillis, and the profile sought. The distillation method is usually included in the specifications laid down with the purchaser.

11.1.7 Strictly controlled ageing

Following distillation, wine spirits to be used for elaboration of Cognac are aged in oak barrels, in the appellation area, for at least two years.

After leaving the still, the new wine spirit stays in oak casks for several years (sometimes even several decades). Ageing of Cognac is a process helped along by the climatic conditions prevalent in the appellation area and by local knowledge developed over the course of the centuries. A range of physicochemical phenomena occur: evaporation of water and alcohol, changes in the concentration of various substances, extraction of compounds produced by wood, oxidation, etc. These phenomena are directed by the spirit's initial characteristics (proof and acidity), by the type of barrel in which ageing occurs, and by the hygrometric and temperature conditions in the cellars in which the casks are kept (Cantagrel *et al.*, 1993).

During the ageing process, the '*eaux-de-vie*' are exposed to moderately damp conditions and not-too-extreme changes of season. Localisation and construction of cellars are adapted to ensure harmonious ageing. Oaks of Troncais or Limousin types (mainly sessile and pedunculate oak) are used because they enable exchanges to take place over long periods between the wine spirit, the external environment and the wood. In collaboration with Cognac companies, the many cooperages active in the geographical area have developed expertise in the creation of storage conditions best adapted to the ageing of Cognac.

It is up to the Master Blender to select the most appropriate storage conditions depending on the spirits' initial characteristics, the stage of ageing, and his or her qualitative objectives. The Master Blender also decides when to end the ageing process. Once maturity is reached, he or she transfers the wine spirits into glass demijohns known as 'Dame-Jeanne', in which they may remain sheltered from the outside air for decades on end without further development. The oldest *eaux-de-vie* are stored in a dark storehouse, referred to as 'Paradise'.

A Cognac wine spirit usually reaches its peak after around 50–60 years of ageing. However, certain *eaux-de-vie* that have been stored in oak casks a good deal longer (sometimes up to 100 years) can be used in blends in very small quantities, to bring a final touch to the most prestigious Cognacs.

11.1.8 The art of blending

Ageing of Cognac is inseparable from the art of blending. Depending on its elaboration and ageing, every wine spirit has its own aromatic profile, which will be put to full use through its blending with other wine spirits having different characteristics. This crucial and highly complex stage cannot be accomplished

through the application of simple technical recipes. The Master Blender depends on empirical knowledge, gained over the course of time and necessitating constant monitoring through tasting, along with a perfect sensory memory of *eaux-de-vie* at their different stages of elaboration. Such knowledge, which requires many years of apprenticeship under the elders of the profession, has been differentiated, maintained and transmitted through exchanges in the Cognac region's fabric of companies – between Master Blenders, vine growers, Cognac companies and brokers. On the scientific side, Cantagrel *et al.* (1991a) have described the development of chemical balances occurring during the blending and reduction of wine spirits.

11.1.9 Ageing designations

As explained above, Cognac must be aged in oak casks for at least two years before being put on the market for direct human consumption. Inventory and age control of all Cognac producers are performed by the Bureau National Interprofessionnel du Cognac (BNIC) (Executive order of July 2003).

The age of an *eau-de-vie* corresponds to the period during which it has matured in oak casks. In contrast to wine, *eau-de-vie* virtually ceases to age as soon as it is transferred to a glass container. A Cognac will always be the same age it was when bottled. Ageing designations refer to the age of the youngest component in the blend (Fig. 11.4). It is not the age of the Cognac in the bottle. Cognac companies generally use products much older than the minimum requirement in their blends. Those bearing the most prestigious designations may have aged for decades. Compte '0' begins on 1 April of the year following the harvest. Ageing designations are optional indications, regulated in application of European Community legislation. A decision of the French Government Commissioner to the BNIC

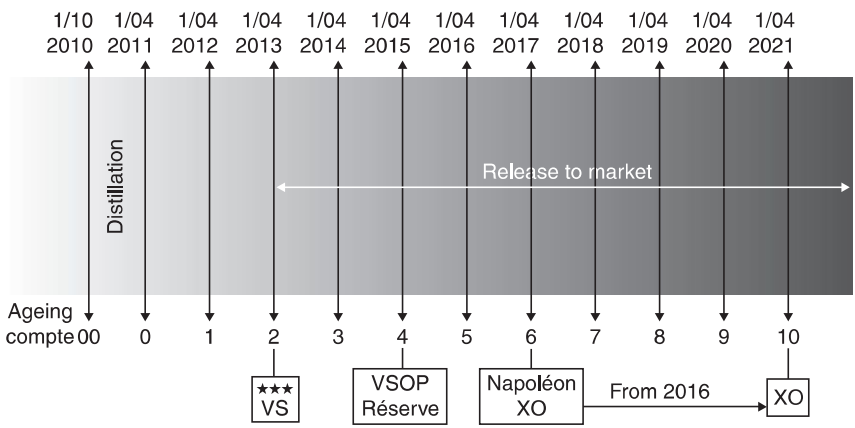

Fig. 11.4 Cognac ageing counts and designations (© BNIC).

