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Sensory Analysis of Virgin Olive Oil

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1. Introduction

Virgin olive oil (VOO) is the supernatant of the fresh juice obtained from olives by crushing, pressure and centrifugation, without additional refining. Its flavour is characteristic and is markedly different from those of other edible fats and oils. The combined effect of odour (directly via the nose or indirectly through a retronasal path, via the mouth), taste and chemical responses (as pungency) gives rise to the sensation generally perceived as “flavour”.

Sensory analysis is an essential technique to characterize food and investigate consumer preferences. International cooperative studies, supported by the International Olive Oil Council (IOOC) have provided a sensory codified methodology for VOOs, known as the “COI Panel test”. Such an approach is based on the judgments of a panel of assessors, conducted by a panel leader, who has sufficient knowledge and skills to prepare sessions of sensory analysis, motivate judgement, process data, interpret results and draft the report. The panel generally consists of a group of 8 to 12 persons, selected and trained to identify and measure the intensity of the different positive and negative sensations perceived. Sensory assessment is carried out according to codified rules, in a specific tasting room, using controlled conditions to minimize external influences, using a proper tasting glass and adopting both a specific vocabulary and a profile sheet that includes positive and negative sensory attributes (Dec-23/98-V/2010). Collection of the results and statistical elaboration must be standardized (EEC Reg. 2568/91, EC Reg. 640/08). The colour of VOO, which is not significantly related to its quality, may produce expectations and interferences in the flavour perception phase. In order to eliminate any prejudices that may affect the smelling and tasting phases, panelists use a dark-coloured (blue or amber-coloured) tasting glass.

Many chemical parameters and sensory analyses (EEC Reg. 2568/91 and EC Reg. 640/08), with the latter carried out by both olfactory and gustatory assessments, can classify oils in different quality categories (extra virgin, virgin, lampant). Extra virgin olive oil (EVOO) extracted from fresh and healthy olive fruits (*Olea europaea* L.), properly processed and adequately stored, is characterized by a unique and measurable combination of aroma and taste. Moreover, the category of EVOO should not show any defects (e.g. fusty, musty, winey, metallic, rancid) that can originate from incorrect production or storage procedures.

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Positive or negative sensory descriptors of VOO have been related to volatile and phenol profiles, which are responsible for aroma and taste, respectively.

The characteristic taste of VOO, and in particular some positive attributes such as bitterness and pungency that are related to important health benefits, is not completely understood or appreciated by consumers. In this respect, it is interesting to consider the degree of acceptability of VOO in several countries based on literature data. In this way, it is possible to lay the foundations for correct instruction of the sensory characteristics of EVOO. The main chemical, biochemical and technological processes responsible for the positive and negative (defects) descriptors of VOO are summarized in this chapter. An overview on the sensory methodologies proposed, applied and modified during the last 20 years is also presented.

2. Flavours and off-flavours of virgin olive oil: The molecules responsible for sensory perceptions

VOOs are defined by the European Community as those "...oils obtained from the fruit of the olive tree solely by mechanical or other physical means under conditions that do not lead to alteration in the oil..." (EEC Reg. 2568/91). This production method renders VOO different from other vegetable oils that undergo refining, which leads to loss of most of the minor components such as volatile molecules and "polar" phenolic compounds.

Many authors (Angerosa et al., 2004; Kalua et al., 2007) have clarified that several variables affect the sensory characteristics and chemical composition of an EVOO. These include environmental factors, cultivation and agronomic techniques, genetic factors (cultivar), ripening degree of drupes, harvesting, transport and storage systems of olives, processing techniques, storage and packaging conditions of the oil.

The sensory attributes of EVOO mainly depend on the content of minor components, such as phenolic and volatile compounds. The independent odours and tastes of different volatile and phenolic compounds that contribute to various and typical EVOO flavours have been extensively studied; the sensory and chemical parameters of EVOO have been correlated in a large number of investigations (Bendini et al., 2007; Cerretani et al., 2008).

Each single component can contribute to different sensory perceptions. It is well established that specific phenolic compounds are responsible for bitterness and pungency (Andrewes et al., 2003; Gutiérrez-Rosales et al., 2003; Mateos et al., 2004). Few individuals, except for trained tasters of EVOO, know that the bitterness and pungency perceived are considered positive attributes. These two sensory characteristics, more intense in oils produced from olives at the start of crop year, are strictly related to the quali-quantitative phenolic profile of EVOO.

