5

Sensory Methods for Optimizing and Adding Value to Extra Virgin Olive Oil

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5.1 Introduction

It is very well known that the sensory properties of extra virgin olive oil vary widely depending on a number of factors (Servili *et al.*, 2004). Differences in genetic resources, environmental conditions, process specifications, and local know-how induce sensory differences among oils (Caporale *et al.*, 2006). As already pointed out in Chapter 1, the variety of sensory profiles is extraordinarily rich in connection with the biodiversity of the olive and the ability of producers. Hence there is the need for producers and researchers to put emphasis on variety and sensory style for differentiating brands and also on the consistency of the sensory profiles within each brand identity over time.

Most of the attention on the sensory characteristics of olive oil is currently focused on how to evaluate whether a given oil is free of defects and how extra virgin olive oil is qualified. The International Olive Council (IOC) standards for the sensory evaluation of oils represent an effective method to qualify oils in categories such as extra virgin or virgin. These standards consist in evaluating both "positive" and "negative" attributes. The latter is the category of defects that cannot be present in an extra virgin olive oil. Positive

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sensory attributes are bitterness, pungency, and fruity notes. It should be emphasized that this necessary evaluation (mandatory in the European Union) is not sufficient to describe the sensory characteristics of extra virgin olive oils (Figure 5.1). The description of the sensory characteristics of oils should be seen as a necessary step to link the world of production with the world of use and consumption. In relation to the production system, the sensory profile of an oil represents a product specification describing characteristics due to cultivar type, climatic conditions, and operational process conditions; it also represents the product specifications necessary to verify the producer's capability to control the critical factors of sensory quality and to guarantee the consistency of the sensory profile of an oil over time.

In relation to the use and consumption of oils, the sensory profile is necessary to improve the communication of the sensory style and the culinary use of a product; it is also necessary to study the sensory functionality of an oil in dish preparations and oil–food pairings and to understand and interpret consumer likes and dislikes. In other words, this information is necessary in order to promote the excellence of an oil.

The aim of this chapter is to present sensory methods and to describe sensory similarities and differences among products based on small-panel data and suitable extra virgin olive oils. Particular relevance is given to the appropriate methods used to obtain so-called perceptual maps, and included are those that are alternatives to conventional descriptive analysis. The chapter introduces dynamic methods of sensory evaluation suitable for olive oils such as Time–Intensity (TI) and Temporal Dominance Of Sensation (TDS) methods. The latter is fully described and discussed in Chapter 7.

The evaluation of sensory defects is not considered here. This evaluation, described in Chapter 4, is a preliminary step in the sensory characterization of oils (see Chapter 1). Furthermore, consumers' data are not considered here.

5.2 Perceptual maps

The use of perceptual maps is common in food and beverage development and optimization. A perceptual map is defined as a "pictorial representation that captures the relationships among a set of products" (Lawless and Heymann, 1998) and it is obtained by submitting sensory data to a variety of multivariate statistical techniques. These techniques can extract from complex data (a matrix with many products and variables) the most important information (how different the products are to each other and how much each variable contributes to the difference among samples) and present the results in a simplified picture or map in two or three dimensions that can be easily understood. Because of its characteristics, perceptual mapping is very attractive but also effective. In Figure 5.2, an example of a perceptual map is illustrated. It shows the differences and similarities among a set of oils: products that are similar to one another are positioned close together.

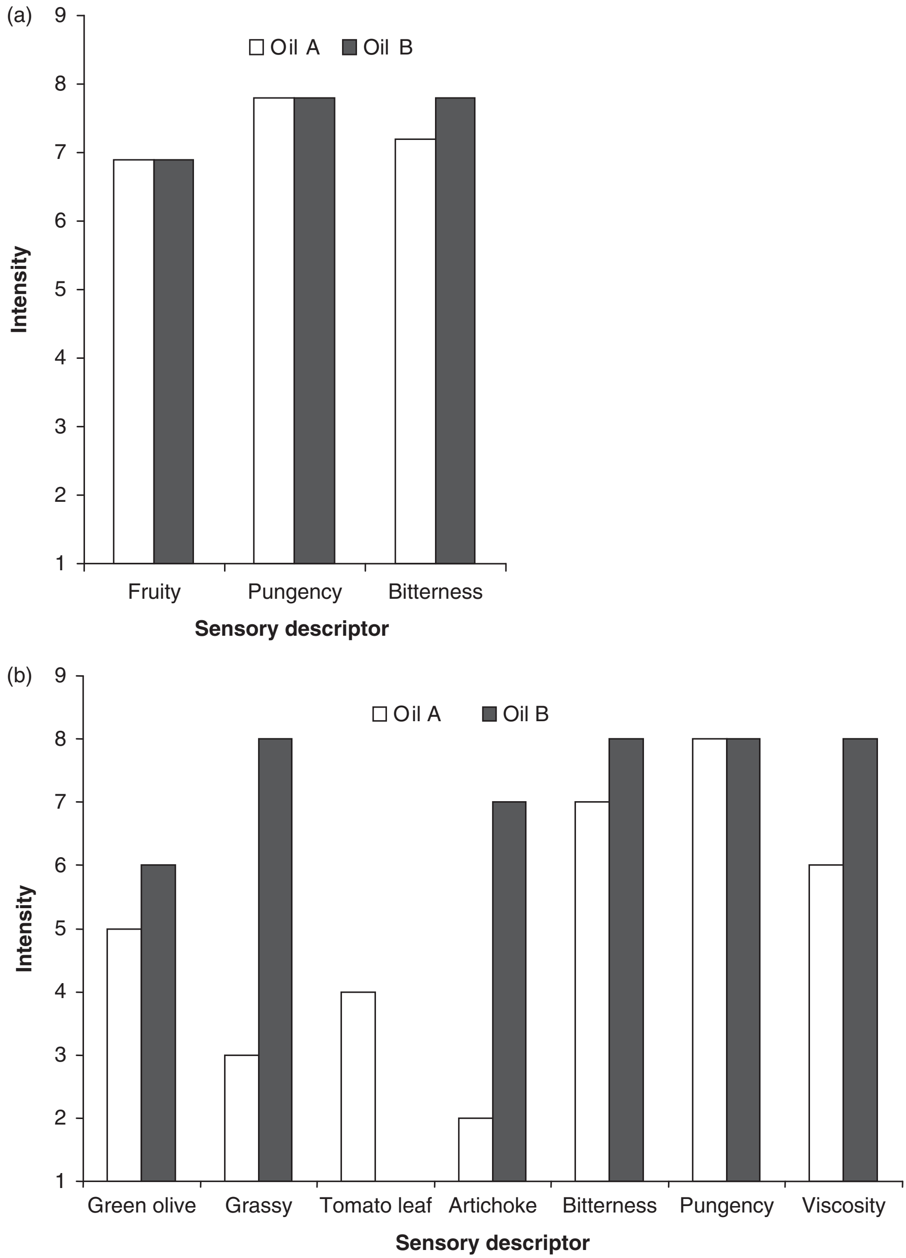


Figure 5.1 Sensory profile of two extra virgin olive oils as described by means (a) the IOC method and (b) conventional descriptive analysis. The bars in (a) indicate that the two oils are very similar whereas those in (b) clearly illustrate the differences between the oils.

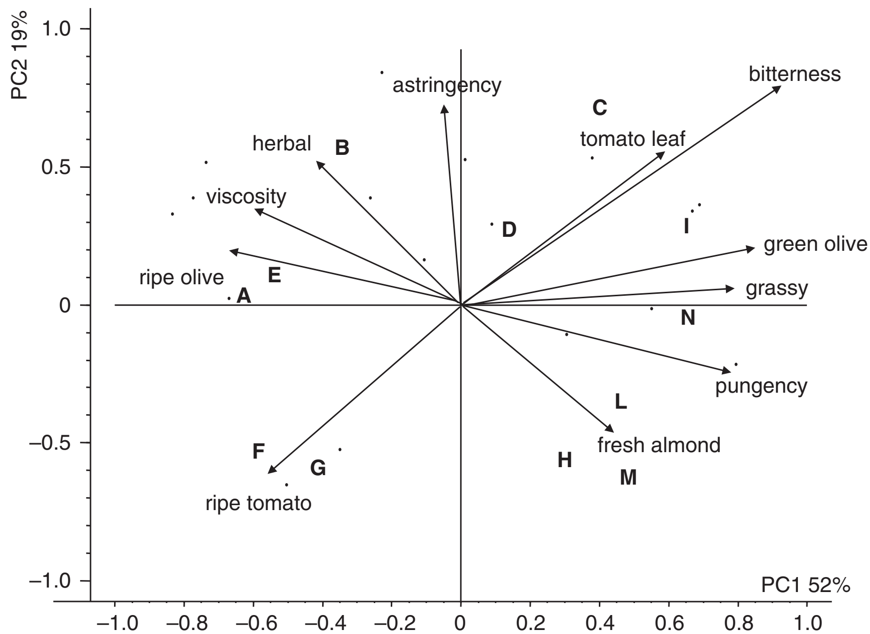


Figure 5.2 Example of a perceptual map. The graph shows the bi-plot (scores and loadings) from principal component analysis (PCA) of sensory descriptive data (11 aroma attributes) from 12 extra virgin olive oils. The first two dimensions account for 71% of the variation (52 and 19%). The first dimension, from left to right of the map, primarily discriminates samples I and N from the rest of the oils by contrasting green olive, grassy, bitterness, and pungency attributes with ripe olive and viscosity attributes. Visual inspection of the second dimension, from the bottom to the top of the map, indicates that oil C differs from samples H, L, and M by contrasting tomato leaf and astringency with fresh almond. Furthermore, the second dimension discriminates samples F and G from A, E, and B by contrasting ripe tomato note to astringency and herbal attributes.

