16

Pisco: production, flavor chemistry, sensory analysis and product development

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Abstract: Pisco is a young brandy produced predominantly from Muscat wines in the north of Chile and also in Peru. The chapter describes the areas of production in Chile, wine production and distillation techniques and gives an overview of production figures and the main markets nowadays. The sensory properties and flavor chemistry of Pisco are described emphasizing the properties that make it different from other young or non-aged wine brandies. Sensory practice and consumer research in particular for product development in the Chilean Pisco industry are finally discussed.

Key words: Pisco, brandy, muscat, wine distillation, odour activity value, aroma, flavor, sensory properties, gas chromatography, mass spectrometry, gas chromatography-olfactometry, aroma extract dilution analysis, free choice profiling.

16.1 Introduction

According to Chilean legislation Pisco is defined as a brandy produced and bottled in units of consumption in the III (Atacama) and IV (Coquimbo) Regions, through the distillation of genuine wine, from *Vitis vinifera* varieties specified by law and planted in those regions.

Pisco is by far the most important distilled beverage produced and consumed in Chile. It corresponds to a non-aged or slightly aged kind of brandy, produced in the north of Chile and protected by one of the oldest denominations of origin of the country. The other particularity of Pisco as a young brandy is the inclusion of Muscat grapes to obtain the wines that are distilled. This coupled with a traditional distillation gives most Piscos a distinctive Muscat fruity aroma that clearly differentiates it from other spirits. Along with wine and beer, Pisco in Chile is clearly one of the most popular drinks, consumed mostly in different cocktails or mixed with sodas and fruit juices. Both in Chile and in Peru, Pisco is the most important distilled beverage. However, it is almost unknown elsewhere and exports are still minimal, mostly to neighbor countries or to Chilean colonies residing outside Chile.

According to Chilean tradition the production of this kind of brandy is even older than independent Chile having originated during the colony, when Peru and Chile belonged to the same Spanish Viceroyalty, which explains why Pisco exists in both countries. Information about bottled brandy labeled Pisco in Chile was already available in the second half of the nineteenth century, and as early as 1931 the official Denomination of Origin was created, specifying the area of production and grape varieties that can be used. Pisco also exists in Peru, and a similar brandy called Singani exists in Bolivia. According to the Peruvian position, the use of the word Pisco to designate a brandy would have started earlier in Peru from the name of the Peruvian port, Pisco, from where it was exported.

16.2 Pisco production

The area of production is restricted to five valleys: Copiapó, Huasco, Elqui, Limarí and Choapa. They run from the Andes to the Pacific Ocean in an extremely dry and luminous environment in the southern border of the Atacama Desert, the driest place on earth. Snow melting in the Andes provides the limited water supply that allows viticulture in this very arid condition. The region is located between the 27th and 32nd parallels of latitude south. The climate that characterizes the central portion of the valleys can be described as sub-desertic with a strong influence of the Pacific anticyclone, determining minimal cloud cover and no rainfall nine to ten months of the year, giving a high level of solar radiation during the growing season. This area, with higher temperatures and easy grape maturation, is where Pisco production started and where most of the acreage of vineyards was concentrated. Currently, viticulture has also extended closer to the Pacific Ocean, which strongly modulates the climate, lowering heat accumulation and provides a great diversity of 'terroirs' depending on the distance to the sea. This makes it possible to find optimal conditions for different grape varieties and styles. Currently, high-quality wine production for direct consumption in this area is under strong development. Extremely dry conditions, with no rain at all during the growing season, assure an excellent maturation and the best sanitary conditions, making it very easy to obtain organic products.

Grape varieties for Pisco production are mostly characterized by their strong fruity aromas, including several Muscat-type grapes like the world renowned Muscat of Alexandria, known locally also as Italia, White, Yellow, Orange and Black Muscats, Chasselas Musque Vrai, Frontignan Muscat, Hamburg Muscat, Moscato de Canelli, Torontel, and Moscatel Rosada (Pink Muscat), a local selection also with a strong terpenic aroma. Besides these Muscat-style varieties, Pedro Jimenez and a variety known as Austria Muscat, both with low Muscat aroma, are also considered for Pisco production providing the more neutral spirits necessary for blending. Most vineyards are trained as overhead 'pergolas' in the valleys and as traditional vertical trellises in the hillsides. Irrigation is essential considering the absence of rain. Enough water supply is provided by the Andes and a system of reservoirs in each valley.

Winemaking has evolved from very traditional techniques, still seen in some small enterprises (Bordeu and Pszczolkowski, 1982), to very modern facilities in the larger companies with stainless steel tanks, up-to-date equipment and highly technological enology providing the high-quality, aromatic white wines to be distilled. Winemaking is typical of modern white wine styles with low-temperature fermentation of low-solid clarified musts protected from oxygen. The use of sulfur dioxide is minimized as in other wines for distillation to avoid the distillation of sulphur dioxide and high levels of acetaldehyde. Wine conservation before it is distilled is basically assured by high alcohol and hygiene because pH tends to be high. The storage period is shortened by early distillation.