Even in small quantities, phenols are fundamental for protecting triacylglycerols from oxidation. Several authors (Gallina Toschi et al., 2005; Carrasco-Pancorbo et al., 2005; Bendini et al., 2006; Bendini et al., 2007) have reported their importance as antioxidants as well as nutraceutical components. The major phenolic compounds identified and quantified in olive oil belong to five different classes: phenolic acids (especially derivatives of benzoic and cinnamic acids), flavones (luteolin and apigenin), lignans ((+)-pinoresinol and (+)-

acetoxypinoresinol), phenyl-ethyl alcohols (hydroxytyrosol, tyrosol) and secoiridoids (aglycon derivatives of oleuropein and ligstroside). The latter are characteristic of EVOOs.

Several investigations (Gutiérrez-Rosales et al., 2003; Mateos et al., 2004) have demonstrated that some phenols, and in particular secoiridoid derivatives of hydroxytyrosol, are the main contributors to the bitterness of olive oil; other phenolic molecules such as decarboxymethyl-ligstroside aglycone, which seems to be a key source of the burning sensation, can stimulate the free endings of the trigeminal nerve located in the palate and gustative buds giving rise to the chemesthetic perceptions of pungency and astringency (Andrewes et al., 2003). Using a trained olive oil sensory panel, some investigators (Sinesio et al., 2005) have studied the temporal perception of bitterness and pungency with a time-intensity (TI) evaluation technique. It has been shown that the bitterness curves had a faster rate of increase and decline than the pungency curves. It was also demonstrated that differences in kinetic perception are linked to the slower signal transmission of thermal nociceptors compared to other neurons.

On the other hand, approximately 180 compounds belonging to several chemical classes (aldehydes, alcohols, esters, ketones, hydrocarbons, acids) have been separated from the volatile fractions of EVOOs of different quality. Typical flavours and off-flavour compounds that affect the volatile fraction of an oil obtained from olives originate by different mechanisms: positive odours are due to molecules that are produced enzymatically by the so-called lipoxygenase (LOX) pathway. Specifically both C₆ aldehydes, alcohols and their corresponding esters and minor amounts of C₅ carbonyl compounds, alcohols and pentene dimers are responsible for pleasant notes. In contrast, the main defects or off-flavours are due to sugar fermentation (*winey*), amino acid (leucine, isoleucine, and valine) conversion (*fusty*), enzymatic activities of moulds (*musty*) or anaerobic microorganisms (*muddy*), and to auto-oxidative processes (*rancid*).

Volatile molecules can be perceived in very small amounts (micrograms per kilogram or ppb) and these compounds do not have the same contribution to the global aroma of EVOO; in fact, their influence must be evaluated not only on the basis of concentration, but also on their sensory threshold values (Angerosa et al., 2004; Kalua et al., 2007). In addition, antagonism and/or synergism among different molecules can occur, affecting the global flavour of EVOO. Chemical factors of molecules (volatility, hydrophobic character, size, shape, conformational structure), type and position of functional groups appear to affect the odour and taste intensity more than their concentration due to their importance in establishing bonds with receptor proteins (Angerosa et al., 2004).

In general, it is correct to surmise that from healthy olives, picked at the right degree of ripening and properly processed, it is always possible to obtain an EVOO, independent of the olive variety. However, from unhealthy olives or from those harvested off the ground it is inevitable to produce an olive oil characterized by unpleasant flavours and sensory defects. Thus, both natural (olive variety, environmental conditions, degree of ripening and health status of olives) and extrinsic (technological processing by olive farmer/mill worker) factors may profoundly influence olfactory and gustative notes.

Several agronomic and climatic parameters can affect the volatile and phenolic composition of VOOs. The genetic characteristics of the olive cultivar are some of the most important

aspects that determine the level of enzymes in fruit (Angerosa et al., 1999) that are involved in synthesis of volatile molecules (LOX pathway) and phenol compounds (biosynthetic pathways via PPO and β -glucosidase) present in VOOs.

Even if enzymatic activity depends on the stage of ripeness (Morales et al., 1996; Aparicio & Morales 1998) agronomic (fertilization, irrigation) and climatic (temperature and rainfall) conditions also play an important role.

2.1 Key points in obtaining a high quality VOO

- Processing of healthy olives:

When the common olive fly (*Bactrocera oleae*) attacks olives (from the beginning of summer to the start of harvesting), damage occurs as a result of larval growth: oils from damaged fruits show changes in both volatile and phenolic compounds that influence negatively the sensory properties and oxidative stability of the product, especially during oil storage (polar phenols have a fundamental role as antioxidants during storage). The bad taste due to these changes caused by the olive fly is well known as a *grubby defect* (Angerosa et al., 1992; Gómez-Caravaca et al. 2008).