(1983 decision) codified the designations to be used, based on the age of the spirits making up the blends:

- *** (3-star) or VS (Very Special): The youngest *eau-de-vie* in the blend is at least two years old (compte 2),
- VSOP (Very Superior Old Pale): The youngest *eau-de-vie* in the blend is at least four years old (compte 4),
- Napoléon, XO (Extra Old), Extra, Hors d'âge: The youngest *eau-de-vie* in the blend is at least six years old (compte 6). As of 2016, XO (Extra Old), Extra and Hors d'âge are expected to require compte 10 for the youngest *eau-de-vie*.

A producer may also create a 'vintage' Cognac, although this practice is not very common. In order to do so, he or she must make a request to the BNIC, and a specific traceability of the batch involved right up to its sale has to be set up. The wine spirit so declared must be stored in a separate warehouse and the BNIC carries out regular monitoring until it is marketed. In such vintage Cognacs, the wine spirits used are all produced in the same year, and it is therefore the harvest year that appears on the label (Fig. 11.4).

11.1.10 A well-established typicity

Compliance with the strict set of rules concerning origin and production conditions confers very specific organoleptic and analytic characteristics, a fact that does much to help combat counterfeiting (Mazerolles *et al.*, 1991, 1993), which is one of the BNIC's main tasks.

11.2 Overview of flavour chemistry and sensory properties

11.2.1 Aromatic complexity

A Cognac wine spirit's aroma results from the great variety of volatile substances formed and modified throughout the elaboration process, from vine to bottle. Production of quality grapes, winemaking, distillation and ageing – mastery of each stage in the production chain is essential to the aromatic quality of *eaux-de-vie* used for creation of Cognac (Cantagrel *et al.*, 1995; Ferrari *et al.*, 2004).

In 1900, Ravaz, Director of the Station Viticole de Cognac, expressed his approach to the aromatic composition of Cognac wine spirits and its connection with sensory perception as follows:

> 'Its qualities are due to all the other fixed (. . .) and above all volatile substances that accompany the ethyl alcohol during distillation; it is these that give the mellowness, aroma and bouquet (. . .).
>
> Separately, none of them, even when diluted, is any pleasanter than the ethyl alcohol. It is only when brought together in the right mixture of water and alcohol that they confer upon the latter those well known gustative qualities.

> And as most of them exist in imponderable quantities in the mixture, one can see that the slightest modification in their proportions may deeply affect the quality of the wine spirit. It only needs one of them to disappear or simply decrease in quantity for the taste and flavour of the spirit to change completely.
>
> Hence, the influence that soil, climate, variety of grape, distillation etc. has on the quality of the product is not hard to explain; a mere nothing can bring about radical changes in a product as complex as a wine spirit.'

Up until now, several hundred volatile compounds have been identified in Cognac (De Rijke and Ter Heide, 1983; Ter Heide, 1986; TNO, 1989; Ledauphin *et al.* 2010), with many chemical families represented: alcohols, acids, esters, ethers, aldehydes, acetyls, ketones, hydrocarbons, terpenes, C_{13}-norisoprenoids, lactones, sulphur and nitrogenous compounds, phenols, etc.

Such chemical diversity goes alongside a wide range of concentrations, from several hundred mg/l (esters and alcohols) to a few ng/l (pyrazines and lactones). Perception thresholds for these molecules are also extremely varied. Figure 11.5 illustrates the great diversity of volatile substances of which a wine spirit is

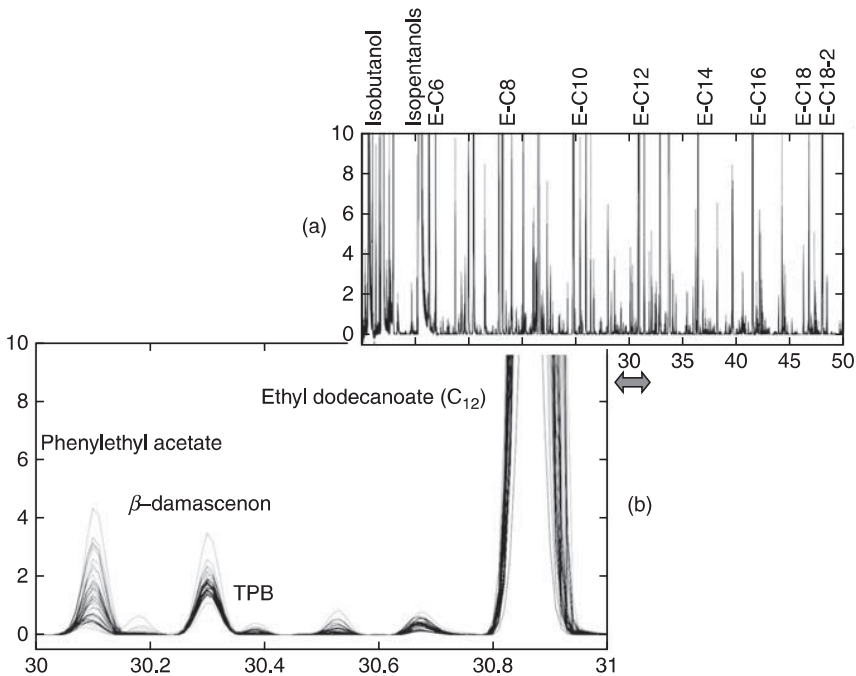

Fig. 11.5 Superposition of 40 FID chromatograms of Cognac wine spirits. (a) Global. (b) Focus upon a small zone. E-C6: ethyl hexanoate, E-C8: ethyl octanoate, E-C10: ethyl decanoate, E-C12: ethyl dodecanoate, E-C14: ethyl hexadecanoate, E-C16: ethyl hexadecanoate, E-C18: ethyl octadecanoate, E-C18-2: ethyl linoleate (© BNIC).

composed, as well as the variability of different products that makes no two Cognac wine spirits identical.