As soon as wines are finished with fermentation, the distillation process is started using traditional copper alambics, similar to those used for Cognac production in France. Alcohol is usually obtained in a single-batch distillation process with the classic separation of heads, heart or brandy and tails. Short rectification columns are generally used at the end of the heart fraction and the raw alcohol obtained is around 60°. Some new distillation techniques have evolved recently such as double distillation, looking for more neutral products to compete with spirits such as vodka.

An important difference with other types of brandy is that Pisco is not usually aged significantly, being bottled after a short period of maturation in wood, basically to refine the aroma. However, some types are aged longer in oak barrels looking for styles where wooden and age-related aromas are predominant. This style, found in some of the more expensive products, represents only a small segment of the market. Not all high-quality and expensive Pisco undergoes this ageing process; they rely mostly on the quality and intensity of the Muscat aromas. After maturation or aging Pisco is adjusted to the final consumption alcohol content (35–50°), clarified and bottled. The resulting distillate ranges from completely colorless to light amber, and is characterized by fruity Muscat aromas combined in different degrees with aromas coming from aging and oak.

There is no legal classification of Pisco types; however, four types are usually found on the market with different alcohol contents: traditional, 30–35°; special, 35°; reserve, 40° and 'Gran Pisco' 43–46° alcohol.

Four commercial categories of Pisco can also be described as relatively typical:

- Artisanal Pisco: small producers using traditional technologies like skin contact during winemaking, originating complex products requiring some maturation or aging.
- White Pisco: young distillates with less than six months aging, in general no contact with wood, frequently coming from single varietal wines, only 'heart distillates' low in non-alcohol fractions. Can be triple distilled.
- Mature Pisco: aging between six and twelve months in used cooperage with a combination of fruity aromas and some wooden notes and light color. Usually coming from a mixture of grape varieties.

- Aged Pisco: over twelve months aging in young American oak barrels. Clearly amber in color and with an important participation of wood-derived aromas combined with fruity aromas coming from grapes. Multi-varietal also.

The total area dedicated to Pisco production was 10 508 hectares in 2007; most was concentrated in the Coquimbo Region (9816 hectares) while only 693 hectares exist in the dryer northern region of Atacama. Around 215 000 tons of Pisco grapes are produced every year. The resulting 170 million liters of wine are used for distillation (116 000 000 l) and direct consumption as wine (54 000 000 l) (SAG, 2007).

The industry has a strong social impact in the regions of production. There are 2734 grape growers, most of them very small, 83% have less than 5 hectares and 36.6% less than 1 hectare, while only 3.3% have more than 20 hectares. Most growers also have other agricultural sources of income and only 18.8% of them are dedicated exclusively to Pisco grapes. It is estimated that over 30 000 people live from the production of Pisco, including industrial workers (INE, 2007).

The Pisco industry in Chile is clearly organized around two very large companies with a cooperative structure in terms of grape provision. These companies process over 90% of the 120 millions of tons of grapes used for Pisco production. Both companies sell several Pisco brands and are also involved in other alcoholic beverages like bottled ‘Pisco Sour’, a cocktail with lemon juice. Other smaller companies also exist, usually selling one brand of Pisco in the domestic market.

Pisco production in Chile is now around 45 000 000 l, above 5 million 9 l cases. The production is basically consumed locally where Pisco represents around 65% of the distillates market. Annual consumption in Chile is around 3 l per capita. Pisco exports are still limited, with a volume of only 296 000 l representing US$ 1 115 250 in 2007. Exports are concentrated in the two large producers, Capel and Compañía Pisquera de Chile, plus two smaller enterprises, Aba and Bauzá. The main export markets are the United States, Argentina and Germany. The industry is interested in increasing exports as local demand is stagnant and competition from imported spirits, in particular rum, is increasing.

16.3 Pisco flavor chemistry

16.3.1 Impact odorant compounds in Pisco

The concentration range of odor-active compounds from several commercial Piscos is illustrated in Table 16.1. Among the more than 120 volatile compounds present in these distillates, identified by gas chromatography-mass spectrometry (GC-MS) analyses, only a subset of less than 30 are sensory detectable. Several of these compounds show an olfactory impact despite being present in very low concentrations (mg/l or ng/l) because of their low sensory detection thresholds (Belitz *et al.*, 2004; Guth, 1997). Odor activity values (OAV), defined as the ratio between the concentration of the compound and its detection threshold, were used to evaluate the potential sensory contribution of the volatiles found in the distillates; only those showing OAVs higher than 0.5 were reported in Table 16.1.

