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Gin: production and sensory properties

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Abstract: Gin is a colourless distilled beverage widely consumed around the world, produced by a number of different methods, but always with juniper as the predominant taste. The volatile content of gin is made up of terpenoid compounds, mainly from juniper berries, but also from other botanicals such as coriander seeds, angelica root or citrus peel. Although some authors have used various methods to develop a vocabulary to describe the sensory characteristics of gin, no uniform vocabulary has been widely adopted. The most usual attributes defined by the tasters were juniper and coriander but spice, liquorice, aniseed, floral and fruity attributes were also reported.

Key words: gin, sensory analysis, volatile composition, botanicals.

12.1 Introduction

Spirits flavoured with juniper, the most famous of which are the beverages known as gin, are now widely consumed across the world and are very important in the market. Gin was produced for the first time by Franciscus de la Boe, a Dutch physician at the University of Leiden (the Netherlands) in 1650, who carried out research into inexpensive medication for the treatment of kidney problems. He worked with neutral grain spirit flavoured with juniper to give it a pleasant taste (Greer *et al.*, 2008).

There are various types and formulations of gin, but in all cases the predominant flavour is juniper and it is typically colourless. According to the most recent European regulation (European Union, 2008), spirits with a predominant flavour of juniper are categorised principally according to their strength, ingredients and method of production as 'juniper-flavoured spirit drinks', 'gin', 'distilled gin', or 'London gin'. Throughout this chapter, gin and distilled gin refer to these products as defined in Regulation (EC), no. 110/2008 (European Union, 2008). Gin refers to the wider family of products. Gin, distilled gin and London gin are required to have an alcoholic strength of at least 40% in the United States, but only 37.5% in the European Union (EU) (Greer *et al.*, 2008, European Union, 2008). Juniper-flavoured spirit drinks have a minimum alcoholic strength of 30% (European Union, 2008).

Gin can be produced simply by flavouring organoleptically suitable ethyl alcohol with natural or artificial flavouring or by redistilling organoleptically suitable spirits of agricultural origin with juniper berries and other botanicals. Gins made by the former method are often referred to as compound gins; those produced by the latter as distilled gins. According to Regulation (EC), no. 110/2008 (European Union, 2008) distilled gin and London gin are exclusively produced by redistilling organoleptically suitable ethyl alcohol of agricultural origin and appropriate quality to a minimum of 96%, in the stills traditionally used for gin. Distillation is carried out in the presence of juniper berries (*Juniperus communis* L.) (Fig. 12.1). Other botanicals may also be added, provided that the juniper taste is predominant. For London gin, recently recognised as an especially high-quality beverage, the ethyl alcohol used should be of higher quality than that used to produce distilled gin, with maximum methanol values being 5 g/Hl of 100% volume alcohol, and no flavourings can be added after distillation.

Gin, on the other hand, may be produced by flavouring ethyl alcohol with the natural and/or nature-identical flavouring and flavouring preparations permitted by the regulation. In the EU, juniper-flavoured spirit drinks, which may also bear the sales denominations of Wacholder or genebra (but which may not be called gin), are produced by flavouring ethyl alcohol of an agricultural origin and/or grain spirit and/or grain distillate with juniper (*Juniperus communis* L. and/or *Juniperus oxicedrus* L.) berries (European Union, 2008).

Finally, some juniper-flavoured spirit drinks and gins bear geographical indications which, according to recent regulation, identify not only the origin of a spirit but also its quality or some characteristic of the beverage. These include:

- Genièvre/Jenever/Genever (Belgium, the Netherlands, France and Germany),
- Jonge jenever, Oude jenever (Belgium, the Netherlands),
- Genièvre Flandres Artois (France),

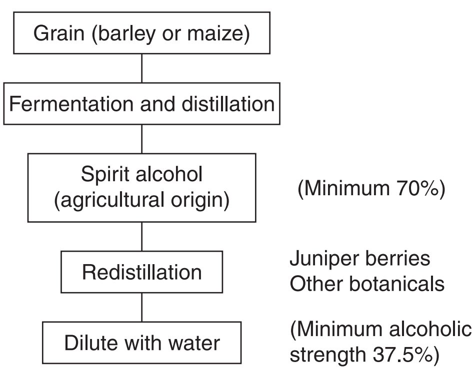

Fig. 12.1 Production of London Dry Gin.

- Ostfriesischer Korngenever and Steinhäger (Germany),
- Plymouth Gin (United Kingdom),
- Gin de Mahón (Spain),
- Vilniaus Džinas/Vilnius Gin (Lithuania),
- Spišká borovička (Slovakia).

12.2 Gin production

The production process for compound gin simply involves the addition of flavourings to ethyl alcohol. However, for distilled gins and London gin, the spirit is instead redistilled in the presence of juniper and other natural flavourings, known as botanicals, which are discussed in detail in Section 12.2.2.