In order to obtain a high quality olive oil, it is necessary to process olives that are not overripe. The use of fruits that have partially degraded tissues cause an increase in enzymatic and microorganism activities and oxidative reactions; therefore the produced oil probably will be characterized by an higher free acidity and perceivable sensory defects. When olives are accumulated in piles for many days, the high temperature and humidity inside the mass promotes proliferation of bacteria, yeasts and moulds, producing undesirable fermentation and degradation that give rise to specific volatile molecules responsible for unpleasant odours (i.e. winey, fusty and mouldy).

Winey, the typical pungent sensory note perceptible in oils produced by olives stored in piles or in jute sacks for several days, arises from alcoholic fermentation: *Lactobacillus* and *Acetobacter* have been detected in olives inducing fermentative processes. The main microorganism found in olives depends on the length of storage: at the beginning the enterobacteriaceae genera *Aerobacter* and *Escherichia* prevail, while *Pseudomonas*, *Clostridium* and *Serratia* are predominant after longer periods of time. The activity of these microorganisms results in the presence of low concentrations of biosynthetic volatiles and large amounts of compounds such as the branched alcohols due to degradation of amino acids that lead to the typical undesirable sensory note known as fusty (Angerosa, 2002; Morales et al 2005). The most abundant deuteromycetes found in olives stored at high humidity are several species of the genus *Aspergillus* together with ascomycetes *Penicillium*; these organisms oxidize free fatty acids producing mainly methyl ketones, in contrast to yeasts of the genera *Candida*, *Saccharomyces* and *Pichia* which are able to reduce carbonylic compounds. Enzymes from these microorganisms interfere with the LOX pathway to produce volatile C_8 molecules characterized by very low odour thresholds, and reduce some C_6 compounds. This volatile profile is responsible for the musty defect of EVOO.

- Selection of the most suitable milling conditions

The phenolic content is greatly influenced by this technological step. In general, the use of the more violent crushing systems (i. e. with hammers instead of blades) causes an increase

in extraction of phenolic compounds due to more intense tissue breaking; therefore, a more vigorous milling system should be used to process olive varieties that are naturally low in phenolic compounds, and permit enrichment of bitter and pungency intensities. The use of more violent milling systems also produces a significant increase in olive paste temperature and a corresponding decrease of the activity of enzymes that play a key role in the production of volatile compounds responsible for fruity and other green notes (Salas & Sanchez, 1999; Servili et al., 2002).

Concerning the malaxation phase, which consists in a slow kneading of the olive paste, the time-temperature pair should be carefully controlled to obtain a high quality EVOO. The lipoxygenase pathway is triggered by milling of olives and is active during malaxation. The volatile compounds produced are incorporated into the oil phase to confer its characteristic aroma. Specifically, a temperature above 28°C for more than 45 min should be avoided; in fact, these conditions can lead to the deactivation of enzymes that produce both positive volatile compounds and oxidize the phenolic compounds causing changes in oil flavour (Salas & Sanchez 1999; Kalua et al., 2007). The reduced concentration of oxygen in paste, obtained by replacing air with nitrogen in the headspace of malaxer during processing, can inhibit these enzymes and minimize the oxidative degradation of phenolic compounds during processing (Servili et al., 1999; Servili et al., 2003). Malaxation under erroneous conditions is responsible for the unpleasant flavor known as a “*heated defect*” due to the formation of specific volatile compounds (Angerosa et al., 2004).

- The application of different oil separation systems

One of the main disadvantages of discontinuous mill systems is the possible fermentation and/or degradation phenomena of residues of pulp and vegetation waters on filtering diaphragms; these reactions give rise to a defect termed “*pressing mats*”, but also promote winey and fusty defects (Angerosa et al., 2004). It is well known that among continuous systems, discontinuous mill systems with a three-phase decanter need lukewarm water to dilute olive paste in contrast to a two-phase decanter, which has two exits producing oil and pomace and separates the oil phase from the olive paste. This latter system has advantages in terms of water reduction and major transfer of phenols from the olive paste to the oil, with a consequent increase in oxidative stability, bitterness and pungency.

The amount of water added determines the dilution of the aqueous phase and lowers the concentration of phenolic substances that are more soluble in vegetable waste water. Consequently, a large amount of antioxidants is lost with the wastewater during processing. In addition to phenolic compounds, some volatile compounds accumulate more in oil from a dual-phase decanter than in oils extracted with three-phase decanters. Therefore, the use of a two-phase decanter promotes greater accumulation of volatile and phenolic compounds that are not lost in the additional water as in a three phase decanter. The higher concentrations of these compounds are related to the high intensities of bitter, pungent, green fruity, freshly cut lawn, almond and tomato perceptions (Angerosa et al., 2000; Angerosa et al., 2004; Kalua et al., 2007).