11.2.2 Compounds from the grape

A number of aroma substances come from the grapes themselves. Extracted during the early stages of winemaking and revealed by complex chemical and biochemical transformations (Cantagrel *et al.*, 1998), they are present in both new and aged wine spirits, to which they give floral, fruity and vegetal notes in particular.

The grape, whose composition is conditioned by terroir, climate vineyard, management and harvest date, contains numerous precursors whose transformation during winemaking and distillation generates aroma substances. Grape compounds found in wine spirits include six-carbon-atom alcohols (hexanol and hexenols), terpenes (linalool and derivatives, α-terpineol), products of carotenoid degradation (vitispiranes, α-ionone, β-damascenone and E)-1-(2,3,6-trimethylphenyl)buta-1,3-diène (TPB)), and aldehydes (Lurton *et al.*, 1991).

Some of these play a major part in the wine spirit's aroma. Analysis by gas chromatography coupled with olfactometry (GC-O) enables the linking of certain volatile compounds coming from the grape to aromatic notes perceptible in wine spirits (Fig. 11.6). Using the aroma extract dilution analysis (AEDA) olfactometric method, it has therefore been possible to demonstrate that β-damascenone (zone 41) and TPB (zone 42), stemming from odourless precursors present in grapes, are compounds essential to the aroma of a freshly distilled spirit, and are still perceptible at 1/100 dilution.

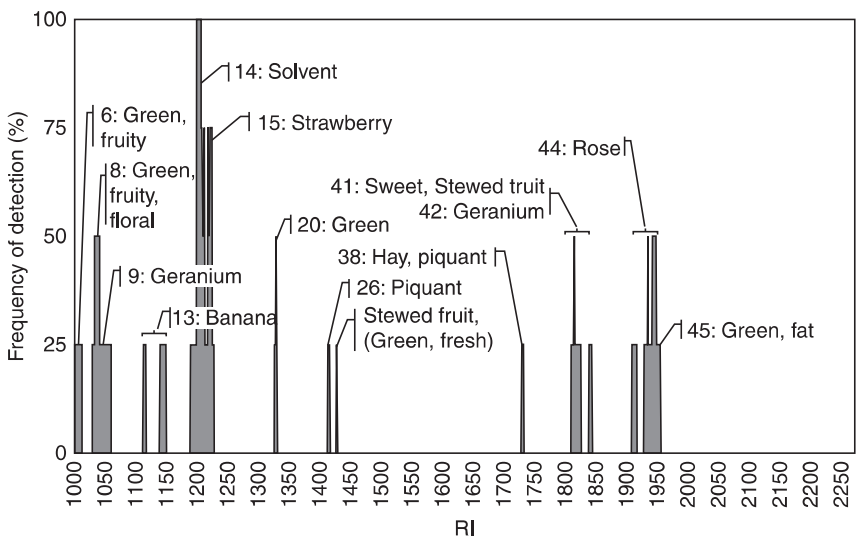

Fig. 11.6 Olfactogram of a 100-times diluted extract from a freshly distilled wine spirit (© BNIC).

The ripening stage at harvesting affects grapes' composition in aromatic compounds. As an example, Fig. 11.7 shows the development of the average *cis*-3-hexenol and *β*-damascenone content of maturing grapes.