12.2.1 Distillation process for distilled gins and London gin

The distillation process for distilled gins takes place in traditional copper stills that typically hold up to 20 000 l. The details of the distillation process vary between producers, but a typical method used is as follows. The spirit is first diluted with pure water in order to obtain the required alcoholic strength (around 45% abv), before being added to the stills along with the selected botanicals and left to steep. Heating (using a steam coil or jacket) to a temperature of 70–80 °C then causes the release of essential oils from the botanicals, which give the spirit its flavour. The early part of the distillate and the end of the distillate, which are of lower quality, are redistilled. The middle part of the run is used to produce high-quality gin (Lea and Piggott, 2003).

In distilled gin production, the flavourings permissible according to Regulation (EC), no. 110/2008 (European Union, 2008) may be added after this distillation process, while for London gin, only water and further alcohol may be added once distillation is complete. Pure demineralised water is then added to the spirit to achieve the correct level of alcoholic strength, which must be at least 37.5% but can also be higher.

One common method of improving distillation is the use of a vacuum, which allows lower temperatures of around 60 °C to be used (Greer *et al.*, 2008). Some authors have studied the use of a vacuum in the distillation of essential oils such as *Curcuma longa* L. leaf (Babu *et al.*, 2007), *Citrus sinensis* (Lopes *et al.*, 2003), and bergamot oil (Fang *et al.*, 2004). In all cases, using a vacuum increases the level of oxygenated monoterpenes and decreases the levels of heat-stimulated monoterpenes. The low quantity of monoterpenes indicates a high level of stability in the essential oil. In the study conducted by Greer *et al.* (2008) in which the traditional gin distillation method was compared with a novel vacuum distillation method, it could be observed that the level of monoterpenes is lower in gin produced with high vacuum distillation. Monoterpenes can cause the formation of off-flavours in the final product, rendering the use of a vacuum desirable. A trained panel described the gin obtained using this novel method as spicy and more floral, while also presenting less nasal pungency. Furthermore, according to some authors, oxygenated compounds are considered responsible for the aroma while terpenes act as a flavour carrier.

12.2.2 Botanicals

Although the primary flavourings used in gin are juniper (*Juniperus communis* L.) and coriander (*Coriandrum sativum* L.), a large number of other botanicals can be used in order to obtain a beverage with a particular character. Some authors have described more than 100 different botanicals that can be added in order to provide a particular character to the product. Some of these botanicals are discussed below.

Juniper berries (Juniperus communis L.)

Juniperus communis L belongs to the Cupressaceae family and is an evergreen shrub commonly found in Europe and North America. The berries are often used in flavours, perfumes and pharmaceutical compounds (for example, for their diuretic, hypoglycaemic, anti-inflammatory, antibacterial and antifungal properties) and in the aromatisation of alcoholic beverages.

According to EU regulation, juniper must be the predominant taste in all types of gin, and has been identified as the sensory characteristic that distinguishes gin from other alcoholic beverages (Mc Donnell *et al.*, 2001). The composition of juniper essential oil has been widely studied and has been shown to be affected by the age and geographical origin of the plant, as well as the ripeness of the berries (Vichi *et al.* 2007). Juniper berries have been shown to contain between 0.2–3.42% of essential oil (Barjaktarović *et al.*, 2005). The oil consists mainly of monoterpenes (58–85%), sesquiterpenes (2–10.2%), aldehydes, alcohols and other oxygenated compounds.

In the study performed by Vichi *et al.* the use of head space-solid phase microextraction (HS-SPME) for the quality control of juniper berries was tested by comparison of simultaneous distillation-extraction (SDE). The results obtained led to the identification of 77 compounds, representing 80% of the total gin flavour (Vichi *et al.*, 2005). The main group identified was oxygenated monoterpenes (31.2%) followed by monoterpenes (29.9%), sesquiterpenes (22%) and oxygenated sesquiterpenes (5.2%). Monoterpenoid compounds have a high impact on juniper aroma due to their greater volatility.

Barrero *et al.* (2005) also studied the diterpenic composition of juniper berries. Diterpenic compounds are widely studied as a result of their biological activity: they can function as antimicrobial, antiulcer, antioxidant and antitumor agents, and can have an effect on cardiovascular activity (Barrero *et al.*, 2005). Abietane, totarane, sempervirane and labdane have previously been identified in juniper berries. Vichi *et al.* (2008) further evaluated the diterpenoid composition of beverages aromatised with juniper. These compounds can be used to characterise different types of gin and can act as a guarantee of the quality of a product. Ten diterpenoids were identified; three labdane structures (manool, manoyl oxide and epi-manoyl oxide), five abietane derivatives (abieta-8,13(15)-dien-18-ol, dehydroabietal, abieta-8,11,13-trien-7-one, *trans*-ferruginol and 4-epi-dehydroabietol) and two totarane derivatives (*trans*-totarol and *cis*-totarol). The diterpenes identified mainly originate from juniper extract while three of them, manoyl oxide, epi-manoyl oxide and *cis*-totarol, may originate from other botanicals used in the elaboration of gin. Diterpenoid compounds in gin samples were determined using the simple and reliable direct immersion-solid-phase microextraction (DI/SPME) method.