- Storage of oil under suitable conditions

In unfiltered oil, the low amounts of sugars or proteins that remain for extended times in oil can be fermented or degraded by specific anaerobic microorganisms of the *Clostridium* genus,

producing volatile compounds responsible for an unpleasant muddy odour by butyric fermentation. The filtration of newly-produced oil can avoid this phenomenon. It is known (Fregapane et al., 2006; Mendez & Falque, 2007; Lozano-Sanchez et al., 2010) that EVOO has a low amount of water, and for this reason it can be considered as a water-in-oil emulsion (Koidis et al., 2008)

The orientation of phenolic compounds in the oil-water interface and the active surface of water droplets can protect against the oxidation of oil. According to some researchers (Tsimidou et al., 2004; Gómez-Caravaca et al., 2007), the stability of unfiltered samples is significantly higher than that of the corresponding filtered oils. This coincides with a higher total phenolic content in unfiltered oils due to a greater amount of emulsified water. On the other hand, higher water levels are expected to favour enzymatic catalysis, including lipase, lipoxygenase and polyphenol oxidase activities. Thus, a more rapid oxidation of unfiltered oil is expected. Some authors (Montedoro et al., 1993) observed that hydrolytic processes occur in parallel with oxidation during long term storage.

Lipid oxidation is an inevitable process that begins immediately after oil extraction and leads to a deterioration that becomes increasingly problematic during oil storage. The presence of a rancid defect, typical off-flavour for the fatty matrices, can be avoided or substantially slowed. The most advanced oxidation stages are characterized by the complete disappearance of compounds arising from the LOX cascade and by very high concentrations of saturated and unsaturated aldehydes together with unsaturated hydrocarbons, furans and ketones that contribute mainly to the rancid defect because of their low odour thresholds (Guth & Grosch, 1990; Morales et al., 1997; Bendini et al., 2009). To avoid the rancid perception, it is fundamental to control factors that promote lipid oxidation. These include a decrease in the availability of oxygen, the protection of the oil from light and storage at a temperature of 12-14°C. Before bottling, it is advisable to maintain the oil in stainless steel tanks under an inert gas such as nitrogen equipped with devices that periodically eliminate sediments from the bottom of the tank.

3. Sensory methodology for evaluating the quality of VOO: Basic concepts

A sensory codified methodology for virgin olive oils, known as the “COI Panel test”, represents the most valuable approach to evaluate the sensory characteristics of VOO. The use of statistical procedures to analyze data from assessors’ evaluation provides results that can be trusted as well as methods usually adopted in scientific fields. The purpose of this international method is to standardize procedures for assessing the organoleptic characteristics of VOO, and to establish the methodology for its classification. This methodology, incorporated into regulations of the European Union since 1991, uses, as an analysis tool, a group of 8-12 persons selected in a controlled manner, who are suitably trained to identify and measure the intensity of positive and negative sensations (EEC Reg. 2568/91).

A collection of methods and standards has been adopted by the International Olive Oil Council (IOOC or COI) for sensory analysis of olive oils. These documents (IOOC/T.20/Doc. 4/rev.1 and IOOC/T.20/Doc.15/rev.2) describe the general and specific terms that tasters use. Part of the vocabulary is common to sensory analysis of all foods (general vocabulary), while a specific vocabulary has been developed *ad hoc* and established by sensory

experts of IOOC. In addition, the official method (IOOC/T.20/Doc.5/rev.1 and IOOC/T.20/Doc.14/rev.2) includes precise recording of the correct tasting temperature, as well as the dimensions and colour of the tasting glass and characteristics of the test room.

The panel leader is the person responsible for selecting, training and monitoring tasters to ascertain their level of aptitude according to (IOOC/T.20/Doc.14/rev.2). The number of candidates is generally greater than that needed in order to select people that have a greater sensitivity and discrimination capability. Screening criteria of candidates are founded on sensory capacity, but also on some personal characteristics of candidates. Given this, the panel leader will personally interview a large number of candidates to become familiar with their personality and understand habits, hobbies, and interest in the food field. He uses this information to screen candidates and rejects those who show little interest, are not readily available or who are incapable of expressing themselves clearly.

The determination of the detection threshold of the group of candidates for characteristic attributes is necessary because the "threshold concentration" is a point of reference common to a "normal group" and may be used to form homogeneous panels on the basis of olfactory-gustatory sensitivity.