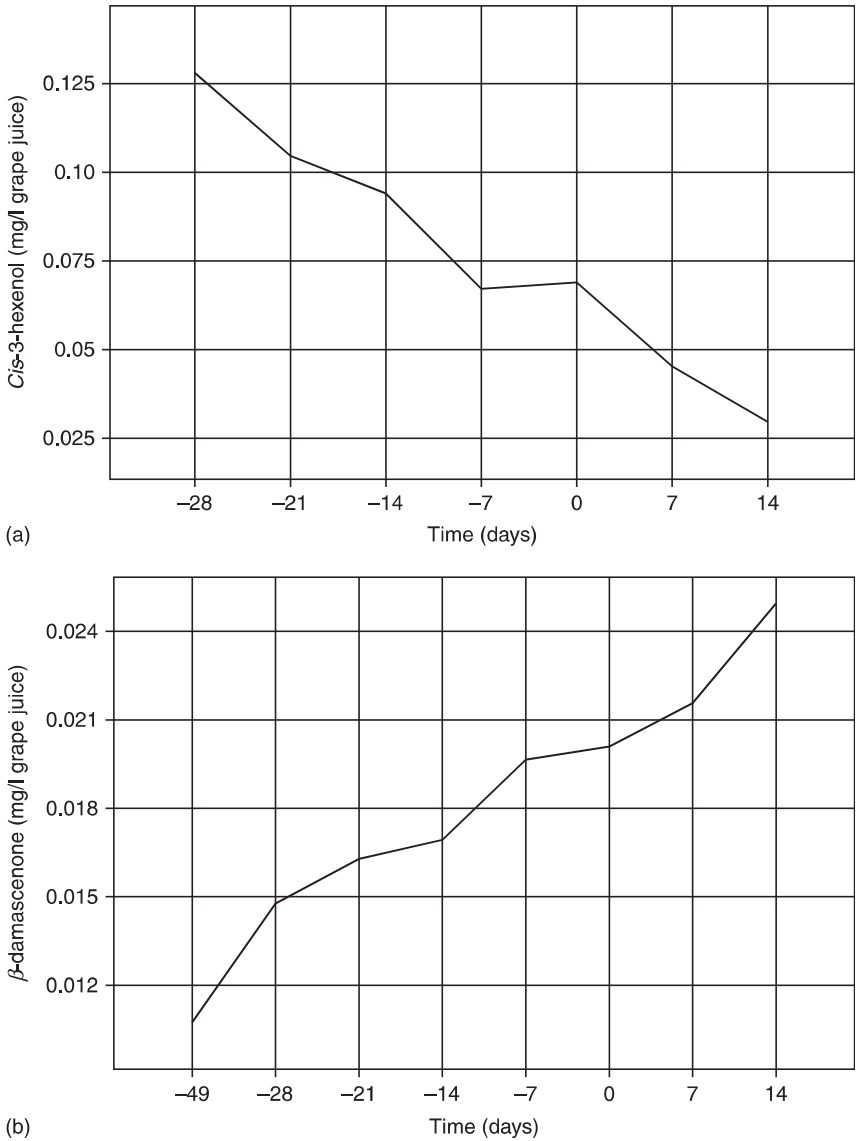

Fig. 11.7 Evolution of *cis*-3-hexenol and *β*-damascenone in the juice during grape ripening, 2008. (a) *cis*-3-hexenol. (b) *β*-damascenone. GC is performed on the micro-distillate of an average regional must sample from 55 different parcels. Date 0 = beginning of harvest (© BNIC).

Some unwanted notes may also find their origin in the grapes. It is the case with the 'kerosene-like' notes due to trimethyl-1-1-6-dihydro-1,2-naphthalene (TDN) (Vidal *et al.*, 1991) and connected to the conditions of grape mechanical processing before fermentation (Lurton *et al.*, 1991). It is also the case with certain markers linked to the presence of grey mould (*Botrytis cinerea*) in the crop, a study of which was made by Urruty *et al.* (2008).

11.2.3 Compounds of fermentative origin

Numerous volatile compounds (higher alcohols, esters, aldehydes, acetyls, fatty acids, etc.) are formed by yeasts during the alcoholic fermentation stage (Lurton *et al.*, 1995). Composition of grape musts (nitrogen, matter in suspension, etc.), along with conditions of fermentation (temperature, oxygen, yeast strain, etc.) and wine storage before distillation, determine their presence in a wine spirit.

Nitrogenous composition of the musts is especially important as it influences the nutrition of yeasts and hence the development of alcoholic fermentation (Nedjma, 1997; Ferrari, 2002).

Although they have high perception thresholds, ethyl esters, whose concentrations may vary in a wide range, contribute to the fruity perception (Léauté, 1990).

Distilling wine in the presence of yeasts contained in fermentation lees leads to enrichment in fatty acid esters, such as ethyl octanoate (fruity, floral, pineapple, apple and pear), and ethyl decanoate (fruity, pear, wine, etc.). Aromatic synergy between those esters strengthens their olfactory impact. Fermentation lees also supply the wine spirit with fatty acids (C_8–C_{18}, saturated and unsaturated) which are at the origin of aromatic derivatives formed by their oxidation into aldehydes or ketones during the ageing process.

Acetates floral and fruity notes decrease over time because of their gradual hydrolysis during preservation of wines and spirits.

11.2.4 The role of distillation

Distillation has a triple role of concentration of aromas, selection of certain fractions, and formation of new compounds (Cantagrel *et al.*, 1991b). Certain volatile substances, favourable or not to quality, may be formed or eliminated during the process. Its effect on the quality of Cognac wine spirits has been frequently described (Lafon *et al.*, 1964; Gay-Bellile, 1981; Léauté, 1990; Cantagrel *et al.*, 1991b).

Newly-formed compounds

Distillation performed by naked flame heating is accompanied by cooking phenomena that result in a wide range of chemical reactions dependent upon temperature conditions, duration, acidity of the wine, and also the role

that copper plays as a catalyst. Gay-Bellile (1981) and Léauté (1990) describe such reactions as hydrolysis of esters and terpenes, as well as the production of new compounds: furans, pyridines and pyrazines (cocoa and grilled nuts notes) through Maillard reaction, and aldehydes and acetals through Strecker degradation. A typical example of such reactions is the production of furfural and its derivatives from sugars. Different compounds produced during Charentaise distillation have been identified (Gay-Bellile, 1981; Galy *et al.*, 2008).

The role of rectification

The alcohol content of freshly distilled Cognac spirits is limited to 72.4% vol. The low level of rectification during the Charentaise distillation process results in a high concentration of wine volatile substances in the distillate. This implies specific constraints in the choice of wines to be distilled, which must be free of defects likely to be concentrated in the wine spirit. Such constraints apply less in the case of spirits distilled to a higher degree, where greater rectification leads to lower content of aromatic substances coming from the wine.