Coriander seeds (Coriander sativum L.)
Coriander sativum L. is the second ingredient added to distilled gins. It belongs to the Umbelliferae (Apiaceae) family, typically found in the Mediterranean region, and the seeds are widely used in perfumery, tobacco products and liqueurs (Kiralan *et al.*, 2009). The weight of coriander essential oil accounts for between 0.3–1.2% of the total weight of the seeds: 60–70% of this weight is linalool. This essential oil is used in the pharmaceutical industry for its antibacterial, bacteriostatic, fungicidal and insecticidal properties (Lo Cantore *et al.*, 2004; Kiralan *et al.*, 2009).

Coriander seeds can be added to distilled gin to provide complexity; gin produced using coriander was described by the panellists as having citrus, floral and fruity attributes (Phelan *et al.*, 2004).

Other botanicals
Other products that can be used to give character and complexity to gins include:

- Orange peel (*Citrus sinensis*),
- Purging cassia (*Cassia fistula*),
- Orris root (*Iris florentina* L.),
- Cardamom seeds (*Elettaria cardamomum* L.),
- Angelica root (*Angelica archangelica* L.),
- Cinnamon bark (*Cinnamomum zeylandicum*),
- Calamus (A*corus calamus* L.),
- Fennel (*Foeniculum vulgare*),
- Aniseed (*Pimpinella anisum*),
- Lemon peel (*Citrus limon* L.),
- Cumin (*Cuminum cynimum* L.),
- Almond (*Prunus amygdalus* L.),
- Liquorice root (*Glycyrrhiza glaba*).

All of these species contain essential oils that add to the flavour of gins. The carefully balanced mixture of botanicals selected depends on the producers and the characteristics that they are trying to obtain.

12.3 Flavour chemistry

Although gin is widely consumed, few studies have been carried out on its composition and characteristics (Clutton and Evans, 1978; Villalón-Mir *et al.*, 1984a, 1984b; Martin-Alvarez and Herranz, 1991; Vichi *et al.*, 2005; MacNamara *et al.*, 2007; Greer *et al.*, 2008). The volatile composition of gins, like all alcoholic beverages, depends on the botanicals used in its production. All of these botanicals contain essential oils, which are themselves complex mixtures made up of hundreds of individual compounds. The volatile composition of gin samples principally includes both oxygenated and non-oxygenated terpenoid compounds, which play an important role in determining the aroma of the final product. Their high volatility and low perception threshold cause a considerable aromatic impact, but there is limited data available on the sensory notes of these compounds. Usually, the volatile composition of gins is analysed by gas chromatography coupled with mass spectrometry. The extraction of the volatile fraction is performed by liquid–liquid extraction (Martin-Alvarez and Herranz, 1991) or solid phase microextraction (SPME) (Vichi *et al.*, 2005).

According to the literature, the volatile compounds of gin samples can be divided into monoterpenes, oxygenated monoterpenes, sesquiterpenes and oxygenated sesquiterpenes. In most of the studies, the main group that was found were non-oxygenated monoterpenes (Table 12.1). In the study performed by Vichi *et al.*, (2005) six distilled gins (labelled G1–G6), which were amongst the most popular commercial beverages, were compared. Four of them were London dry gins while two were gins with geographical indications (Mahón gin and Plymouth gin).

The main non-oxygenated monoterpenes detected in the gin samples were α-pinene, β-myrcene, limonene, γ-terpinene and *p*-cymene. These compounds have previously been identified as the main compounds found in juniper extracts (Angioni *et al.*, 2003). Additionally, limonene and γ-terpinene are very important compounds in the essential oils of citrus fruits while *p*-cymene is found in cumin essential oil.

The oxygenated monoterpenes were an aromatic group composed of alcohols, esters, ketones and aldehydes. The main compounds identified were linalool and geranyl acetate. Linalool was the most important compound found in coriander essential oil (accounting for more than 60% of its composition). This volatile compound can be used as a marker in other botanicals, especially coriander (Lo Cantore *et al.*, 2004; Greer *et al.*, 2008), but also in cinnamon (Kaul *et al.*, 2003), angelica root (Doneanu and Anitescu, 1998) and citrus fruits (Angioni *et al.*, 2003). Other quantitatively important compounds found in gin and described in juniper berries were 1-4-terpineol and bornyl acetate. Geranyl acetate has previously been detected in gin (Clutton and Evans, 1978) but has never been detected in the more typical botanicals used in gin production.