Table 16.1 Concentration range of odor active compounds (mg/l) in commercial Piscos

Compounds[b]	Concentration range (μg/l)	Olfaction threshold[†] (μg/l)	Odor activity value (OAV) range	Description	Reference
Acids					
Octanoic	2 420–6 833	8 800 (a)	0.3–0.8	Fatty acid	Cuillere *et al*. (2004)
Dodecanoic	409–2 155	1 000 (a)	0.4–2.2	Dry, metallic	Cuillere *et al*. (2004)
Isovaleric	78–411	33.4 (c)	2.3–12.3	Sweat, acid, rancid	Delfini *et al*. (2001)
Alcohols					
1-Hexanol	1 647–4 785	8 000 (a)	0.2–0.6	Toasty, green, dry	Cuillere *et al*. (2004)
Isoamyl alcohol	58 699–84 203	30 000 (a)	2.0–2.8	Whiskey, malt, burnt	Delfini *et al*. (2001)
Isobutyl alcohol	5 174–14 320	7 000 (b)	0.7–2.1	Sweet, chemical	Benn and Peppard (1996)
1-Heptanol	75–240	3 (b)	25.0–80.0	Green	Curionia and Bosset (2002)
C_6 compounds					
cis-3-hexenol	68–112	400 (a)	< 0.5	Grass	Cuillere *et al*. (2004)
Terpenols					
Linalool	672–2 910	15 (a)	45.0–194.0	Flowery, muscat	Cuillere *et al*. (2004)
Citronellol	9–264	100 (a)	0.0–2.6	Citrus	Peter *et al*. (1999)
α-terpineol	446–1 091	250 (c)	1.8–4.4	Anis	Cuillere *et al*. (2004)
Geraniol	18–158	30 (a)	0.6–5.3	Fruity	Peter *et al*. (1999)
Nerol	34–177	300 (b)	0.1–0.6	Rose	Semikolenov *et al*. (2003)
Ho-trienol	513–1 920	100 (a)	5.1–19.2	Sweet, honey	Rocha *et al*. (2005)
Farnesol	8.0–27	20 (b)	0.4–1.4	Lemon, anis	Cuillere *et al*. (2004)
C_{13}-Norisoprenoids					
β-Damascenone	0.0–17.0	0.05 (a)	0–340	Baked apple	Cuillere *et al*. (2004)
β-Ionone	4.0–38.0	0.09 (a)	44–422	Violets	Cuillere *et al*. (2004)
Furans					
5-Hidroxymethyl furfural	1242–2 914	15 000 (a)	0.3–6.5	Aldehyde, caramel	Câmara *et al*. (2004)

(Continued overleaf)

Table 16.1 Continued

Compounds[b]	Concentration range (μg/l)	Olfaction threshold† (μg/l)	Odor activity value (OAV) range	Description	Reference
Vainillins					
Vainillin	7–354	200 (a)	0–1.8	Vanilla	Peter *et al.* (1999)
Lactones					
γ-Butyrolactone	19–122	100 (a)	0.2–1.2	Sweet aromatic	Tateo and Bononi (2003)
cis Oak-lactone	13–171	35 (a)	0.4–4.9	Coconut, flower	Delfini *et al.* (2001)
Phenolic derivatives					
4-Vinyl guaiacol	12–29.0	40 (a)	0.3–0.7	Clove, curry	Delfini *et al.* (2001)
Esters					
Isoamyl acetate	538–3 192	30 (a)	18.0–106.0	Banana	Delfini *et al.* (2001)
Ethyl hexanoate	669–16 448	14 (a)	48.0–1175.0	Fruity, anis	Cuillere *et al.* (2004)
Ethyl octanoate	1759–5 241	2 (a)	880.0–2620.0	Fruity, anis	Cuillere *et al.* (2004)
Ethyl decanoate	1 416–6 412	200 (c)	7.0–32.0	Grape	Delfini *et al.* (2001)
Isobutyl acetate	39–140	30 (a)	1.3–4.7	Flowery	Cuillere *et al.* (2004)
Ethyl hexadecanoate	5.0–2 341	2 000 (b)	0.0–1.2	Fatty, rancid, fruity, sweet	Yong-Sheng Tao and Hua Li (2009)
Ethyl heptanoate	17–326	2.2 (b)	7.7–148.0	Banana, strawberry	Giri (2010)
cis-3-hexenyl acetate	43–49	8 (b)	5.4–6.1	Banana	Greger and Schieberle (2007)

Notes: Commercial Piscos analyzed: Horcon quemado, Capel 35, Alto del Carmen 35, Alto del Carmen envejecido, Artesanos de Cochiguaz, Campanario; Mistral, Ruta Norte.

†Olfaction thresholds determined in (a) water/ethanol (10–15% v/v), (b) water, (c) water/ethanol (13%) with glycerol and pH 3–3.4

Although the latter only provides a rough evaluation of the real contribution of each compound to the global aroma, this 'odor activity scale' is much closer to reality than the concentration scale.