Furthermore, vectors corresponding to important attributes are projected to interpret directions through space.

It is easy to understand that perceptual maps can be useful for many purposes in product optimization and development. They can be used in an early phase of investigation as an explorative tool in order to provide an overview. They can also be used to generate hypotheses and ideas for further experimentations (Næs, Brockhoff, and Tomic, 2010) and to confirm previous hypotheses. Visual inspection of perceptual maps permits the identification and grouping of samples with similar characteristics that at the same time are different from other samples or sample groups. Because of its characteristics, perceptual mapping is very effective in identifying oils with varied sensory styles. The term "style" does not indicate a quality model, but rather the sensory profile that describes an oil (or a group of oils) as different from others.

Table 5.1 Sensory methods applied in laboratory small-panel studies to obtain a perceptual map.

Sensory response	Sensory method	Statistical method
Descriptive data	Descriptive Analysis (conventional profile)	Principal Component Analysis (PCA)
	Temporal Dominance of Sensations	
	Free Choice Profiling	Generalized Procrustes Analysis (GPA)
	Flash Analysis	
Similarity data	Sorting	Multidimensional Scaling (MDS)
	Projective Mapping or "Nappe" method	MDS; GPA; PCA; Multifactor Analysis (MFA)

Perceptual mapping is a necessary step to relate sensory properties effectively to both consumer hedonic responses (or expert quality assessments) by means of preference mapping and the physico-chemical characteristics of samples in multi-product studies.

In detail, by interpreting perceptual maps from small-panel studies data it is possible:

- to compare a product with its competitors;
- to show the effect of modifications on agricultural practices, olive ripening stages, extraction techniques, and oil storage conditions;
- to define desired changes of the sensory properties of a product;
- to group oils in varied sensory styles;
- to select products to study the sensory functionality of oils;
- to select products to study consumer affective responses (e.g., liking, emotions) to oils and oil–food pairings.

Perceptual maps can be obtained using different sensory methods and applying a variety of statistical analyses, as reported in Table 5.1. The table presents methods that can be applied in laboratory small-panel studies to obtain a map. Descriptive analysis is probably the most important tool in sensory analysis in describing products and differences between products; however, alternative ways of capturing sensory differences between products, such as Free Choice Profiling, Flash Analysis, Sorting and Napping, are available for specific aims and needs. In this chapter, these methods are illustrated in consideration of their use in product optimization and development of olive oils with particular reference to extra virgin olive oils.

5.3 Conventional descriptive analysis

Descriptive analysis is a term generally used to describe a sensory method by which identification, quantification, and description of sensory attributes (the so-called sensory profile) of food by human subjects are obtained (Piggott, Simpson, and Williams, 1998). Several descriptive methods are considered: the Flavor Profile (Cairncross and Sjostrom, 1950), the Texture Profile (Szczesniak, 1963), Quantitative Descriptive Analysis (Stone *et al.*, 1974), and Sensory Spectrum (Meilgaard, Civille, and Carr, 1991). However, the most widely used profile technique combines different aspects from the above mentioned methods and is generally named "conventional descriptive analysis" (see ISO, 1994; Lawless and Heymann, 1998, p. 362). Free Choice Profiling (Williams and Langron, 1984), and Flash Analysis (Sieffermann, 2000) are further descriptive techniques that are separately presented in this chapter.

Conventional descriptive analysis has been widely used to provide both qualitative and quantitative measures of food and beverage properties, including extra virgin olive oil (Bertuccioli, 1994; Lyon and Watson, 1994; Mojet and de Jong 1994; Monteleone *et al.*, 1995, 1996, 1997; Caporale *et al.* 2006; Delgado and Guinard, 2011a,b; Dinnella *et al.*, 2012). It is based on independent judgments of panelists (trained subjects) and statistical testing rather that group discussion and consensus procedures. Hence this method is capable of providing a picture of how products differ among themselves, implying a comparison among products. Several products are assessed together, and the descriptive profile of a single product is both placed in and compared with the context of other products. It is a multi-product test that uses a limited number of subjects. It requires a language development process and subjects provide an intensity rating for each descriptive term. The data are averaged across the panel and thus a statistical evaluation of results is obtained.

5.3.1 Subjects

Usually, a descriptive panel involves between 10 and 15 trained assessors, recruited according to their ability to detect differences in important product attributes. Subjects must be qualified prior to their participation. They must be users of the product class to be evaluated. Previous exposure to varied extra virgin olive oils is an important qualification. It is also important that individuals participate in a series of difference tests organized to represent a range of difficulty and to include relevant modalities (olfaction, taste, etc.).

5.3.2 Language development, subject training, and subject reproducibility

Before assessment of products, assessors participate in a series of language sessions managed by a panel leader. Generally, a new panel develops the sensory language itself. This is a consensus-building process aimed at defining the attributes that the panel utilizes to represent their perceptions. Subjects familiarize themselves with the product space and generate attributes that describe the differences among products. The way in which products are presented to the subjects may vary. For example, subjects can be exposed to the entire range of products and then be asked to write down the descriptors that describe perceived differences. The number of training sessions is dependent on the number of the products, but in general 6–10 training sessions of 1 h duration are needed. The initial list of attributes is normally reduced to achieve a list that comprehensively and accurately describes the product space: redundant and/or less cited terms are grouped on a semantic basis and/or eliminated according to the subjects' consensual decisions. To facilitate the consensus and to calibrate the subjects, reference standards are presented to the panel, discussed, and modified if necessary. Refining of descriptive terms, reference standards, and definitions continues until the panelists reach a consensus. Unlike wine or cheese, there are a limited number of scientific papers that have reported attributes generated by descriptive panels to describe the sensory properties of virgin olive oils.

Early in the 1990s, as part of a European Union research program[1], a project was undertaken on the "Sensory and Nutritional Quality of Virgin Olive Oil." A key objective of the project was to establish a standardized terminology for describing virgin olive oils. Sensory characteristics of samples from different countries (Italy, Spain, and Greece), different varieties (Moraiolo, Coratina, Frantoio, Coroneiki, Tzunnati, Picual, and Arbequina), varied olive ripeness levels (unripe, ripe, and over-ripe) and varied extraction technologies (centrifugation, expression, and percolation) were described by three descriptive panels from Italy, the United Kingdom, and The Netherlands by using the descriptive analysis technique. The main results of the study in terms of a sensory vocabulary used to describe virgin olive oils were reported by Lyon and Watson (1994) and Mojet and de Jong (1994). The number of sensory descriptors generated varied considerably, with 26 British attributes, 68 Dutch attributes, and 18 Italian attributes (Table 5.2). Superficially, some of the terms were fairly similar but a number of the terms were panel specific. Differences in language, culture, and food experience affect the way in which samples are described. Nevertheless, the results of the study indicated that oil samples were perceived in a similar way, irrespective of the panel or country that analyzed the oils.

Figure 5.3 reports the perceptual map resulting from a Generalized Procrustes Analysis (GPA) applied on the sensory mean panel data from each panel (Lyon and Watson, 1994). For each sample, the triangles represent the different positioning for each panel. The smaller the triangles, the more similar is the perception of the samples between the countries. It can be noted

[1] EC FLAIR Research Program 1991: The Study of Sensory and Nutritional Quality of Virgin Olive Oil in Relation to Variety, Ripeness, and Extraction Technology.

Table 5.2 Sensory descriptors generated by three panels [Italian (IT), British (UK), and Dutch (NL) evaluating the same extra virgin olive oils.

Sensory dimension	Panel	Descriptors				
Appearance	IT	Yellow	Green			
	UK	Depth	Bright	Yellow	Green	Brown
	NL	Yellow particles	Green syrup	Brown	Glossy	Transparent
Mouthfeel	IT	Astringent				
	UK	Thickness	Throatcatching			
	NL	Velvet	Sticky	Astringent	Cooling	Rough
		Dry	Sharp	Pungent		
Flavor	IT	Tomato leaf	Green olive	Ripe black olive	Grassy	Artichoke
		Apple	Yeast	Bitter	Pungent	
	UK	Grassy	Almond	Banana	Pungent	Tomato
		Hay	Perfume			
	NL	Sea breeze	Prickly	Apple	Twig	Harshy
		Dry wood	Lemon	Orange	Soft fruit	Candies
		Wild flowers	Ferment	Farm	Salad oil	Tallow
		Rancid	Cod liver	Nuts	Medicine	Earthy
		Sweet	Salty	Sour vinegar	Olives	Green leaf
		Grass	Green banana	Herbs	Green pepper	Chilli pepper
		Butter	Rancid	Coconuts	caramel	grotty
		Roasted	Ashtray	Envelope glue	Refinery	Metallic
		Bitter	Green	Fruity	Putty	Dusty

Source: Reproduced from Lyon, D.H., and Watson, M.P. (1994) with kind permission from Grasas Y Aceites.