Sesquiterpenes are less important compounds in terms of sensory perception because they have higher perception thresholds. Sesquiterpenes are usually defined as balsamic, grassy or woody. These compounds may have an important role in the chemical characterisation of a product. The sesquiterpenic profile of a gin must be highly representative of the botanicals that it contains. The main sesquiterpenic compounds detected in the gins were δ and γ-cadinene, caryophyllene, β and γ-elemene, α-humulene and germacrene D. All of these components were typical of juniper berries. The oxygenated sesquiterpenes were

Table 12.1 Minimum and maximum values of the volatile compounds identified in gins

Volatile compounds	Min		Max	Volatile compounds	Min		Max
α-Pinene	1.95	±	6.12	Cuminal	0.07	±	0.96
α-Thujene	0.20	±	0.70	β-Citronellol	0.05	±	1.97
Camphene	0.06	±	0.16	Myrtenol	0.02	±	0.37
β-Pinene	0.37	±	1.53	Nerol	0.01	±	0.10
Sabinene	0.09	±	2.53	t-Carveol	0.05	±	0.54
Verbenene	0.05	±	0.32	t-Geraniol	0.19	±	0.63
δ-3-Carene	0.03	±	0.11	α-Cubebene	0.07	±	0.24
I-Phellandrene	0.06	±	0.19	α-Copaene	0.04	±	0.10
β-Myrcene	2.38	±	11.09	β-Cubebene	0.04	±	0.14
α-Terpinene	0.31	±	0.65	t-β-Caryophyllene and β-Elemene	0.41	±	0.93
dl-Limonene	1.22	±	17.21				
β-Phellandrene	0.20	±	0.64	γ-Elemene	0.22	±	0.92
γ-Terpinene	1.16	±	2.87	α-Humulene	0.25	±	0.90
t-Ocimene	0.04	±	0.11	t-β-Farnesene	0.02	±	0.09
p-Cymene	0.53	±	1.74	γ-Muurolene	0.07	±	0.19
α-Terpinolene	0.25	±	0.59	Germacrene D	0.13	±	0.62
(Z)-Rose oxide	nq	±	nq	α-Selinene	0.06	±	0.15
Verbenyl ethyl ether	2.55	±	24.43	α-Muurolene	0.08	±	0.15
Citronellal	0.06	±	0.41	δ- and γ-cadinene	0.32	±	1.15
Campholenal	0.51	±	4.55	Cadina-1,4-diene	0.02	±	0.11
Camphor	0.83	±	1.54	Germacrene B	0.08	±	0.18
Linalool	1.93	±	36.99	α-Calacorene	0.02	±	0.19
cis-Sabinene hidrate	nq	±	nq	Caryophyllene oxide	0.09	±	5.13
Bornyl acetate	0.18	±	2.01	Torreyol	0.08	±	1.52
1-4-Terpineol	0.22	±	0.79	Elemol	0.01	±	0.32
Myrtenal	nq	±	nq	Spathulenol	0.05	±	1.29
α-Terpineol	1.13	±	9.03	t-Cadinol	0.03	±	0.97
Terpenyl acetate	0.08	±	0.71	t-Muurulol	0.03	±	1.27
Neryl acetate	0.05	±	0.31	Eudesmol	0.01	±	0.18
Geranyl acetate	0.25	±	2.09	α-Cadinol	0.06	±	1.45

Notes: volatile compounds are listed following wax column elution order in wax column. nq not quantified.

Source: Vichi *et al.*, 2005.

mainly alcohol derivatives of the sesquiterpenes. All of the compounds detected have previously been found in juniper berries, but this is the first time that these compounds have been detected in gins (Vichi *et al.*, 2005). The main compounds that were quantified are caryophyllene oxide, torreyol, elemol, spathulenol, t-cadinol, t-muurolol, eudesmol and α-cadinol.

The volatile composition may account for the differences observed between gins in terms of their sensory profile (Fig. 12.2). According to Vichi *et al.* (2005), when an analysis of the principal components was performed, gin G6 (which had

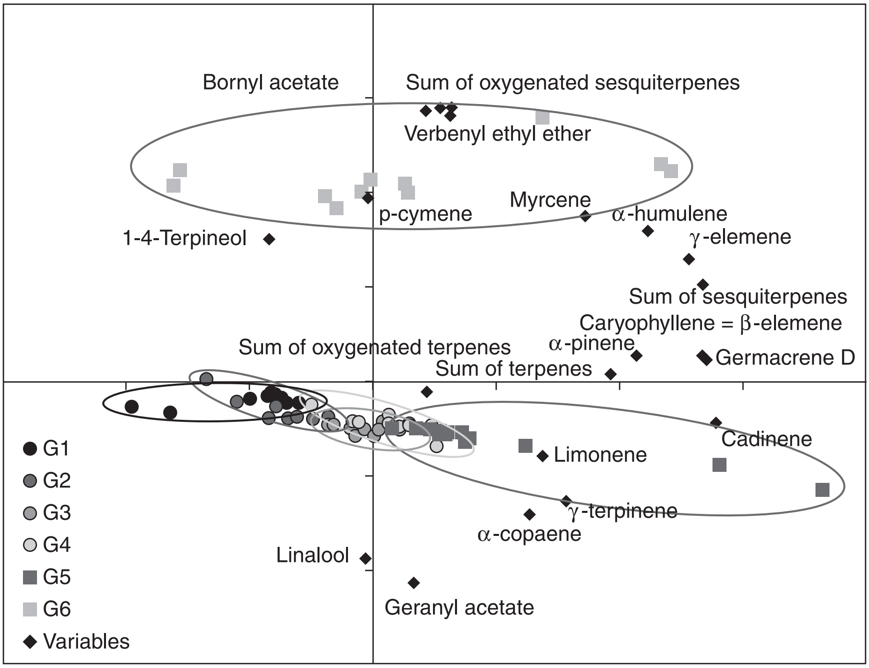

Fig. 12.2 Principal components analysis of volatile compounds of gin.