11.2.5 The olfactometric profile of a freshly distilled spirit

Olfactometric techniques have been adapted to study the aromatic structures of freshly distilled spirits (Leclaire *et al.*, 1999; Lablanquie *et al.*, 2002). High-quality new spirits were selected in partnership with different Cognac companies, and a panel of olfactors was trained and assessed. The nasal impact frequencies (NIF) method was applied to the *eau-de-vie* selected, whose sensory profiles had previously been described. This approach allowed the identification of some forty major olfactory zones characteristic of the new high-quality wine spirits. A number of these zones are always present, while others are met with less systematically. This ensemble of zones may be regarded as the aromatic 'skeleton' of a newly distilled wine spirit (Ferrari *et al.*, 2004; Leyrat *et al.*, 2005). Major work bearing on identification of volatile compounds present in these zones was undertaken (Ledauphin *et al.*, 2004) with a view to pinpointing their olfactory roles and also to determining their origins (raw material, vinification or distillation). Once the compounds were identified, and when pure molecules were available, their aromatic impact was checked by measured-out addition. Recent extension to that work has been carried out by identification of new aroma-marker compounds in different zones, along with characterisation of the aromatic impact of some that were already known, in relation to their concentrations in wine spirits (Ferrari *et al.*, 2008). Figure 11.8 presents a typical olfactogram of a wine spirit of the 'fruity-floral' type. Table 11.1 presents the current state of knowledge with regard to these olfactory zones and the marker compounds identified.

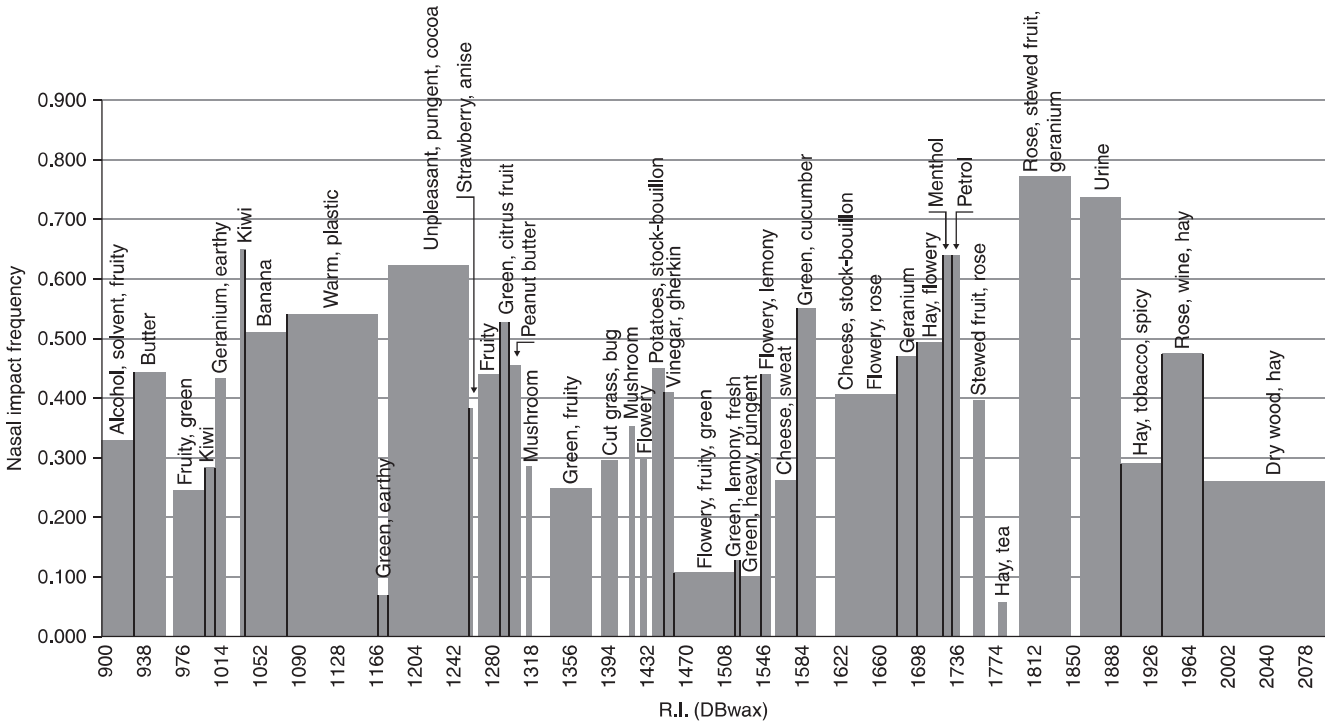

Fig. 11.8 Average olfactogram of a 'fruity-floral' type Cognac wine spirit (Leyrat, 2005).