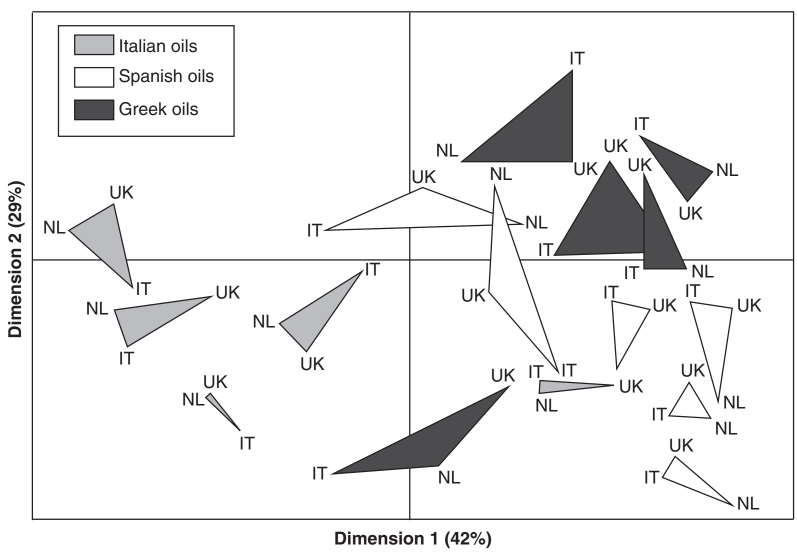


Figure 5.3 Results from the EC FLAIR Research Program 1991: The Study of Sensory and Nutritional Quality of Virgin Olive Oil in Relation to Variety, Ripeness and Extraction Technology". Consensus map resulting from a Generalized Procrustes Analysis (GPA) applied on the sensory mean panel data from the Italian (IT), British (UK) and Dutch (NL) panels. *Source:* Reproduced from Lyon, D.H., and Watson, M.P. (1994) with kind permission from Grasas Y Aceites.

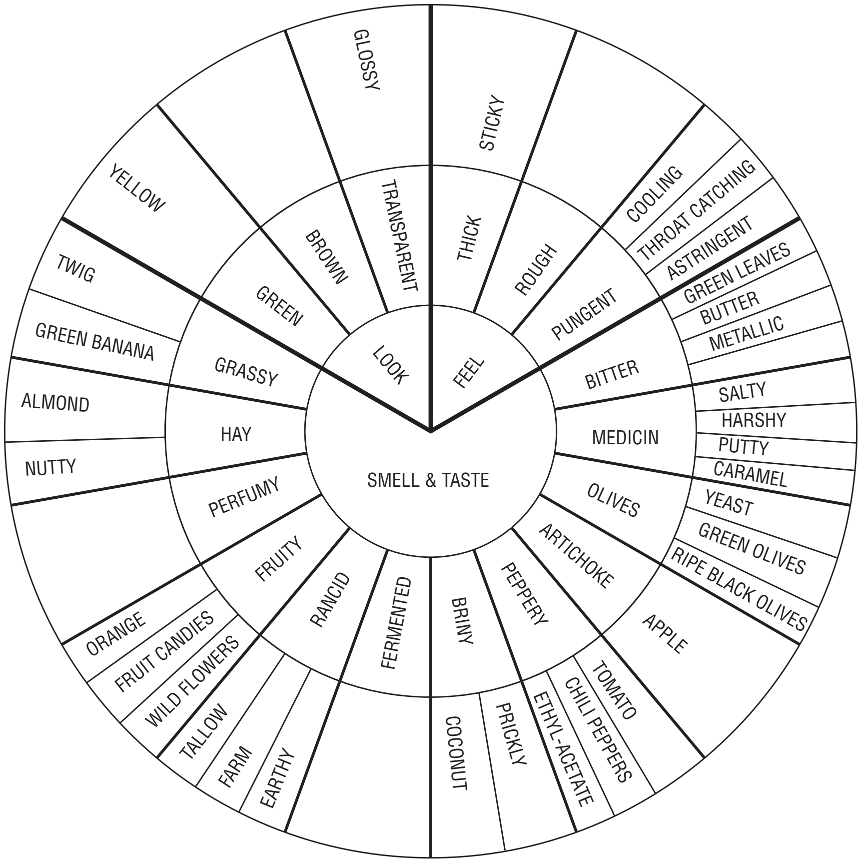


Figure 5.4 The sensory wheel of virgin olive oil. *Source:* Reproduced from Mojet, J., and de Jong, S. (1994) with kind permission from Grasas Y Aceites.

that samples from each country are in a similar area of the plot. Based on this evidence, Mojet and de Jong (1994) studied the correlations between the attributes evaluated by the three panels and generated the first Sensory Wheel of Virgin Olive Oil (Figure 5.4). Using the central attributes from the wheel, they proposed a score form for profiling virgin olive oils.

Further contributions to the sensory description of extra virgin olive can be found in Monteleone *et al.* (1997), Caporale, Policastro, and Monteleone (2004), Gawel (2007), Delagdo and Guinard (2011b), Dinnella *et al.*, (2012) and Recchia, Monteleone, and Tuorila (2012). Table 5.3 reports the terms used to describe the sensory characteristics of extra virgin olive oils according to three key papers: Mojet and de Jong (1994), Delagdo and Guinard (2011b), and Monteleone *et al.* (2012). These papers were selected for two main reasons: (a) descriptive studies were carried out in different countries and in qualified research sensory laboratories and (b) descriptive terms were generated to profile oils with varied origins (country and variety). It can be

Table 5.3 List of sensory descriptors of extra virgin olive oils as reported in three key papers from 1994 to 2012. Descriptors of defects or off-flavors are not reported.

	Ref.		
Descriptor	Mojet and de Jong (1994)	Delagdo and Guinard (2011b)	Monteleone *et al.* (2012)
Grassy	+	+	+
Green fruit (green olives, green banana; green apple)	+	+	+
Ripe fruit (olives, banana, apple)	+	+	+
Tropical fruit	–	+	–
Hay	+	–	–
Tea	–	+	–
Tomato leaf	+	+	+
Tomato fruit	+	–	+
Herbs	–	+	–
Citrus	–	+	+
Floral	+	+	–
Spicy	–	+	–
Nutty	+	+	–
Butter	–	–	–
Mint	–	–	–
Perfume	+	–	–
Almond	+	+	+
Briny	+	–	–
Artichoke	+	–	+
Bitter	+	+	+
Thick	+	+	+
Rough	+	–	–
Pungent	+	+	+
Peppery	+	+	+
Astringent	+	+	+

Source: Adapted from Mojet, J., and de Jong, S. (1994) with kind permission from Grasas Y Aceites; Delgado, C., and Guinard, J. (2011b) with kind permission from Wiley; and Monteleone, E., Bendini, A., Dinnella, C., Gallina Toschi, T., Giomo, A., Migliorini, M., Pagliarini, E., Recchia, A. (2012) with kind permission from Società Italiana di Scienze Sensoriali.

noted that there are several descriptors that are recurrent across the three considered papers. Hence a new panel may adopt an already existing terminology. In that case, if the descriptive vocabulary was developed by another laboratory or in a different country or region, difficulties in understanding and interpreting the terms could arise. This problem could be bypassed by providing full definitions and standards to panelists (Hunter and McEwan, 1998).

Table 5.4 and Table 5.5 report examples of descriptive terms and their relative definitions and standards as reported in Delagdo and Guinard (2011b) and Monteleone *et al.* (2012). During language development, subjects practice scoring products in order to familiarize themselves with products and

Table 5.4 Vocabulary and references used in the descriptive analysis of 23 extra virgin olive oils varying in origin (country and variety).