a geographical indication) was shown to contain higher levels of terpenic compounds typically found in juniper berries and lower levels of volatiles typically found in other botanicals such as coriander or citrus fruits. The other gin with a geographical indication (G5 in Fig. 12.2) showed higher levels of limonene and γ-terpinene and linalool, probably due to the use of citrus species during its production. Moreover, the levels of compounds typically found in juniper berries were significantly lower. The other gins (G1–G4 in Fig. 12.2) had more similar volatile compositions.

12.4 Sensory properties of gin and sensory analysis practice in the industry

The differences between types of gin both in terms of composition and elaboration method make it very difficult to obtain a standardised sensory evaluation. Furthermore, the gin production process requires rigorous sensory controls in order to obtain gin with optimal sensory characteristics. Sensory analysis is a quality control method using human senses as measuring instruments. The methods used in sensory analysis can be divided into difference tests (which include overall difference tests and attribute difference tests), preference tests such as a consumer test, and descriptive tests. Other authors such as Muñoz *et al.* (1992) categorised the most usual sensory methods used in the industry as follows:

- Overall difference test,
- Difference from control,
- Descriptive test,
- In/out of specifications,
- Preference test,
- Typical measurements,
- Qualitative description of typical production,
- Quality grading.

Discrimination methods (difference tests) are used to evaluate differences or similarities between samples, demonstrating whether two samples are different or sufficiently similar (Meilgaard *et al.*, 1990). Discrimination techniques include the triangle test, the duo-trio, the two-out-of-five tests, and the difference for control test, for example, and require between 20–100 semi-trained panellists, depending on the test.

In addition, the preference or acceptance test aims to assess the personal response of current or potential customers to a product or product characteristic (Meilgaard *et al.*, 1990).

The consumer test constitutes the main sensory analysis carried out by producers and has been proven to be highly effective in the development of new products. The consumer test requires a large number of people (a panel consisting of anywhere between 100–500 people is usual). The affective methods can be qualitative or quantitative.

Finally, the most sophisticated tools of sensory analysis are descriptive methods. Descriptive analysis involves the detection and description of both qualitative and quantitative sensory components by a trained panel of judges. Descriptive analyses are widely used in the industry for quality control, in order to understand consumer responses to the sensory attributes of products, to study packaging effects, the effect of ingredients or processing variables or to investigate consumer perception regarding a product (Murray *et al.*, 2001). The training of the panel is described in detail in order to obtain a high quality panel of judges (ISO, 1994). There are several descriptive analysis methods, including the Flavour Profile Method (FPM), Quantitative Descriptive Analysis™, the Spectrum™ Method, the Texture Profile Method, Quantitative Flavour Profiling, Free-Choice Profiling and Generic Descriptive Analysis (GDA). Each method has different requirements and determined specificities. However, GDA can combine multiple different approaches found in each method, and is commonly used in the food industry.

The different processes and different combinations of botanicals used in gin production lead to differences in flavour profile between the various types of gin. There is therefore no standard method for its sensory evaluation. The first step in describing a type of gin is to draw up a list of terms (Mc Donnell, *et al.*, 2001). Three studies on the creation of gin-related vocabulary can be found in the literature: Piggott and Holm (1983), Phelan *et al.*, (2004) and Riu-Aumatell *et al.* (2008). In the study by Piggott and Holm (1983), 21 descriptive terms were developed for gin flavour. The character of gin is a result of both the alcohol content and the juniper essential oils, while each of the botanicals makes a sensory contribution depending on its source, concentration and relationship with other botanicals. Some of the particular notes detected were citrus, spicy and earthy characteristics from angelica (Piggott and Holm, 1983). The vocabulary used in this study requires some further refinement, as well as chemical reference standards to define the meaning of each descriptive term. In the study conducted by Phelan *et al.* (2004), the vocabulary was generated by a panel of experts from the Scotch Whisky Research Institute. The tasters produced a large list of terms which was then reduced and refined for a final list of 16 attributes: pungent, spicy, herbal, citrus, floral, aniseed, juniper, fruity, sweet, sour, buttery, stale, oily, solventy, soapy and sulphury. The panel then underwent training with botanical distillates, in order to recognise all of the attributes that had been analysed.