The most important odorants in Pisco are the terpenes linalool and Ho-trienol; the C_{13} norisoprenoids β-ionone and β-damascenone; ethyl esters, in particular ethyl hexanoate, heptanoate and octanoate, and acetate esters, such as isoamyl acetate. Other compounds that increase the aroma complexity of the distillate are lactones and phenolic derivatives, furans, heptanol and isovaleric acid.

16.3.2 Origin of the odor-active compounds found in Pisco

Pisco is obtained after distillation of white wines produced from Muscat grape varieties. Therefore, most of the aroma in the distillate results from a unique mixture of volatile compounds originated from grapes (varietal aromas), secondary products formed during the wine fermentation (fermentative aromas) and, to a lower extent, from a short aging process (post-fermentative aromas) (Lambrechts and Pretorius, 2000; Swiegers and Pretorius, 2005). Moreover, winemaking from Muscat grapes has progressively evolved from red to white winemaking techniques to retain as much aroma as possible (Agosin *et al.*, 2000). Finally, during wine distillation, several aroma compounds are also released or degraded as a consequence of the harsh environmental conditions prevailing in the still.

Varietal aromas

Monoterpenols, such as linalool, geraniol, nerol or ho-trienol, among others, represent the basis of Muscat typicity which distinguishes Pisco from other young distillates (Baumes *et al.*, 1994); surprisingly, few C_{13}-norisoprenoids also contribute significantly to the fruity aroma of the distillate. It is worth noticing that these flavor compounds are also present in significant amounts in Muscat wines as sugar-bound non-volatile – i.e. odorless – precursors, including glycosides. This is important in the case of wine distillates because, during distillation, the latter undergo fast acid-catalyzed hydrolysis, yielding free volatiles.

Both free and bound odorants are particularly abundant in the grape varieties Muscat de Alexandria and Moscatel Rosada (Belancic *et al.*, 1997). Other grape varieties also grown for Pisco, such as Pedro Jimenez in Chile or Quebranta in Peru, contribute little to aroma (Bordeu *et al.*, 2004).

Fermentative aromas

The aroma complexity dramatically increases during alcoholic fermentation as a result of the synthesis of important volatile compounds by the wine yeast *Saccharomyces cerevisiae* (Swiegers *et al.*, 2006). The nature and amount of the synthesized volatile compounds depends on multiple factors, such as the nitrogen content of the must, the temperature of fermentation, and the yeast strain (Molina *et al.*, 2009; Lambrechts and Pretorius, 2000; Swiegers *et al.*, 2006).

The volatile compounds synthesized by wine yeasts include higher alcohols, like the isoamylic alcohol (fusel, marzipan and floral aromas), medium- and long-chain volatile acids (fatty, cheesy and sweaty aromas), acetate esters and ethyl esters (fruity and floral aromas), and aldehydes (buttery, fruity and nutty aromas), among others (Delfini *et al.*, 2001; Lambrechts and Pretorius, 2000; Stashenko *et al.*, 1992). The capacity of yeast to synthesize these compounds varies between different strains (Lambrechts and Pretorius, 2000; Wondra and Boveric, 2001).

It is worth noticing that the varietal bound precursor fraction, i.e. non-volatile aroma compounds linked to sugar moieties, is not hydrolyzed during wine fermentation and remains odorless.

Fate of free and bound aroma compounds during wine distillation

Rigorous control and operation of the distillation process is critical to retain in the final distillate the complex aroma reached after the fermentation. Unfortunately, information about the reactions occurring during this operation is scarce. Ohta (1995) studied the transformation of geraniol and nerol in linalool and alfa-terpineol during distillation of *shochu*, a traditional Japanese distillate. He also reported a significant hydrolysis of the glycosidic conjugates into the free aglycones.

We also determined a significant increase in free terpenols during distillation of Muscat wines, resulting in more than twice the concentration initially present in the original wine. The latter results from the hydrolysis of a significant portion of the glycosidic fraction as a consequence of the harsh conditions – acidic pH and high temperatures – prevailing in the still; however, linalool oxides increased and some key terpenols were partially degraded as well (Agosin *et al.*, unpublished), suggesting that complex reactions are taking place during this operation, which deserves further study.

Aging

An increasingly common practice in the Pisco industry is to expose the distillates to a short aging process or to add caramel. The presence of lactones, furans and, eventually, of phenolic derivatives in commercial Piscos (Table 16.1) is a direct indication of these treatments.

16.3.3 Off-flavors

Off-flavors in Pisco could be generated either by concentration of wine volatiles over their detection threshold after distillation – alcohol content increases around three-fold in distillate compared to wine – or by faulty distillation. Isovaleric acid and isoamylic alcohol are examples of the former; hydroxymethylfurfural of the latter (Table 16.1). Other off-flavor compounds commonly determined in Pisco are acetaldehyde and a few fatty acids, as well as unknown compound(s) responsible for a sulfury, artichoke-like taste.