Descriptive term	Definition	Reference[a]
Grassy	Fresh cut grass	1 drop of *cis*-3-hexen-1-ol (courtesy of Robertet Flavors, Mexico) in 200 ml of Carapelli Extra Light Olive Oil
Green fruit	Unripe fruit (green olive, banana, green, apple, etc.)	Verbal description
Ripe fruit	Ripe fruit (olives, apple, banana, berries, etc.), "sweet aroma"	Verbal description
Tropical fruit	Aroma of pineapple, guava, lychee, mango, etc.	100% Spanish EVOO from Wholefoods
Green tomato	Aroma of green tomato/tomato leaves and tomato seeds	1492 EVOOs
Tea	Aroma of green tea	Bigelow Green Tea (8 bags/5 g per 4 bags) in 100 ml of Carapelli Extra Light Olive Oil
Herbs	Fresh herbs (e.g., rosemary, basil, oregano)	Basil: 10 g of fresh basil in a coffee filter bag in 150 ml of Carapelli Extra Light Olive Oil Rosemary: 10 g of fresh rosemary in a coffee filter bag in 150 ml of Carapelli Extra Light Olive Oil
Citrus	Lemon aroma	Bartolini Lemon Oil EVOO flavored with lemon (product of Italy)
Floral	Flowers aroma	1 g of Miracle by Lancome Solid Fragrance in 100 ml of Carapelli Extra Light Olive Oil
Nutty	Almonds, pecans, walnuts, etc.	Pecans: 28 g of pecans in a coffee filter bag in 150 ml of Carapelli Extra Light Olive Oil Almond: Sweet Almond Oil International Collection
Butter	Aroma of butter	Fresh butter bar, Imperial Butter from Unilever
Spicy	Spices, e.g., pepper/"pungent" smell	Verbal description
Mint	Mint/eucalyptus aroma	1 drop of artificial flavor (courtesy of Robertet Flavors, Mexico) in 100 ml of Carapelli Extra Light Olive Oil
Bitter	Bitter taste	Caffeine (0.7 g/l), Fisher Scientific
Pungent	Trigeminal sensation/chemical irritation	Capsaicin (0.08m g/l), Fisher Scientific
Thick	Thin–thick	Verbal description
Astringent	Dryness in the mouth	Tannic acid (1.1 g/l), Sigma-Aldrich

[a]Fresh ingredients were weighed over a coffee filter bag, sealed, stapled, and dipped into the oil. The standards were prepared at least 3–4 days in advance to let the oil absorb the aromas of the ingredient.
EVOO, extra virgin olive oil.
Source: Reproduced from Delgado, C., and Guinard, J. (2011b) with kind permission from Wiley.

Table 5.5 Vocabulary and references used in descriptive analysis of extra virgin olive oils varying by origin (country and variety).

Descriptive term	Definition	Reference[a]
Green olive	Odor associated with freshly milled green olives	100 g of olive paste from fresh green olives in 100 ml of seed oil. The standard should be presented to the panelists within 60 min of the preparation
Ripe olive	Odor associated with black (ripe) olives malaxed for 30 min	Olive pastes from black (ripe) olives malaxed for 30 min
Grassy	Odor associated with fresh cut grass	14 μl of *cis*-3-hexen-1-ol in 100 ml of seed oil. The standard should be presented to the panelists within 4 h of the preparation
Tomato fruit	Aroma of ripe tomato	100 g of fresh and ripe "pachito" cherries in 100 ml of seed oil. The standard should be presented to the panelists within 60 min of the preparation
Tomato leaf	Aroma of tomato leaves	Fresh tomato leaves
Apple	Aroma of Golden apple	20 g of skin and 20 g of pulp from a ripe Golden apple in 100 ml of seed oil. The standard should be presented to the panelists within 60 min of the preparation
Citrus	Aroma of lemon/orange	2 g of lemon skin and 2 g of orange skin in 100 ml of seed oil. The standard should be presented to the panelists within 60 min from the preparation
Artichoke	Aroma of artichoke	12 g of artichoke heads in 100 ml of seed oil. The standard should be presented to the panelists within 60 min. of the preparation
Astringency	Dryness in the mouth	Aqueous solution of aluminum potassium sulfate (0.3 g/l)
Bitterness	Bitter taste	Water–oil emulsions of quinine dihydrochloride solutions (intensities from weak to strong 50, 100, and 200 ppm). The model oil should be prepared by using an odorless and tasteless food-grade seed oil and a food-grade water–oil emulsifier
Pungency	Leaving a burning sensation in the back of the throat	Verbal description
Viscosity	Thin–thick	Verbal description

[a]Odorless and tasteless food-grade seed oil is used to prepare references in oil.
Source: Adapted from Monteleone, E., Bendini, A., Dinnella, C., Gallina Toschi, T., Giomo, A., Migliorini, M., Pagliarini, E., Recchia, A. (2012) with kind permission from Società Italiana di Scienze Sensoriali.

the scale rating system. Different scaling methods are used by different researchers, and their efficiency seems to be similar. The unstructured, 10 cm linear scale anchored "not perceived" at the left end and "very intense" at the right end (other anchors are frequently used) is very common, but 9-point category and 15-point unlabeled box scales are also used.

In conventional descriptive analysis, it is important to determine assessor reproducibility. Normally, panel performance is evaluated at the end of the training period by having the panel evaluate, in triplicate, a subset of samples to be used for the real study. Data are frequently analyzed for each attribute by means of a two-way (sample and assessor) or three-way (sample, assessor, replication) analysis of variance (ANOVA) to determine whether there are significant assessor–sample interactions. The significant effect of this interaction implies that the panel leader will determine which assessor should be further trained in the use of which attribute. The need for solid and validated information from sensory data in decision-making processes is extremely clear to sensory scientists. It is not the case that user-friendly statistical tools for validating panel performance are now available for free. Panel Check software developed at Nofima (Norway) allows the panel leader to control the quality of sensory profile data using both univariate and multivariate approaches (Næs, Brockhoff and Tomic, 2010). The software provides a series of graphs for quick visual inspection of data:

- mean and standard deviation and box plot for all assessors for each attribute;
- line plot showing the panel average;
- individual scores for all assessor for each product.

The *F*-values of either two or three-way ANOVA associated with sample, assessor, and their two-way interaction effects are plotted in different colors depending on the significance level, allowing for the rapid detection of significant effects. Furthermore, the comparison of assessors' ability to detect differences among products for each attribute can be checked using the p-MSE plot. The plot allows the analyst easily to detect subjects able to discriminate between samples and, at the same time, able to reproduce their own scores reliably. Finally, the software permits an overall assessment of assessor differences using all variables simultaneously by means a methodology referred to as Tucker1. This is a multivariate method (consensus principal component analysis) able to detect assessors who differ from the rest and attributes that are affected by poorly performing assessors.

5.3.3 Experimental design

The sample evaluation in descriptive analysis is run after defining an appropriate experimental design. This term indicates a series of experimental procedures that have been developed to provide as much information as possible in the most efficient way. A design can be defined only after the aim and the unique properties of the experiment have been stated. In descriptive analysis, the objective is to collect a sensory profile of a heterogeneous group of treatments (products) using a defined number of assessors and replicates. In general, the design should take into account assessor variation, presentation order effect, first-order and carryover effects, and any specific limitation associated with samples and assessors (Piggott, Simpson, and Williams, 1998).

It is possible to say that when planning a profile study there are two important aspects to consider: the first is the initial choice of products (Næs, Brockhoff and Tomic, 2010). It is important to select products carefully. When the objective is to compare a product with similar products on the market, products that span the entire variation in the study must be included. Some sensory methods applied to obtain perceptual maps (e.g., Free Choice Profile, Flash Analysis, and Projective Map) can be very helpful for this purpose.

As already stated, before running a descriptive analysis, samples should be evaluated to test the absence of defects. The second important aspect of an experimental design is how to present the samples to panelists. In sensory olive oil research, the use of a complete design with replicates involving three factors, sample, replicate, and assessors, is extremely frequent. Randomization is a key principle in experimental design. A proper randomization ensures that the effect of extraneous factors is averaged out in the long run. The presentation order represents a source of variation of sensory data in themselves and a balanced design for first-order and carryover effects is needed. This can be obtained by adopting modified Latin-square designs reported by MacFie *et al.* (1989). Software for collecting sensory data and running tests normally allow the experimenter easily to design the presentation order with respect to this important requirement. In descriptive analysis, each assessor is asked to replicate the evaluation of samples. The number of replicates depends on the size of the differences that the experimenter is required to detect. Small expected differences require a higher number of replicates. However, the number of replicates in olive oil sensory studies is frequently in the range 2–4 with 10–12 panelists involved in the test.

5.3.4 Sensory procedure

Bitterness, astringency, pungency, and peppery are common descriptors of extra virgin olive oils due to their phenol content and profile. These sensations tend to persist for a fairly long time after swallowing, showing a clear after-effect that can vary strongly among olive oils in intensity and duration and might affect consumer acceptance (Esti *et al.* 2009; Caporale *et al.*, 2006). Hence they are important sensory characteristics of oils. In a study that explored the dynamic perception of bitterness and pungency by time–intensity measurements (Sinesio, Moneta, and Esti, 2005), the attribute variation over time showed that each sensation acts according to a regular temporal sequence. The difference between the two attribute maxima, of ~10 s (in the order bitterness and pungency) is independent of the intensity. In agreement with these observations, Dinnella *et al.* (2012) showed that the dynamic changes of sensory dominances when tasting oils for 90 s follow the temporal sequence bitterness, pungency, astringency.