In the study performed by Riu-Aumatell *et al.* (2008) the development of a sensory vocabulary for gin was performed according to ISO 11035. First, a triangle test was performed with two objectives. The aims were firstly to detect sensory differences between samples and secondly to familiarise the panel with gins and gin vocabulary. The results obtained showed significant differences between gins. ISO 11035 is focused on the selection and generation of vocabulary using a multidimensional approach. This International Standard allows verification of the relevance and independence of each descriptor, and is based on the use of at least six tasters, on the use of products (botanicals for example) to train the panel, a very important role for the panel leader, and on the use of multivariate statistical methods. The panel was extensively trained with hydroalcoholic solutions with standards previously found in gins (myrcene, limonene, linalool, γ-terpinene and α-pinene), natural sensory references such as juniper, coriander, aniseed and lemon peel and gin enriched with ethanolic extracts of juniper, aniseed, coriander and angelica root. The vocabulary was generated by tasting three London Dry gins with the use of a perfumery wheel, natural sensory references and a discussion with the panel leader to eliminate synonyms and hedonistic and irrelevant terms. Finally, a list of ten attributes was drawn up: angelica root, aniseed/fennel, cardamom, citrus peel, coriander, floral, fruity, juniper, liquorice and spice. According to ISO 11035, the first list obtained was too large and had to be reduced. The first reduction was performed using the geometric mean (M). M is the square root of the product of the frequency quotation (F) and the relative intensity (I) of each descriptor.

$$(M = (F \times I)^{1/2}) \qquad [12.1]$$

An analysis of the principal components was then carried out and the discriminative capacity of each descriptor was evaluated using the one-way analysis of variance (ANOVA).

The initial list of ten descriptors was reduced to five descriptors (juniper, citric, liquorice, aniseed and spice) using multivariate analysis, after which the descriptive analysis was performed. In the study conducted by Phelan *et al.* (2004) and Mc Donnell (2001), quantitative descriptive analysis (QDA) was used, while the study performed by Riu-Aumatell (2008) employed generic descriptive analysis (GDA). When a sensory analysis of distilled beverages is performed, the drink must be diluted in order to avoid taster fatigue resulting from alcohol content, and to standardise the alcoholic strength. The samples must be presented in randomised order coded by three digit numbers.

The results obtained showed that the gins could be clearly differentiated according to their sensory flavour profile. Moreover, the flavour profile is in accordance with the previously determined volatile composition (Vichi *et al.*, 2005). The aroma profiles of gin obtained in the study comparing six different distilled gins are shown in Fig. 12.3. G5 and G6, which are gins with geographical indication, are clearly different with respect to London Dry gins. G6 was judged to have the highest intensity of juniper note. At the same time, according to the study performed by Vichi *et al.* (2005) and Riu-Aumatell *et al.* (2008) it showed significantly higher levels of juniper monoterpenes such as sabinene, myrcene and *p*-cymene. The panel judged G5 to have the greatest intensity of citrus attributes and the lowest juniper note. The levels of juniper compounds in G5 were similar to those in G6, but the concentration of limonene and γ-terpinene was clearly higher. It is likely that the higher citrus attribute masks the juniper note in this gin. Similar levels of liquorice were judged to be present in all the

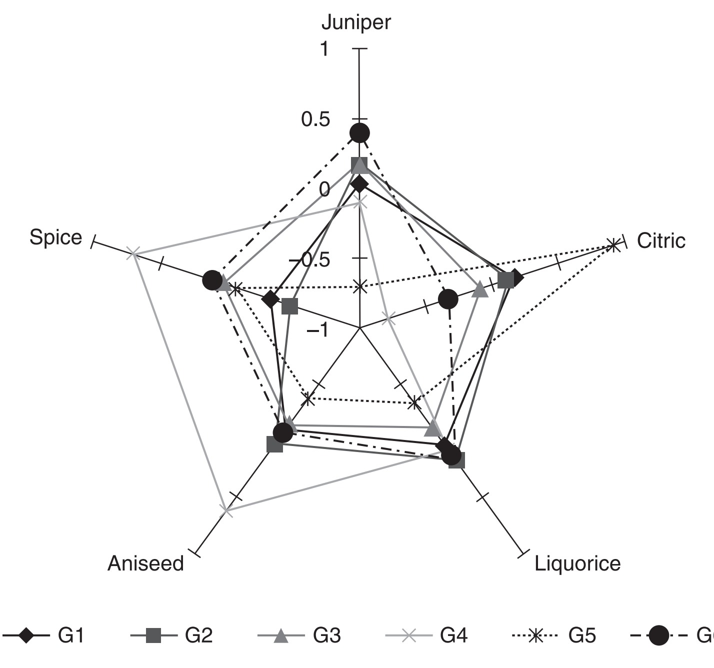

Fig. 12.3 Aroma profiles of gin samples.

samples. Spice and aniseed attributes were reported to be significantly higher in G4 gin. According to Riu-Aumatell *et al.* (2008) the presence of spice attributes could be explained by the levels of sabinene, δ-3-carene and *p*-cymene, compounds which were described as peppery and resinous. G2–G4 gins showed moderate intensities of all the tested notes with no dominant attribute. The results obtained are in accordance with the study conducted by Mc Donnell *et al.* (2001). These authors developed a sensory vocabulary to describe colourless distilled beverages, including gin, in 12 panel hours and to monitor the performance of the panel and the performance of each assessor throughout this procedure. Again, the panel associated the sensory notes of gin with citrus and juniper attributes.