16.4 Main sensory properties of Pisco

An important group of sensory properties of Pisco are similar to those of young wine distillates. However what differentiates it from other wine spirits is the use of Muscat varieties, providing their typical terpenic aromas.

A set of descriptors to be used by the industry was proposed in 2004 (Bordeu *et al.*, 2004) and part of the terminology was later validated in a study about odor and aroma profiles of Chilean Pisco (Peña y Lillo *et al.*, 2005). The terminology proposed (see Fig. 16.1) was organized in the typical wheel format similar to those for wine and whiskey. Like that for whiskey, the Pisco wheel incorporates aroma descriptors and also mouth-feel and primary taste terms. A set of standards for most descriptors was also proposed. Similar to the wine wheel, standards correspond to easily available products and materials or chemicals easy to obtain. The wheel is organized in three concentric levels going from general to more specific descriptors in the outer ring. A total of 48 terms is proposed in this outer ring; far less than those proposed in other wheels. Several of the terms proposed are similar to those proposed for other spirits; however, some terms are specific to a young spirit with Muscat aroma, like geraniol, linalool, raisin and honey. Even

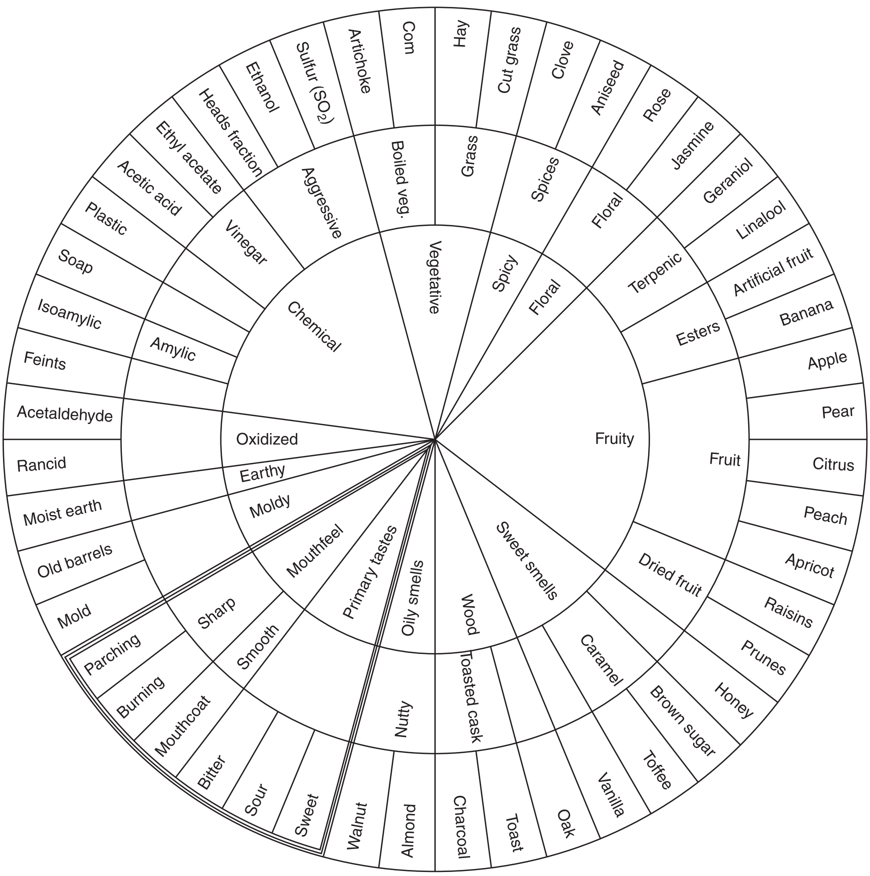

Fig. 16.1 Pisco and mouth-feel wheel, displaying its 48 outer-ring descriptors.
(Source: Bordeu *et al.* 2004. © 2004 ASEV. Reprinted with permission.)

if Pisco is not aged for long periods in wood, descriptors like vanilla, oak and toasted are important in describing products with some aging. The aroma descriptors with higher frequency of use in the development of the Pisco wheel were vanilla, raisins, linalool charcoal and prunes (Bordeu *et al.*, 2004).

In another study relating odor perception and physicochemical properties of volatiles in Pisco, terms as 'distillation tails' and 'oak' correlated with acids (hexanoic, octanoic, decanoic) and esters (ethyl lactate, diethyl succinate) while 'artificial fruit' correlated with total and individual ester content, 'linalool odor' correlated with linalool content and 'vanilla', 'caramel' and 'citric' correlated with higher alcohol and terpene (linalool, geraniol and nerol) content. Linalool and esters like ethyl octanoate, ethyl hexanoate and isoamyl acetate, respectively correlated with linalool and artificial fruit descriptors and were pointed out as possible odor impact molecules in Pisco (Peña y Lillo *et al.*, 2003a, 2003b).