A good procedure to describe the sensory characteristics of olive oils should consider the main sensory properties of oils in relation to the following points:

- Conditions of constant stimulation determine a decrease in responsiveness to bitterness (adaptation).
- Astringency is a tactile sensation perceived as a diffuse stimulus in the mouth and commonly described as a puckering, roughening, and drying of the oral surface (Lee and Lawless, 1991). The perceived intensity of an astringent stimulus increases with repeated ingestion (Lyman and Green, 1990). Because of this well-known carryover effect, the evaluation of astringent products such as olive oil with a very high phenolic content cannot be made using a typical side-by-side comparison (Lesschave and Noble, 2005).
- Pungency and peppery are burning sensations and in general have a long-lasting nature. They are defined as chemesthetic sensations (chemical responsiveness mediated by trigeminal nerves). When the rest period between the evaluation of samples is omitted (or it is too short), the perceived strength of these sensations continues to build to higher levels.

Considering all these aspects, it seems appropriate to suggest the sensory procedure for profiling extra virgin oils described by Monteleone *et al.* (2012). Panelists are presented with up to four samples per session (served monadically). Each sample, identified by a three-digit code, is placed in a 100 ml amber-glass vessel containing 30 ml of oil, covered with a plastic Petri dish. The presentation order of samples should be balanced for first-order and carryover effects. Following the presentation order, subjects are asked to smell a sample and score the intensity of aroma (odor by nose) descriptors. Then they are asked to pour part of the sample into a teaspoon (around 3.5 ml), take it into their mouth and rate the perceived viscosity. Panelists are instructed to hold the sample in their mouth for up to 8 s. spit it out, and, after a further 12 s, rate the perceived intensity of bitterness, pungency, and astringency. Finally, subjects are asked again to pour the sample into a teaspoon, take it into the mouth, and rate the intensity of odors perceived retronasally. Specific rinsing procedures between the evaluation of two samples are required to control possible carryover effects. For this purpose, after each sample, subjects can be instructed to rinse their mouths with distilled water for 30 s, chew some plain crackers (or plain unsalted white bread) for 30 s, and finally rinse their mouths with water for a further 30 s. Tests should be conducted in isolated booths, under red light (in order to limit visual bias). Scores are frequently recorded directly on a computer system using dedicated software. When more than four samples are evaluated, it is possible to run more than two sessions per day. However, a break of at least 1 h between each session is recommended. In these cases, the presentation order of samples should be balanced within each replicate rather than each session.

Other general rules are recommended. Before the evaluation, oils should be kept at a temperature ranging from 14 to 15 °C in containers of made inert materials and impermeable to light, and closed tightly. The presence of air in the headspace of storage containers should be avoided. Oils should be presented at room temperature (around 25 °C). Oils should be evaluated within 20 min of the sample preparation.

5.3.5 Data analysis

ANOVA is the most common statistical method used to test the significance of effects included in descriptive analysis experimental designs. As reported above, a three-way ANOVA, involving sample, assessor, and repetition as fixed factors and all first-order interactions, is frequently computed for each attribute in order to evaluate panel performance. When replicate and interaction effects are not significant for the tested attributes, the panel is assumed to have performed well and the data are analyzed in order to study similarities and differences between products. Spider-plots are used to represent the sensory profile of each sample using the mean (over assessors and replicates) intensity score.

In product development studies, mixed ANOVA models are often computed before submitting sensory data to a multivariate analysis in order to obtain a perceptual map. Two-way mixed models are used to test the importance of sensory attributes (sample effect) considering assessors at random. In these cases, Næs, Brockhoff and Tomic (2010) suggested checking for interaction effects in order to obtain a complete overview of differences between products. Nonsignificant sample effects identify unimportant attributes in discriminating between products. These attributes are not used in perceptual mapping.

Principal component analysis (PCA) is a very well-known multivariate statistical method and probably the most commonly applied approach to obtain a perceptual map from descriptive data (Martens and Martens, 2001). For this purpose, PCA models are computed on the product-by-attribute matrix, after having averaged out both replicates and assessors. The method is based on the computation of the most interesting directions of variability, called principal components. The main results are presented graphically in a score plot, which describes the relations between the products, and a loading plot, which describes the relations between the sensory attributes and the principal components. Martens and Martens (2001) proposed a modification of the loading plot that can facilitate the interpretation of the importance of variables in discriminating between products, particularly when the PCA model relies on nonstandardized sensory data, namely a correlation loading plot. This is a two-dimensional scatter plot of correlations between the principal components and the variables themselves. The advantage of this plot is that the researcher can directly obtain information about how much each variable is explained by each component. Moreover, the correlation plot also provides the possibility of drawing circles in the plot corresponding to various degrees of explained variances. Typically, circles for 100% explained variance and for 50% explained variance for the two components are drawn. Furthermore, in order to improve the visual interpretation of the correlation plot, samples can be included as dummy (down-weighted) variables in the data matrix (Martens and Martens, 2001). The graphical interpretation of the plots follows simple rules (Næs, Brockhoff and Tomic, 2010):

- Products which are close to each other have similar overall properties and samples which are far apart are very different.
- Attributes which are close are strongly and positively correlated, whereas those on opposite sides of the origin have a negative correlation.
- Products to the left of the score plot are characterized by attributes to the left in the loading plot, and products to the top of the score plot are characterized by attributes to the top in the loading plot, etc.
- The higher the explained variance, the more valid is the information obtained from the perceptual map.

In PCA models, each component describes as much variance as possible and each new component is orthogonal to the previous one. The explained variance is largest for the first component, next largest for the second component, and so on. The problem is, how many components can be looked at safely? Often, two or three components are computed in order to explain a substantial amount of variance in the data, but even for a small number of components there is the interest in evaluating how reliable the components are. Cross-validation is frequently used to test the goodness of PCA models. The procedure computes an explained "validation" variance for each component. The explained validation variance can be plotted as a function of the number of components. The point where the curve flattens out and becomes stable is where one should stop interpreting components.

Figure 5.5 presents examples of all the plots mentioned above.

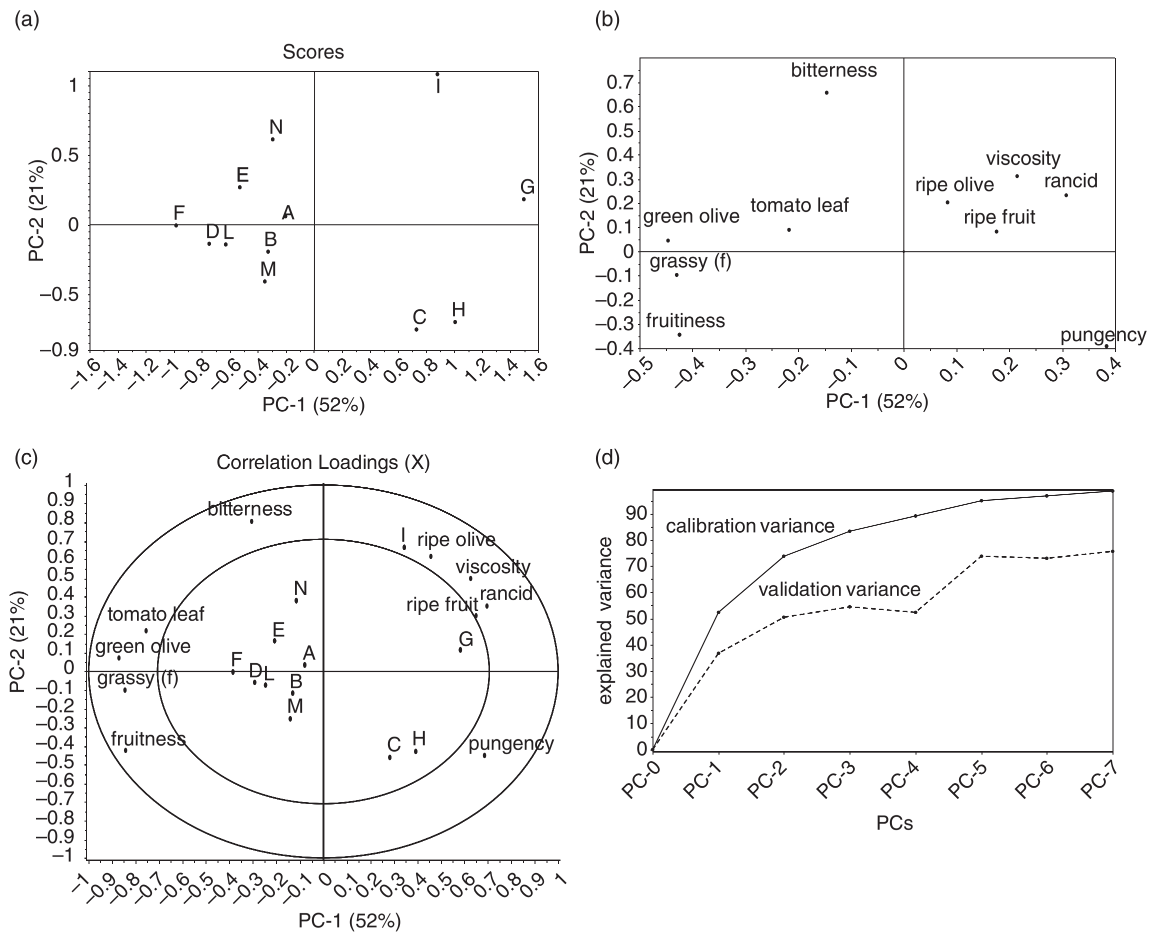


Figure 5.5 PCA of descriptive sensory data: 11 virgin olive oils and 10 attributes. (a) Score plot, which gives information about patterns in the samples; (b) loading plot. which shows which variables are important and which variables correlate; (c) correlation loading plot, where the importance of individual variables is visualized more clearly than in the standard loading plot; (d) explained variance plot, which gives an indication of how much of the variation in the data is described by the different components.