Table 11.1 Gas chromatography-olfactometry profile of freshly distilled Cognac spirit: main zones, odour and markers

Zone	Retention index on DB-wax column	Origin	Odour	Compound responsible
1	<972		Solvent, methylated spirits	Acetaldehyde, isobutyraldehyde, ethyl acetate, 1,1-diethoxyethane
2	972	Fermentation	Butter	2,3-Butanedione
3	975		Methylated spirits	
4	989		Green, earthy, geranium	
5	991		Solvent, plastic	
6	996		Green, fruity	
7	1008		Solvent, earthy, geranium	
8	1032		Kiwi, fruity, slightly acid	Ethyl butyrate
[9]	1051		Geranium, earthy	
10	1053	Fermentation	Kiwi, fruity, slightly acid	Ethyl 2-methylbutyrate
11	1065	Fermentation	Kiwi, fruity, slightly acid	Ethyl 3-methylbutyrate
12	1072		Solvent, plastic	
13	1121	Fermentation	Banana	Isoamyl acetate
14	1181	Fermentation	Solvent, chocolate	Isoamyl alcohol
15	1238	Fermentation	Strawberry, anise	Ethyl hexanoate
[16]	1274		Sweet peanut	
17	1295	Grape	Mushroom	1-Octen-3-one
18	1335	Fermentation	Green, fat, pungent	Ethyl lactate
19	1345	Grape	Green fresh	Hexan-1-ol
20	1350		Green floral	
21	1365		Green, fat	
22	1370	Grape	Green, leaves, grass	(Z)-3-hexen-1-ol
23	1385		Green floral	
[24]	1390	Grape	Mushroom	1-Nonen-3-one
25	1420		Earthy	
26	1430		Pungent, acidic	Ethyl octanoate
[27]	1435	Fermentation	Potato	Methional
[28]	1450		Earthy	
[29]	1470		Mushroom	
[30]	1485		Green pepper	

[31]	1510		Green pepper	(Z)-2-nonenal
32	1520		Green, fat	(E)-2-nonenal
33	1530	Grape	Bergamot, orange blossom	Linalool
34	1565		Cucumber	(E,Z)-2,6-nonadienal
35	1620	Fermentation	Rose	Phenylacetaldehyde
36	1645		Toasty	
[37]	1680		Geranium, metallic	
38	1700		Hay	
[39]	1708	Grape	Hydrocarbon	1,1,6-Trimethyl-1,2-dihydro naphthalene (TDN)
[40]	1781		Rose	2-Phenylethyl acetate
[41]	1791	Grape	Stewed fruit	β-Damascenone
[42]	1824	Grape	Geranium	(E)-1-(2,3,6-trimethylphenyl) buta-1,3-Diene (TPB)
43	1845		Phenol	
44	1895	Fermentation	Rose	2-Phenylethanol
45	1938		Green, fat	

Note: Zones in square brackets [ ] are not systematically present in wine spirits. Compounds were subjected to validation based on their GC-O detection in hydroalcoholic solutions with a content estimated or similar to that found in wine spirits.

11.2.6 Ageing compounds

Extraction of wood compounds

New compounds are extracted from the oak during the early stages of the ageing process. They bring the *eau-de-vie* new, woody, spicy and empyreumatic notes, characteristic of spirits aged in wooden barrels. How this stage develops depends on a variety of factors. The status of the cask (new or previously used) influences levels of extraction as well as the nature of the compounds extracted (Calvo *et al.*, 1993; Snakkers *et al.*, 2008). The wood's botanical and geographical origin (Prida and Puech, 2006), its structure, which is linked to the way the forest was managed (Snakkers *et al.*, 2000), and cooperage techniques – the barrel toasting level in particular (Snakkers *et al.*, 2003) – also affect the contribution brought by the wood.

The main compounds extracted include derivatives of lignin (vanillin being the best known), lactones (mainly methyl octalactones), furanic derivates (furfural, etc.)

Oxidative reactions

Ageing in oak barrels also calls for a carefully monitored oxidation process. After the extraction stage, changes intervene in the pool of compounds extracted from

the wood, e.g. coniferaldehyde is transformed into vanillin and vanillic acid (Calvo *et al.*, 1993).

Compounds coming from the new spirit also evolve: increase in methyl ketones by *β*-oxidation of fatty acids (Marché and Joseph, 1975; Vidal *et al.*, 1993; Watts *et al.*, 2003), and formation of acetaldehyde and ethyl acetate through oxidation of ethanol (Reazin, 1981).

Evaporation, concentration and modification of chemical balances

During ageing under wood, ethanol content diminishes through evaporation (Puech *et al.*, 1984; Cantagrel *et al.*, 1993). In contrast, concentrations of components less volatile than ethanol, such as higher alcohols, increase.

With the lowering of alcohol content, chemical balances regulated by ethanol are subjected to change. Higher alcohol esters produced during fermentation see their content decrease by transesterification. Their impact diminishes while the wine spirits' aromatic power increases.

Interactions between wine spirit and wood compounds

New molecules are formed by reactions between the wine spirit's constituents and compounds coming from the wood. Such reactions illustrate the notion of a 'marriage' between the wine spirit and the wood, which is regarded as a key element in the qualitative development of wine spirits during the ageing process. Among the compounds formed are esters (ethyl vanillate, ethyl syringate, etc.) and ethers (vanillin ethyl ether, etc.) produced by the reaction of ethanol with compounds extracted from the wood.