A quantitative descriptive analysis (QDA) was done over odor and aroma profiles of 15 Pisco spirits and 14 distillation fractions by a panel of 12 trained subjects by the use of a list of 13 attributes: Acetaldehyde, Tails, Acetic acid, Ethyl acetate, Oak, Caramel, Vanilla, Raisins, Citrus, Pear, Artificial fruit, Linalol, Hay (Peña y Lillo *et al.*, 2005). Chilean Piscos were provided by two major distilleries and by smaller, independent ones. Fourteen distillation fractions from five different distillation runs (non-commercial products) were also included. Tasters were trained in the use of the terminology and the scale during 24 sessions before starting the formal tastings. Odor (orthonasal perception obtained by sniffing the samples) and aroma (retronasal perception obtained by sipping the samples) sensory profiling were performed in separate sessions.

The results of two-factor ANOVA showed a significant product effect for all odor attributes except pear ($P = 0.40$) and all aroma attributes except caramel ($P = 0.22$) and ethyl acetate ($P = 0.09$). Principal component analysis (PCA) was applied to odor and aroma data separately, considering only the discriminant attributes. Correlation between sensory attributes in each mode proved to be extremely high. The first two principal components covered 86% of the total variance for odor and 80% for aroma, giving practically the same amount of information in both cases.

For the commercial samples, PCA of odor-significant attribute results showed that samples were differentiated according to the type of distillation fraction and maturation process. In general, the commercial samples were separated by the PC1 (70% of the total variance) and PC2 (15%) in three main groups, one related to fruity/floral Muscat derived aromas, a second associated to oak and the maturation process and finally samples characterized mostly by off-flavors (Fig. 16.2).

Distilled fractions were grouped also in three major groups, the head fractions were related to artificial fruits, associated with esters; heart fractions were close to linalool and citrus attributes, and finally the fractions close to the tail were associated with the off-flavors.

Partial least square (PLS) models gave a good prediction of aroma from odor scores, except for the oak attribute which exhibited a non-linear behavior. Based

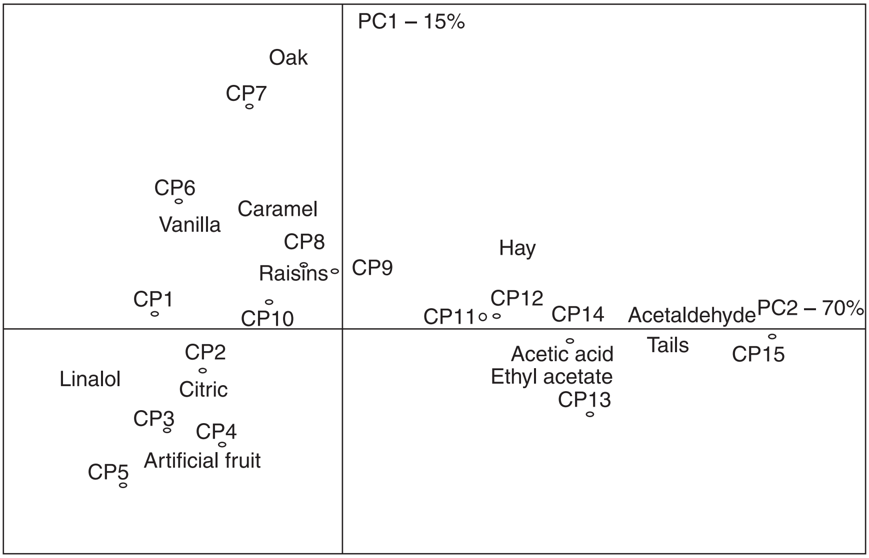

Fig. 16.2 Principal component analysis of 15 Pisco commercial samples, 11 attributes, 12 judges, 4 neplicates.

on the results of this study, Pisco olfactory perception can be limited to odor assessment.

16.5 Sensory analysis practice in the Pisco industry

Some enologists, with five-year university studies as agricultural engineers with a specialization in viticulture and enology, work in the industry and are responsible for the base wines and distillates quality. Sensory training of enologists is concentrated in wine tasting so experience to taste alcohols is gained at the industry level. Sommeliers, who work almost exclusively in the wine industry in Chile, are also beginning to work with Pisco, in particular in relation to cocktails and the relations between Pisco and Pisco-derived products and food that is consumed with this product. A third group of professionals involved in sensory evaluation of products are food engineers, also with formal training in sensory analysis.

Sensory practice in the Pisco industry differs mostly depending on company size. Small Pisco producers usually rely on tastings done by one or two technicians to follow distillation and assess quality of base alcohols and to prepare commercial lots. In large companies, sensory issues are handled by larger groups of technicians and professionals. Teams of enologists are responsible for wine and alcohol quality but panels are also used for quality control and product development. Typically, the technician in charge of each distillation plant first evaluates each lot of distillate and then a sample is sent to a trained panel that ranks it to accept or to reprocess it. Panelists are professionals, technicians and quality control personnel trained by the enologists in charge. Expert panels, with participation of enologists, are in general responsible for assigning each base alcohol to product lines and mixing lots to obtain the final commercial products. Consumer panels with no training are also used for acceptance studies of new products. Collaboration with regional universities offering food engineering is also used to evaluate Piscos and Pisco-based cocktails.