5.4 Alternative descriptive methods to conventional descriptive analysis

Alternative and complementary methods to conventional descriptive analysis are often used to evaluate a set of products, providing quick access to a relative sensory positioning of a set of products. The best use of these tools is for rapid analyses. Free Choice Profiling (FCP) and Flash Analysis (FA) are the two methods reported here. These methods differ from conventional descriptive analysis in the following characteristics:

- Each panelist creates their own list of descriptive terms: panelists are not extensively trained to create a consensus vocabulary for the product.
- The data set obtained from these methods requires a specific statistical procedure to be analyzed in order to obtain a perceptual map: the Procrustes Analysis.

In product development, these methods can be seen as convenient sensory mapping tools for conducting the preliminary phases of sensory studies. In fact, they may provide a general overview of the sensory differences between products, allowing the researcher to select samples that span the entire sensory space. Selected samples can be further studied by mean conventional descriptive analysis and in consumer studies. FCP and FA are also particularly useful when only a one-shot evaluation is possible. They can also be used for conducting the preliminary phases of the language development step in conventional descriptive analysis.

5.4.1 Free Choice Profiling

FCP (Williams and Langron, 1984) is a descriptive technique in which each assessor produces individual profiles of the products, using his or her own terms for describing products. The spatial configurations derived from individual profiles are analyzed by Generalized Procrustes Analysis (GPA), resulting in a consensus configuration (a perceptual map) revealing the interrelationships between the samples for the panel as a whole. In sensory food studies, the method has been largely used with product experts, sensory evaluation experts who have previously participated in several descriptive evaluations, and consumers (Jack and Piggott, 1991–1992). In olive oil studies, FCP has barely been applied. Guerrero, Romero, and Tous (2011) proposed the method in order to explore the information contained in the generic descriptors (such as fruity) of the official sensory profile of virgin olive oil. However, its use can be appropriate in many steps of olive oil product optimization and development. In presenting this method, we do not consider its consumer application.

In FCP, panelists are allowed to term the sensations they perceive and rate them on a scale. Some panelists may use very few descriptors and others may use many. This technique can be applied for many purposes of perceptual mapping, particularly for explorative purposes when a representation of differences between products is required in a short amount of time. For instance, it can be used to check immediately how much and why a new product differs from its competitors or regular products. In this case, its application is suggested with panels composed of either product experts or subjects who have previously participated in several descriptive analyses of the olive oils. It should be recalled that FCP shows the main differences among samples and makes it possible to interpret them, but it does not indicate the stable differences among products that are often very important to product developers (Lawless and Heymann, 1998).

Data from FCP are treated by means GPA (Gower, 1975). This procedure allows one to obtain a consensus space from individual spatial configurations (one for each panelist for each replication) by means of three steps: translation, scaling, and rotation. These steps produce a perceptual space for each panelist which is matched as closely as possible with other panelists (Piggott and Watson, 1992). Then, the consensus map is calculated as an average configuration for all panelists. This is usually simplified as a reduced dimensional plot by PCA. Thus, the consensus configuration is interpreted similarly by the PCA map. The residual errors, which mean the distances between the panelists' individual configurations and the consensus, can be used to identify outliers or groups.

Figure 5.6 shows the consensus map describing differences among 11 oils. It can be noted that oils are represented by an ellipse which is an empirical picture of the variation in the positions of the oils. If ellipses are superimposed,

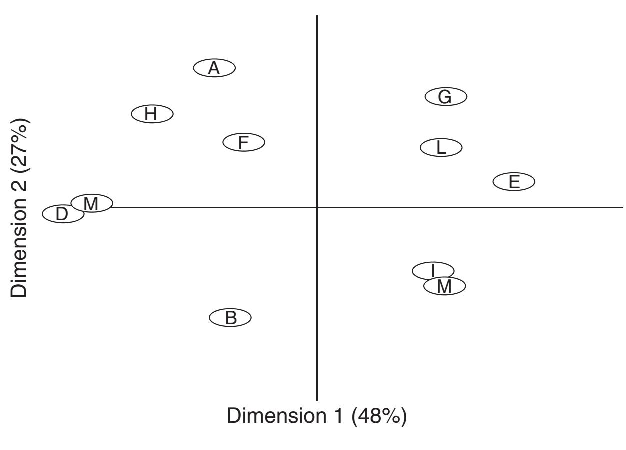


Figure 5.6 Generalized Procrustes Analysis: example of consensus plot.

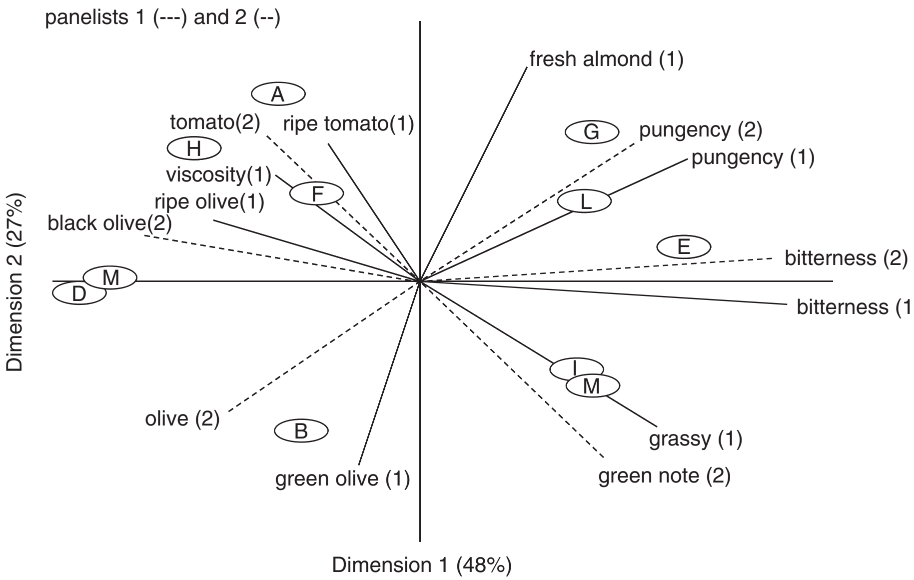


Figure 5.7 Generalized Procrustes Analysis: attribute vectors for subjects 1 and 2.

they are not significantly different. It is possible to plot the descriptors used by the panelists into the consensus space and interpret them in the same fashion as the descriptors on a PCA plot (Figure 5.7). The consensus configuration may be interpreted in terms of each individual panelist's vocabulary and the researcher can evaluate how different terms used by different subjects are related to each other.

The sensory procedure in FCP does not differ from those reported for the conventional profile. Two or three replicates should be run to verify both panelists and panel consistency. Replicate samples should plot together. When it is not possible to run replicates of the entire set of samples, duplicate samples should be included in the test and they should plot together in the consensus map. A permutation test on the data is suggested in order to estimate the statistical validity of the dimensionality of a consensus model. This procedure rearranges at random each individual's rating scores and produces new permuted data sets in which the scores no longer correspond to the products to which they were originally given. The GPA is carried out on a number of permuted data sets (e.g., 50) and the percentage of variance accounted for is computed for each permuted data set. The distribution of these values reflects the probability that a variance accounted for occurs by chance alone. A variance accounted for in the real data higher than the 95th percentile of this distribution indicates a probability of less than 5% that the consensus generated is arisen by chance.

5.4.2 Flash Analysis

Flash Analysis (FA) (Sieffermann, 2000) has strong similarities with FCP. In fact, this method is based on the combination of FCP and a comparative evaluation of the whole product set, which is presented simultaneously. It is applied with a small number of subjects who are allowed to use their own list of attributes to profile the presented products. For this reason, no panel training is needed. On the other hand, it is important to select sensory evaluation experts who have previously participated in several descriptive evaluations, even if they are not necessarily product experts. Products are presented anonymously. At the beginning of the session, subjects are provided with all the samples. They are asked to rank them (with ties allowed) along the sensory characteristics for which the samples differed. In fact, each expert produces their own attributes according to the major differences perceived among the products. Then, the panelist directly ranks products on the chosen descriptors, attribute by attribute. This forces them to focus on the perceived differences and to use discriminating attributes. The sessions are individual and could last from 40–75 min to about half a day. This is because no limitations are given regarding the number of sensory characteristics that they should evaluate, the number of retastings, or the breaks needed. As a repeatability probe, a product can be replicated in the sample set, or the whole evaluation can be replicated. All sessions can be carried out individually, on separate days, and at separate locations, provided that all samples are available. GPA is frequently applied to the data from the FA profile to assess the consensus between assessors' sensory maps (Delarue and Sieffermann, 2004). Considering the main sensory properties of extra virgin olive oils (bitterness, pungency, astringency) and that samples are directly compared with each other, it is strongly suggested that the FA method should be applied when a limited number of samples (4–5) are tested and when well-experienced assessors are recruited. The method could be of some utility when sensory differences between a few samples have to be quickly evaluated.