The 'Cognac rancio'

Different stages may be identified in this complex and continuous process, which takes place over many years. Léauté *et al.* (1998) cite over 50 terms used to describe the development of Cognac wine spirits during ageing (Fig. 11.9). Of these descriptors 19 correspond to fruity characters, 14 to floral characters, 10 to spicy characters, and 10 to woody characters. Aged wine spirits present specific characteristics that are grouped together under the term 'rancio charentais' or 'Cognac rancio'. 'The mixture of highly-smelling methyl-ketones with compounds produced by oxidative degradation of lignins, lignans and various oak resins smelling of vanilla brings old Cognac a balsamic scent that is specific to the spirit and which is known as the rancio charentais' (Marché and Joseph, 1975). Léauté *et al.* (1998) gave a highly detailed description of the various stages in the development of the Cognac rancio, distinguishing four phases: from 12–15 years of ageing (phase one), up to 50 or 60 years (phase four), to which they attached the main descriptors encountered.

11.3 Sensory analysis practice in the industry

Cognac is a wine spirit generally created by blending, a process carried out by the Master Blender and which is a continuous search for harmony and consistency. Just

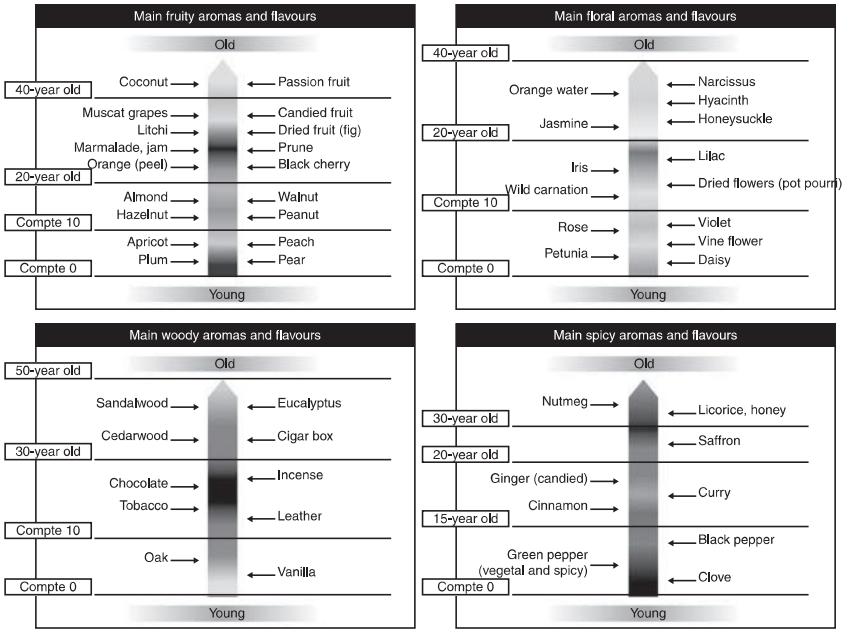

Fig. 11.9 The main aromatic characters of Cognac. Main descriptors for Cognac wine spirits belonging to the fruity, floral, spicy and woody families, for ageing periods of 40 or more years (Source: Léauté *et al.* 1998).

like the perfumer's 'nose', he or she creates subtle blends of wine spirits of different ages and from different crus to ensure that Cognac will not only retain its distinctive personality over the course of the years, but also the fidelity of its consumers.

It is he or she who, along with his or her team, selects and purchases the wine spirits from vine growers and watches over them throughout the ageing process. Once distilled, he or she selects those to be used for elaboration of a young Cognac and those to be aged for longer periods. Finally, it is he or she who creates their own blends, which constitute the real signature of each brand.

In this approach, each Cognac house has its own know-how, combining sensory and physicochemical analysis of the products. This calls upon increasingly sophisticated techniques, such as gas chromatography.

11.4 Consumer research: creation of the Cognac aroma wheel

In 2009, in order to better acquaint consumers with Cognac's wide-ranging aromatic palette, the BNIC undertook the creation of a 'Cognac aroma wheel'. Some 30 Cognac samples corresponding to the different stages in the ageing process were assessed by 44 professional tasters (sommeliers, cellar masters, wines-and-spirits journalists and writers), brought together at the BNIC in the course of the

International Cognac Summit (Nouet, 2010). Over 60 descriptors were used by the tasters in order to meaningfully describe the products involved. The results, processed by principal component analysis (PCA) are presented in Fig. 11.10.

Section I of the chart groups together the notes characteristic of young wine spirits: grape, vine flower, acacia, honeysuckle, litchi, lilac, etc. Such notes largely correspond to aromatic substances coming from the grape, such as terpenes and C_{13} norisoprenoids.

The lower part of the chart (sections II and III) features fruity notes (peach, banana, apricot and passion fruit), as well as notes typical of contact with oak (coconut, vanilla pods, coffee, toasted bread, cloves, etc.)

Finally, in section IV, come the notes typical of Cognac rancio and corresponding to long ageing of wine spirits, including leather, walnuts, hazelnuts, tobacco, cigar boxes, underwood, oak moss, truffles, cedarwood and sandalwood.

Organisation of descriptors used in the comparison chart and defined by components 1 and 2 of the PCA, clearly illustrates the diversity of wine spirits' aromatic profiles which increases during the ageing process as symbolised by arrows on the graph.