New product development is usually started by enologists or expert panels and then marketing personnel and independent market research companies are used to organize focus groups and evaluate acceptance at consumer level.

For more specific situations or problems, the industry also relies on specialized sensory and analytical studies commanded to universities or laboratories offering this service in Chile or sometimes abroad.

Even if Pisco is a denomination of origin, there is no agreement about the tasting of Piscos, as in some European wine denominations of origin. Potability of the final product is checked first by the laboratories of the Pisco producers and then it is controlled by analysis practiced by official laboratories under supervision of the Servicio Agricola y Ganadero: Agricultural and Livestock Service (SAG), belonging to the Ministry of Agriculture. All exported Piscos must comply with an equivalent potability export analysis that includes the parameters proposed internationally by Organisation Internationale de la Vigne et du Vin (OIV) for wine distillates. The contents of total acids, aldehydes, furfural, and methanol are limited to international standards. However, a minimum content of 2.5 g/l (based on 100° alcohol) of non-alcohol volatiles is required to avoid excessive rectification and to guarantee the use of traditional distillation practices.

16.6 Consumer research and product development in the Pisco industry

Among different studies commanded by the Pisco industry to specialized sensory laboratories, two of them have a particular interest because of the methodologies used. One of them deals with the production of a Pisco with a profile competitive with rum and the other was aimed to solve problems with 'Pisco Sour' a ready-to-drink (RTD) product derived from Pisco spirits.

16.6.1 Design of a new category of spirit: Pisco with rum flavor profile

In the last decade, rum has increasingly became a major competitor of Pisco, growing at rates over two digits, while Pisco sales have been stagnant over recent years. The largest Chilean Pisco producer decided to innovate through new product development, to better compete with the aggressive penetration of rum (Casaubon *et al.*, 2009).

Therefore, it was decided to design a new product based on consumer preferences and the application of senso-chemometrics. A multidisciplinary team was established, including the production and marketing managers of the company, researchers from Centro de Aromas y Sabores DICTUC and Compusense Inc.

In 2006, a consumer sensory test was carried out with 110 male drinkers of Pisco and rum, encompassing four socio-demographic segments (ABC1 and C2 crossed with two age ranges, 18–25 and 25+). The sensory space was covered by eleven products: eight Piscos and three rums, including large and small Pisco producers and the major rum brands. Consumers evaluated samples after individually mixing the spirit with cola and ice, as typically consumed by Chileans. A complete balanced block design was used to evaluate preferences using a 10 cm hedonic scale. Simultaneously, an ethnographic questionnaire was applied.

Descriptive analysis was carried out with a trained panel composed of 15 assessors. ANOVA showed that fourteen flavor attributes were discriminant. Principal component analysis (PCA) produced a sensory map in which Pisco samples were characterized by pear, citrus, apple and raisins, while rums were described by woody, vanilla, caramel, toffee and spicy attributes.

Internal preference mapping and cluster analysis were performed on the data. Four consumer sensory preference's segments were clearly clustered. The relationship between consumer preferences and descriptive analysis revealed a business opportunity to compete in the rum flavor sensory segment.

Chemical analysis of volatile compounds of the same samples using GC-MS showed that Piscos had the highest concentration of terpenes (i.e. linalool), esters and norisoprenoids (grape varietal compounds), responsible for the floral-fruity flavors that characterized Pisco; while rums were richer in oaky aromas, like vanilla, contributing to the woody sensory profiles.

The outcome of this study resulted in a new product category, a Pisco with rum flavors, the product is produced with neutral Muscat grapes and quickly aged with new, oak barrels. Finally, the marketing department developed a specific strategy to communicate the sensory attributes of this new product. The practical success of the sensometric design of this novel product has been proven as it is currently sharing a proportion of the shelf with the regular products in the Chilean market.

16.6.2 Sensory optimization of ready-to-drink products (RTD) from Pisco

Ready-to-drink products represent today more or less 25% of the total Pisco spirit commercialized in Chile. These are elaborated with Pisco spirit mixed with different flavors and include a wide range of types as citrus, mango, berries or coconut.

The addition of lemon juice gives a bitter and acidic flavor to the homemade Pisco Sour that is widely accepted by the Chilean population. The problem is the low stability of this product. The bottled product is affected mainly by oxidation problems. The sensorial properties of the Pisco Sour do not have a long lifetime because the raw materials of the lemon essence have low stability in the Pisco matrix.

The main objective was to improve the Pisco Sour stability to keep the fresh Pisco Sour aroma and flavor. To improve the stability of Pisco Sour on time it was necessary to study each compound in the Pisco Sour matrix. The main techniques used for this work were GC-MS, gas chromatography-olfactometry (GC-O), aroma extract dilution analysis (AEDA) and sensorial panels.