5.5 Perceptual maps from similarity data

Sorting and projective mapping (or "Nappe" method) are methods frequently applied to obtain representations of the differences amongst products. Because of their immediateness and ease of application, they are assumed to be useful tools in product development (Buck, 2007).

In the sorting method, subjects are asked to sort items into two or more groups: items that have something in common are placed in the same group, whereas items that differ from one another should be placed in different groups. In this method, similarity is a group-derived estimate; in fact, similarity is inferred from the number of times two items are sorted into the same group across a panel of participants. Data from the sorting task for each sample are converted into a similarity matrix by summing over all participants the number of times each pair of oils is sorted into the same group. This matrix is analyzed with multidimensional scaling to obtain a map. After completing their sorting task, subjects can be asked to give a few words or descriptors that provided the criteria on which they had based their sorting. This information is used to interpret the differences among products.

Sorting tasks have rarely been applied in olive oils studies. In a consumer study, Recchia, Monteleone, and Tuorila (2012) asked subjects to sort four samples. Research studies (unpublished data) conducted at the Sensory Laboratory of the University of Florence allowed us to suggest the use of sorting to categorize up to eight oils when working either with trained assessors or with product experts. Sorting can be usefully applied to study differences among products and to verify the correspondence of some prototypes to specific profiles. For instance, the method might be used with product experts to verify the correspondence of an oil blended from different production batches to a specific sensory style. In a sorting task, product experts use a personal criterion based on their technical knowledge. Thus results from sorting tasks depend mainly on previous knowledge of participants, that is, the level of expertise influences the categorization. It should be clear to the reader that a consensus map from a sorting test performed by experts can be very different, in terms of relative positioning of samples, from a perceptual map obtained from descriptive data. Product experts tend to discriminate samples mainly on their quality (e.g., absence of defects, balance, harmony), rather than on their specific sensory properties. Oils with different sensory profiles categorized as having similar qualities are closely positioned on the consensus map. In contrast, when the sorting task is applied with assessors specifically trained to profile oils, the resulting perceptual map describes the main differences and similarities among the products in relation to specific sensory properties. Therefore, depending on the objective of the test, assessors should be qualified on the basis of clearly defined criteria. A sorting task is usually simple and easy to perform, but there are limitations. As observed by Nestrud and Lawless (2008), one of the limitations of sorting is that it provides only grouped or aggregate data on similarity, which means that it only puts similar products into nominal level categories. Furthermore, the stability of models needs to be checked. From a practical point of view, the simplest way to check the reliability of results is to insert a blind duplicate of one of the products to see whether they plot together on the map.

Projective mapping may provide more graded information than sorting, because it is based on the individualization of similarities and differences using a graphic representation and not a nominal categorization (Pagès, 2005; Nestrud and Lawless, 2008). In fact, this is a simple user-friendly technique that allows subjects (naive consumers, trained subjects, and experts) to express perceptual similarities and groupings among a set of products by placing them on a two-dimensional surface. Subjects are simply required to place products on the surface according to the similarities and differences they perceive, so that similar products appear near to one another and different products further apart. Placing the items on a two-dimensional surface provides a potentially richer amount of information than the simple categorical information of sorting tasks: measuring the distance on the surface amongst products for each person, it is possible to calculate the greater and the smaller similarities (and differences) among products.

This method was originally developed by Risvik and colleagues as a possible alternative to profiling and (dis)similarity scaling methods to obtain perceptual maps (Risvik *et al.*, 1994). From its first application, this method has been viewed as a useful technique for the study of consumer perception. In further work by this group, the mapping dimensions from naive consumers were compared with those from the profile data. The results showed that "the best similarity was found when comparing the first dimension, thus suggesting good agreement on the obvious aspects of the product" (Risvik, McEwan, and Rodbotten, 1997).

In earlier studies, more than one multidimensional method was applied to analyze projective map data, such as MDS, GPA, and PCA. More recently, Pagès (2003, 2005) renewed the projective mapping technique, terming it the "Nappe" method (or napping). This method consists in collecting the perceived differences among products by positioning the products on a sheet of blank paper (in French the word "nappe" means "tablecloth"). The data obtained (the coordinates for each product) are treated by a multiple factor analysis (MFA).

In a further study (Morand and Pagès, 2006), results from GPA and MFA, applied to the same "nappe" data set, were compared, showing that the two approaches give very similar configurations. These findings were subsequently confirmed by Nestrud and Lawless (2008).

With "napping," it is possible to get a representation of the products that integrates the relative importance for the subjects of the characteristics of the products; however, this does not characterize the product itself. Hence the "nappe" method is presented as a complementary method and not as an alternative to descriptive analysis. As any other method applied in food sensory science, the "nappe" procedure shows some weakness, as reported in most of the papers cited above. One important issue is certainly the reliability of the results from this method: results are strongly dependent on the initial question, which needs to be attentively and consciously determined. Another issue is the real contribution of the second dimension of the maps in discriminating among samples; actually, subjects seem to discriminate on the basis of only one dimension.

When applying projective mapping, the following rules are suggested:

- Define the objective of the test, select an appropriate set of samples, and recruit qualified subjects.

- Give instructions about the principle and procedure of the method to the subjects, as outlined by Pagès (2005) and Nestrud and Lawless (2008):
  - *Principle*
    You are asked to evaluate the similarities (or dissimilarities) between several oils. You have to do this according to your own criteria, those that are significant to you. You do not have to indicate your criteria. There is no good or bad answer.
  - *Procedure*
    First, it is important to taste each sample and make any notes or comments about the sample according to your own criteria in the space provided below and on the back of the sheet. Be sure to save enough oil for three or four tastes. Cleanse your palate as needed with water and unsalted crackers. Then, after tasting all the samples, you have to position the oils on the paper in such a way that two oils are very near if they seem identical to you and that two oils are distant to one another if they seem different to you. This must be done according to your own criteria. Do not hesitate to express strongly the differences you perceive by using most of the sheet. When the operation is finished, write down on the sheet the number of the oil in the place it occupies.
  - Notes or comments about the samples can be directly plotted in the consensus map by using MFA (Pagès, 2005). Alternatively, they can be used to arrange a follow-up session to retaste the samples and rate the generated attributes (Nestrud and Lawless, 2008; Perrin *et al.* 2008).
- Run the test with a number of subjects from 15 to 20.
- Run a pilot test to check the number of products to taste. It is important to add duplicate samples in the group of examined products; it is suggested that the number of oils to be tested should be limited to eight.
- Before submitting data to multidimensional methods (GPA or MFA), a visual inspection of data is strongly suggested in order to remove unreliable subjects from the data set.

5.6 Temporal aspects of sensory characteristics of olive oils: Time–Intensity (TI) and Temporal Dominance of Sensations (TDS)

TI is a very well-known method to evaluate the temporality of the sensory perception in food products. In olive oil studies, there are few example of the application of this method. Caporale, Policastro, and Monteleone (2004) used TI to investigate the extent to which the green aroma affects the perception of bitterness in virgin olive oil and described a clear bitterness enhancement induced by a cut grass odorant. Sinesio, Moneta, and Esti (2005) applied the TI method to characterize temporal differences of bitterness and pungency perceptions in stored virgin olive oils. The aim of the study was to determine TI bitterness and pungency evolution in mono-varietal oils derived from autochthonous olive varieties and to follow their evolution in ideal and stressed storage conditions. The same group (Esti *et al.*, 2009) expanded the results from the initial study on temporal intensity variation of bitterness and pungency perception in extra virgin olive oils by exploring the relationship between bitterness and pungency intensity and its phenolic compound contents and their changes during storage due to low and stressed temperature conditions. It was shown that the TI curves for pungency showed a slower rise and decline than those of bitterness for all oil samples.