In conclusion, the sensory description of a distilled gin beverage can be assessed using sensory descriptive analysis. Juniper, aniseed and citrus are the attributes defined in all the published studies, while other notes should also be taken into account. Liquorice, spice, pungent, herbal, floral, fruity, buttery, solventy and soapy attributes could all be used with a discriminative function to define the sensory profile of gin. The results obtained from the sensory description are in accordance with the results obtained from the volatile profile that was found in the literature. The volatile composition of gin principally consisted of oxygenated and non-oxygenated terpenoids, found in the composition of juniper essential oil. The other compounds identified originate from other botanicals such as citrus peel, aniseed or angelica root.

12.5 Future trends

The beverage industry, including the gin production sector, is dynamic and has a bright future. However, counterfeiting could prove to be a global problem in the alcoholic drink industry, particularly in the case of gin. The most effective way to obtain a product with the highest quality is to have a detailed understanding of the chemical and sensory composition of a product. One development required to increase the quality of an alcoholic beverage such as gin is the use of new methodologies for the distillation process. The use of vacuum distillation is likely to prove important in obtaining a volatile profile with optimal characteristics.

Even with the advanced sophistication of modern distilleries, product tasting remains necessary, as does the creation of a unified vocabulary list to evaluate the odour of distilled gins. To achieve this, suitable reference materials for the training of a panel are required. The training of a panel in the tasting of spirit drinks is usually a long process that employs authentic samples of spirits with distinctive flavour characteristics or the addition of pure flavour compounds to clean spirits. The use of reference materials that are stable over time, produced during food grade production, and guaranteed safe for tasters is extremely useful in this respect. For example, microencapsulated flavour standards are useful for the training of tasters, the validation of taster performance, and the development of consumer interest.

12.6 Sources of further information and advice

This chapter was written based on the author's own experience and with the aid of some references. One of the most important sources of information was The Gin and Vodka Association, a non-profit and non-trading association dedicated to promoting and protecting UK gin and vodka around the world. The description of sensory analysis followed ISO 11035, (International Organisation for Standardization http://www.iso.org/iso/catalogue_detail.htm?csnumber=19015). Finally, the book *Distilled Spirits: Tradition and Innovation* edited by J.H. Bryce and G.G. Stewart, Nottingham University Press, United Kingdom, 2004 is an interesting and relevant book that provided more information on distilled spirits, including not only gin but also other beverages such as vodka, whisky and rum.

12.7 References

ANGIONI, A., BARRA, A., RUSSO, M.T., CORONEO, V., DESSÍ, S. *et al.* (2003), 'Chemical composition of the essential oils of *Juniperus* from ripe and unripe berries and leaves and their antimicrobial activity'. *J. Agric. Food Chem.*, **51**, 3073–3080.

BARJAKTAROVIĆ, B., SOVILJ, M., KNEZ, Z. (2005), 'Chemical composition of *Juniperus communis* L. fruits supercritical CO_2 extracts: dependence on pressure and extraction time'. *J. Agric. Food Chem.*, **53**, 2630–2636.

BARRERO, A.F., QUÍLEZ DEL MORAL, J.F., HERRADOR, M.M., ARTEAGA, J.F., AKSSIRA, M. *et al.* (2005), 'Abietane diterpenes from the cones of *Cedrus atlántica*'. *Phytochem.*, **66**, 105–111.

CLUTTON, D.W., EVANS, M.B. (1978), 'The flavour constituents of gin'. *J. Chromatogr.*, **167**, 409–419.

DONEANU, C., ANITESCU, G. (1998), 'Supercritical carbon dioxide extraction of *Angelica archangelica* L. root oil'. *J. Supercrit. Fluids*, **12**, 59–67.

EUROPEAN UNION (2008), 'Regulation (EC) No 110/2008 of the European parliament and of the council of 15 January 2008 on the definition, description, presentation, labelling and the protection of geographical indications of spirit drinks'.

FANG, T., GOTO, M., SASAKI, M., HIROSE, T. (2004), 'Combination of supercritical CO_2 and vacuum distillation for the fractionation of bergamot oil'. *J. Agric. Food Chem.*, **52**, 5162–5167.

GREER, D., PFAHL, L., RIECK, J., DANIELS, T., GARZA, O. (2008), 'Comparison of a novel distillation method versus a traditional distillation method in a model gin system using liquid/liquid extraction'. *J. Agric. Food Chem.*, **56**, 9030–9036.

ISO (1994). *11035. Sensory analysis-identification and selection of descriptors for establishing a sensory profile by a multidimensional approach*. International Organization for Standardization, Geneva.

KAUL, P.N., BHATTACHARYA, A.K., RAJESWARA RAO, B.R., SYAMASUNDAR, K.V., RAMESH, S. (2003), 'Volatile constituents of essential oils isolated from different parts of cinnamon (*Cinnamomum zeylanicum* Blume)'. *J. Sci. Food Agric.*, **83**, 53–55.

KIRALAN, M., CALIKOGLU, E., IPEK, A., BAYRAK, A., GURBUZ, B. (2009), 'Fatty acid and volatile oil composition of different coriander (*Coriandrum sativum*) registered varieties cultivated in Turkey'. *Chem. Natural Comp.*, **45**, 100–102.