Free choice profile studies by an expert panel composed of researchers from Centro de Aromas y Sabores DICTUC and the Pisco company, using GC-O-AEDA, were used to correlate the sensory properties and volatile chemical composition of a 'good Pisco Sour' (bottling time 0), a 'bad Pisco Sour' (bottled after six months), competitors' commercial products and the fresh cocktail produced with natural lemon and the traditional recipe.

Generalized Procrustes analysis applied to the free choice profile data acquired allowed definition of the sensory properties expected from a natural Pisco Sour and compare it with the commercial products and new prototypes of RTD. The first two dimensions accounted for a total of 60.2% of the variance. Dimension 1 (45.4%) was described as a continuum from artificial flavor, oxidized and chemical to fresh lemon, citric, foam and 'sutil' lemon. Dimension 2 (14.8%) was described by the terms sweet and lemon at one end, to sour and floral at the other end (see Fig. 16.3). Natural Pisco Sour samples were related to fresh lemon, citric and foam and few commercial products were close to them, while most of the commercial products were associated with artificial flavor, chemical and oxidize attributes.

The olfactometric technique, using a sensory panel composed of eight panelists trained in this method, allowed description of the odorant zones of the olfactogram and then correlation with the chromatogram obtained from GC-MS analysis of the sample (Cuillere *et al.*, 2004; Curionia and Bosset, 2002; Francis and Newton, 2005; Greger and Schieberle, 2007).

GC-MS analysis of a natural Pisco shows a series of 27 chemical compounds affecting the aroma and flavor impact, according to the odorant activity value (OAV). Correlation analysis of GC-MS and GC-O/AEDA of a natural Pisco Sour found that 35 chemical compounds affect the impact of natural aromatic Pisco

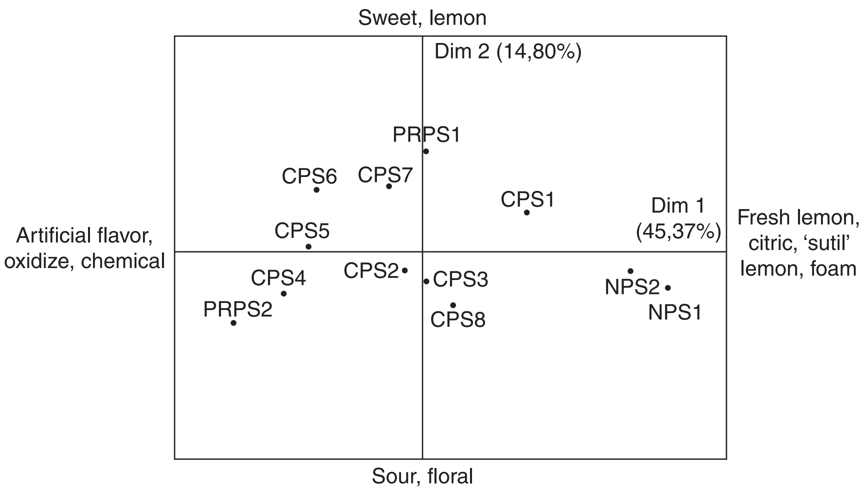

Fig. 16.3 Generalized Procrustes analysis group average, 12 products, 6 expert panelists.

Sour. These results have been useful in the design of new premium RTD, with long shelf life and properties similar to natural Pisco Sour.

16.7 Future trends

Distillation appears as a critical operation in the production of distillates that should preserve the fruity aromas coming from Muscat grapes. All the upstream efforts like viticultural practices, harvest date, crushing, maceration, white style winemaking and others can be annihilated by an improper distillation.

It is worth mentioning that the efforts of the Pisco industry have focused on obtaining a wine retaining most of the potential aromas. This has allowed a significant improvement in Pisco quality. Clearly this strategy is a necessary condition but is not sufficient. To be able to obtain in a reproducible way a range of alcohols differentiated in aromatic content, it is fundamental to understand and optimize the distillation process with the particularities of a batch multi-component system with chemical reactions similar to that of Pisco. This system is not only complex but also most of the components to be separated are in a very low concentration; something very different from studies reported in literature, dealing with binary mixtures or multi-component systems with similar concentrations.

Another aspect that needs to be faced by the Pisco industry is the need for new premium products, allowing it to better compete in international markets. From this point of view, sensory evaluation will be used to select the best raw materials and to define the 'premium profile' from the sensory point of view and to introduce a sensory definition in quality control of the process and blending.

On the other hand, the need to export Pisco to international markets, considering that local markets are stagnant, will require consumer research studies on the target markets. Defining the sensory characteristics that consumers expect in the category in which Pisco will compete is essential: white or aged brandies from *Vitis vinifera*, vodkas or RTD. Sensory consumer research should play a key role on the success of internationalization of Pisco.

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