In a TI measurement, a single sensory characteristic (or occasionally two characteristics) is tracked as it changes over a period of time (Piggott, Hunter, and Margomenou, 2000). The intensity of the same sensation is measured continuously, using a computerized data collection system, and is registered at short time intervals (repeated measures data); the measurement instruments are sensory assessors. For both credibility and precision, many (eight or more) assessors are required in addition to replications. Prior to their participation in the experiment, subjects are trained in the recognition of the sensation to be tested (e.g., bitterness) through standard samples. No more than four samples per session should be evaluated. In order to minimize position bias, the presentation order of the samples within each session should be balanced among assessors. Oils, labeled with a three-digit code, are served in colored tasting glasses to mask color differences, thus eliminating the visual factor. Evaluation should take place in individual sensory testing booths under red light. A horizontal linear scale is displayed on a computer screen where 0 represents no taste and 100 denotes a very strong flavor. Assessors are instructed to take a defined amount of oil (3–5 ml) in their mouth and start the data collection. They are instructed to start rating the intensity of sensation as soon as the sample is in their mouth by moving the rating line away from the 0 position. After 10 s, the subjects are prompted by a screen signal to spit out (or swallow) the sample and to continue assessing the intensity of the evaluated sensation. The computer continues to collect data either until it registers the 0 value again or for a maximum time (around 2 min for oils). The assessors' ratings are recorded by computer every 0.5 s for 1 min. Normally assessors are asked to rinse their mouths with distilled water, eat plain crackers, and rinse again with water after each sample. A 2 min interval between each sample is suggested (Caporale, Policastro, and Monteleone, 2004). Individual TI curves from each assessor can be obtained by plotting collected intensity data as function of time.

It is also possible to obtain average curves (across assessors and replications) for each sample. Owing to the large differences between assessors, the computation of average curves is more complex than it might seem. According to Sinesio, Moneta, and Esti (2005), the application of a non-centered PCA on the row data matrix instead of arithmetic averaging over the individual allows for the representation of all the individual curves and retained information regarding the level and variability in the analysis (it does not

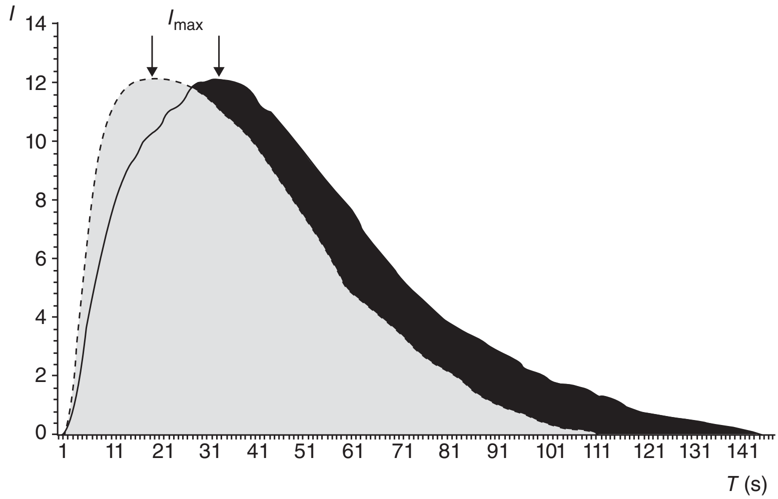


Figure 5.8 Scheme of time–intensity bitterness (- - -) and pungency (—) curves in extra virgin olive oils. *Source:* Reprinted from Esti, M., Contini, M., Moneta, E., and Sinesio, F. (2009) with kind permission from Elsevier.

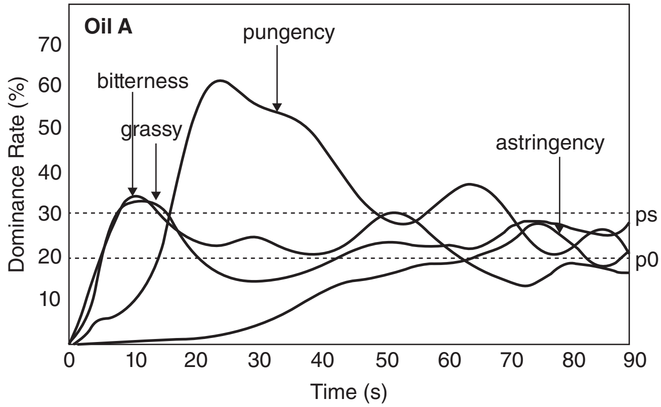
change the shape of the average curve). An example of an average TI curve referred to olive oil bitterness is shown in Figure 5.8. The most common approach in comparing TI curves between samples is the computation for each sample of a number of curve parameters. In their study on olive oils, Sinesio, Moneta, and Esti (2005) considered the following: maximum perceived intensity (I_{max}) during the time of measurement; reaction time to the stimulus, when it is first perceived after initial exposure (T_{onset}) (s); time to reach maximum intensity of the sensation (T_{max}) (s); plateau time, or duration of the maximum intensity ($T_{plateau}$) (s); extinction time, when the sensation returns to zero (T_{ext}) (s); area under the curve before maximum (A_{before}); area under the plateau ($A_{plateau}$); area under the curve after maximum (A_{after}); rate of intensity increase before Imax (slope) (V_1); and rate of intensity decrease after I_{max} (slope) (V_2). These parameters from each individual curve can be submitted to several ANOVA models considering sample, repetition, and assessor effects (Lawless and Heymann, 1998; Piggott, Hunter, and Margomenou, 2000). For instance, Sinesio, Moneta, and Esti (2005) computed a three-way ANOVA model on the above-mentioned parameters of bitterness and pungency curves to evaluate the effects of panelists, samples, and test replicates and all fixed effects. They reported that panelists were a significant source of variation for a few TI parameters. However, they underlined that this is to be expected and common in TI measurements because individuals can differ in sensitivity and use of scale, thus providing different patterns of response. However, test replicates and interactions between panelists were not significant. ANOVA with repeated measure models are frequently used to treat TI curve parameters statistically.

Although the method has been extensively and successfully used to study the temporal aspects of the perception of a given sensory attribute in a product, when it is used for several attributes it quickly becomes very time consuming because one run is needed for each attribute. This limitation was clear to Pangborn (1989), who predicted increasing sensory research activities in analyzing temporal aspects of perception. Temporal dominance of sensation (TDS) (Pineau *et al.*, 2009) is certainly the most innovative method alternative to TI.

TDS was developed as of 1999 at the Centre Européen des Sciences du Goût, in Dijon, France. It consists in presenting to the panelist the complete list of attributes on a computer screen. Thereafter, the panelist is asked to assess which of the attributes is perceived as dominant (i.e., most striking perception at a given time). During the testing of one product, the panelist is free to select an attribute several times. Conversely, another attribute may not be selected at all. In the course of the evaluation, when the panelist considers that the dominant attribute has changed, they have to select the new dominant attribute, and so on, until the perception ends. For each run, this method allows the collection of a sequence of sensory attributes quoted at different times during the tasting.

The TDS method is applied with a trained panel, which means that, as for descriptive panels, qualified subjects develop a vocabulary to describe the sensations they perceive considering the temporal evolution of the sensations. They also establish a consensual definition of each attribute and are trained in the method in itself. For the training sessions, a dominant attribute is defined as the attribute associated with the sensation catching the attention at a given time. Thus the dominant attribute is not necessarily the one with the highest intensity.

The size of a TDS panel is similar to that of descriptive panels. Sample presentation follows the same rules of descriptive analysis. In order to avoid any order effect of the list of attributes, the order of descriptors should be balanced among subjects using Williams Latin squares. The application of the method requires dedicated software for data acquisition, now commercially available. This software also allows for the analysis of the data and the creation of TDS curves for each product. The computation of TDS curves was well explained by Pineau *et al.* (2009). The procedure considers each attribute separately. For each point in time, the proportion of runs (subject × replication) for which the given attribute is assessed as dominant is computed. These proportions, smoothed using appropriate procedures, are plotted against time and are called TDS curves (Figure 5.9). On the plot it is possible to draw a line corresponding to the “chance level,” which means the dominance rate that an attribute can obtain by chance. Its value is equal to $1/p$, where p is the number of attributes. It is also possible to drawn a line corresponding to the 95% significance level.



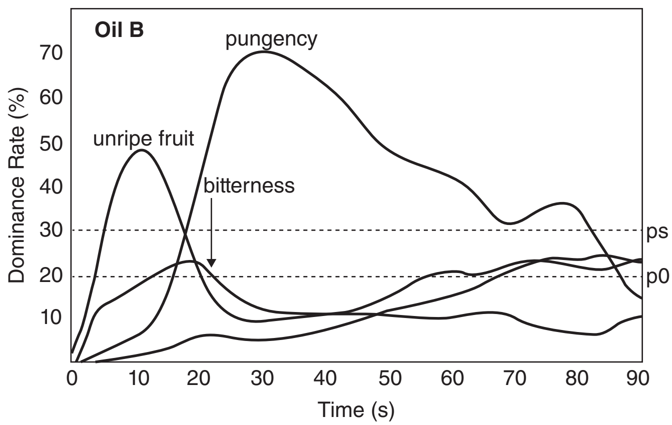


Figure 5.9 TDS curves of olive oil samples: p0 represents the chance level and ps the 95% significance level. *Source:* Reprinted from Dinnella, C., Masi, C., Zoboli, G., and Monteleone, E. (2012) with kind permission from Elsevier.

TDS seems to be more appropriate than descriptive analysis to study sensory interactions occurring when tasting food (such as suppression, release from suppression, and enhancement). For this reason, TDS seems to be a promising method also for developing new approaches in studying oil–food pairing, as demonstrated by Dinnella *et al.* (2012).

More details on TDS application and data validation are reported in Chapter 7.

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