With a view to reaching the widest possible audience in acquainting the public with such aromatic diversity, the range of notes was grouped into four families, corresponding to the four seasons: spring, summer, autumn and winter. The choice of this presentation reached a consensus among International Cognac Summit participants in charge of the creation of the aroma wheel and representatives of Cognac companies gathered at the BNIC.

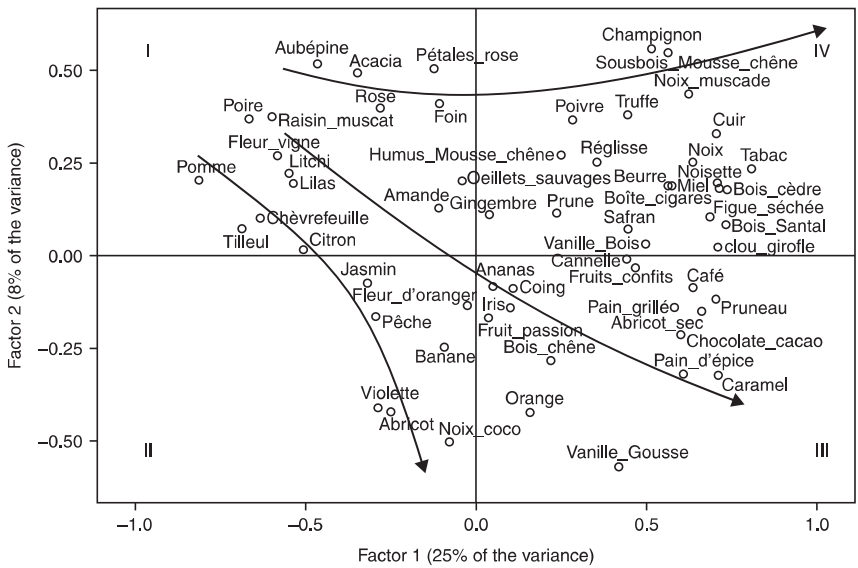

Fig. 11.10 Principal component analysis of the results of tastings carried out during the International Cognac Summit 2009, for the creation of a Cognac aroma wheel (© BNIC).

This classification led to the creation of an original and very complete aroma wheel (Fig. 11.11) that provides a dynamic image of the diversity of Cognac and its development during the ageing process, while leaving the consumer's imagination to run free. The wheel has been widely distributed by the BNIC and is used by Cognac companies and consumer motivators to raise consumer awareness with regard to Cognac's remarkable aromatic palette.

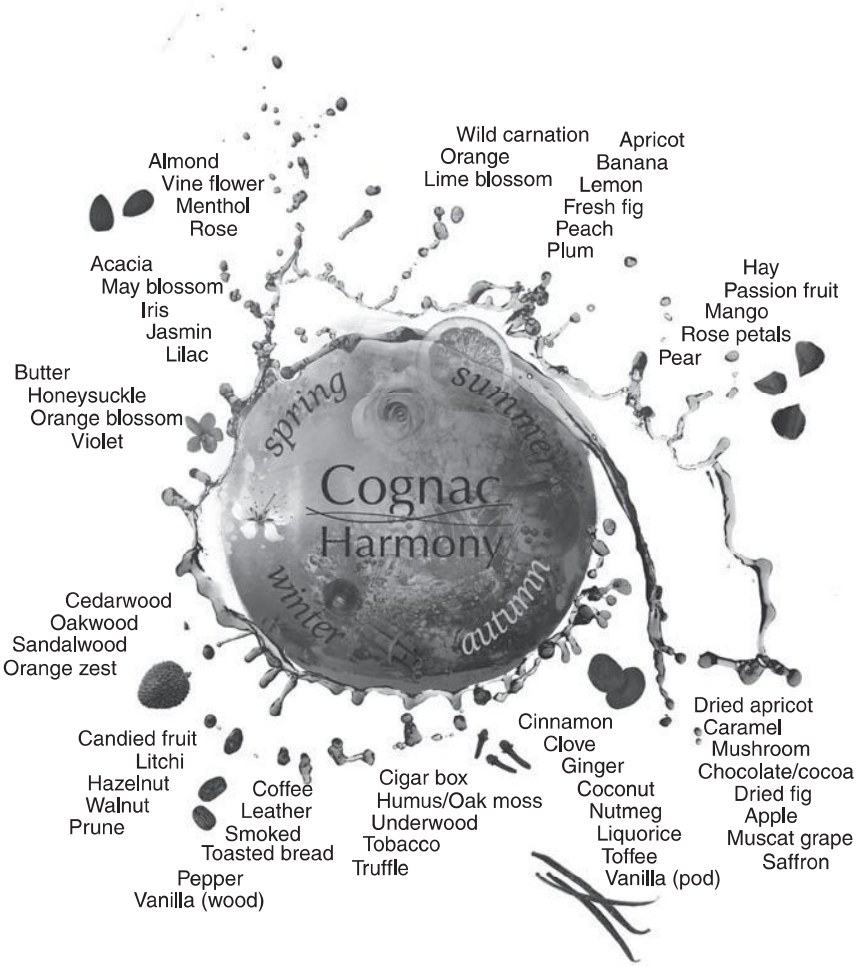

Fig. 11.11 The Cognac Aroma Wheel. Principal aromatic notes. (© BNIC/Gérard Martron).

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