KIRAN BABU, G.D., , SHANMUGAM, V., RAVINDRANATH, S.D., JOSHIS, V.P. (2007), 'Comparison of chemical and antifungal activity of *Curcuma longa* L. leaf oils produced by different water distillation techniques'. *Flavors Fragrance J.*, **22**, 191–196.

LEA, A.G.H., PIGGOTT, J.R. (2003), *Fermented Beverage Production*. 2nd ed., New York, Kluwer.

LO CANTORE, P., IACOBELLIS, N.S., DE MARCO, A., CAPASSO, F., SENATORE, F. (2004), 'Antibacterial activity of *Coriandrum sativum* L. and *Foeniculum vulgare* Miller var. vulgare (Miller) essential oils'. *J. Agric. Food Chem.*, **52**, 7862–7866.

LOPES, D., RAGA, A.C., STUART, G.R., DE OLIVIER, J.V. (2003), 'Influence of vacuum distillation parameters on the chemical composition of five fold sweet orange oil (*Citrus sinensis* Osbeck)'. *J. Essent. Oil Res.*, **15**, 408–411.

MACNAMARA, K., HOWELL, J., HUANG, Y., ROBBAT JR. A. (2007), 'Analysis of gin essential oil mixtures by multidimensional and one-dimensional gas chromatography/mass spectrometry with spectral deconvolution'. *J. Chromatogr.*, **1164**, 281–290.

MARTÍN-ALVAREZ, P.J., HERRANZ, A. (1991), 'Application of multivariate statistical methods to the differentiation of gin brands'. *J. Sci. Food Agric.*, **57**, 263–272.

MC DONNELL, E., HULIN-BERTAUD, S., SHEEHAN, E.M., DELAHUNTY, C.M. (2001), 'Development and learning process of a sensory vocabulary for the odor evaluation of selected distilled beverages using descriptive analysis'. *J. Sens. Stud.*, **16**, 425–445.

MEILGAARD, M., CIVILLE, G.V., CARR, B.T. (1990), *Sensory Evaluation Techniques*, 3rd ed. Boca Raton, New York, CRC Press.

MUÑOZ, A.M., CIVILLE, G.V., CARR, B.T. (1992), *Sensory Evaluation in Quality Control*, New York, Van Nostrand Reinhold.

MURRAY, J.M., DELAHUNTY, C.M., BAXTER, I.A. (2001), 'Descriptive sensory analysis: past, present and future'. *Food Res. Int.*, **34**, 461–471.

PHELAN, A.D., JACK, F.R., CONNER, J.M., REID K.J.G., PRIEST, F.G. (2004), 'Sensory assessment of gin flavour'. In *Distilled Spirits: Tradition and Innovation*. J.H. Bryce and G.G. Stewart (eds), Nottingham University Press.

PIGGOTT, J.R. HOLM, A.M. (1983), 'Descriptive sensory analysis of gin flavour'. In Piggott, J.R. (ed), *Flavour of Distilled Beverages*, Chichester, Ellis Horwood, pp 145–153.

RIU-AUMATELL, M., VICHI, S., MORA-PONS, M., LÓPEZ-TAMAMES, E., BUXADERAS, S. (2008), 'Sensory characterization of dry gins with different volatile profiles'. *J. Food Sci.*, **73**, 286–293.

VICHI, S., RIU-AUMATELL, M., MORA-PONS, M., BUXADERAS, S., LÓPEZ-TAMAMES, E. (2005), 'Characterization of volatiles in different dry gins'. *J. Agric. Food Chem.*, **53**, 10154–10160.

VICHI, S., RIU-AUMATELL, M., MORA-PONS, M., GUADAYOL, J.M., BUXADERAS, S. *et al.* (2007), 'HS-SPME coupled to GC/MS for quality control of *Juniperus communis* L. berries used for gin aromatization'. *Food Chem.*, **105**, 1748–1754.

VICHI, S., RIU-AUMATELL, M., BUXADERAS, S., LÓPEZ-TAMAMES, E. (2008), 'Assessment of some diterpenoids in commercial distilled gin'. *Anal. Chim. Acta*, **628**, 222–229.

VILLALÓN-MIR, M., LÓPEZ DE LA SERRANA, H., LÓPEZ MARTÍNEZ, M.C., GARCÍA VILLANOVA, R. (1984a), 'Estudio comparativo por cromatografia en fase gaseosa de los alcoholes, aldehídos, ésteres y componentes esenciales que integran una ginebra tipo con los de otras ginebras comerciales'. *Anal. Bromatol.*, **36**, 61–69.

VILLALÓN-MIR, M., LÓPEZ DE LA SERRANA, H., LÓPEZ MARTÍNEZ, M.C., GARCÍA VILLANOVA, R. (1984b), 'Determinación de terpineol-4 y alfa-pineno en ginebras comerciales por espectrofotometría y cromatografía en fase gaseosa'. *Anal. Bromatol.*, **36**, 133–136.