A selection of tasters is made by the intensity rating method, as described by Gutiérrez Rosales (Gutiérrez Rosales et al., 1984). A series of 12 samples is prepared by diluting a VOO characterized by a very high intensity of a given attribute in an odourless and tasteless medium (refined oil or paraffin). The panel leader sends out the candidate, removes one of the 12 tasting glasses from the series, and places the remaining together; the candidate is called back in the room and is asked to correctly replace the testing glass withdrawn from the series by comparing the intensity of this last with that of the others. The test is carried out for fusty, rancid, winey and bitter attributes to verify the discriminating capacity of the candidate on the entire scale of intensities.

The stage training of assessors is necessary to familiarize tasters with the specific sensory methodology, to heighten individual skill in recognizing, identifying and quantifying the sensory attributes and to improve sensitivity and retention with regards to the various attributes considered, so that the end result is precise and consistent. In addition, they learn to use a profile sheet.

The maintenance of the panel is made through continuous training over all duration of life of the same panel, the check of the sensory acuity of tasters, and exercises that allow the measurement of the panel performance.

Every year, all panels must assess a number of reference samples in order to verify the reliability of the results obtained and to harmonize the perception criteria; they must also update the Member State on their activity and on composition changes of their group.

3.1 Evolution of sensory methodology: From old to new

A method for the organoleptic evaluation of olive oils was introduced in the Regulation (EEC) No 2568/91, Annex XII, that is inspired by the COI/T.20/Doc. no.15, published in 1987. In the profile sheet of EEC Reg. 2568/91, a number of positive attributes and defects were evaluated, giving each a score from 0 to 5 (Figure 1).

Drawing on experience, the International Olive Oil Council has devised a new method of organoleptic assessment of VOOs (Decision Dec-21/95-V/07) that is simpler and more reliable than that in EEC Reg. 2568/91. In particular, the EC Reg. 796/2002 introduced a reduction of the attributes of the old profile sheet, asking tasters to consider only the defects of the oil (fusty, mustiness/humidity, winey/vinegary, muddy sediment, metallic, rancid and others) and only the three most important positive attributes (fruity, pungent and bitter). The most important innovation of EC Reg. 796/2002 is the use of continuous scales, from 0 to 10 cm, for evaluating the intensity of perception of the different attributes (positive and negative), as reported in Figure 2. In this way, tasters are free to evaluate the intensity of each attribute by ticking the linear-scale, without having a prefixed choice (as with the discrete scale of EEC Reg. 2568/91, see Figure 1).

Sensory analysis and its application to olive and virgin olive oil

VIRGIN OLIVE OIL

PROFILE SHEET

GRADING TABLE

OLFACTORY-GUSTATORY-TACTILE NOTES

	0	1	2	3	4	5
Olive fruity (ripe and green)						
Apple						
Other ripe fruit						
Green (leaves, grass)						
Bitter						
Pungent						
Sweet						
Other allowable attribute(s) (Specify.....)						
Sour/Winey/Vinegary/Acid						
Rough						
Metallic						
Mustiness/humidity						
Muddy sediment						
Fusty ("Atrojado")						
Rancid						
Other unallowable attribute(s) (Specify.....)						

DEFECTS	CHARACTERISTICS	OVERALL MARK: POINTS
None	Olive Fruity	9
	Olive fruity and fruitness of other fresh fruit	8
		7
Barely perceptible	Weak fruitness of any type	6
Slight perceptible	Rather imperfect fruitness, anomalous odours and tastes	5
Considerable, on the border of acceptability	Clearly imperfect, unpleasant odours and tastes	4
Great and/or serious, clearly perceptible	Totally inadmissible odours and tastes for consumption	3
		2
		1

1 Barely perceptible

2 Slight perceptible

3 Average

4 Great

5 Extreme

REMARKS.....

.....

NAME OF ASSESSOR.....

LEGEND OF SAMPLE.....

DATE.....

Fig. 1. Profile sheet for EVOO used for designation of origin (EEC Reg. 2568/91, annex XII).

Profile sheet

(for use by taster)

DEFECTS PERCEIVED	INTENSITY
“Atrojado” (fusty)	<div><div></div></div>
Mustiness/humidity	<div><div></div></div>
Winey/vinegary	<div><div></div></div>
Muddy sediment	<div><div></div></div>
Metallic	<div><div></div></div>
Rancid	<div><div></div></div>
Other (specify)	<div><div></div></div>

POSITIVE ATTRIBUTES PERCEIVED	INTENSITY
Fruity	<div><div></div></div>
Bitter	<div><div></div></div>
Pungent	<div><div></div></div>

Name of taster

Sample code

Date

Fig. 2. Profile sheet for VOO assessment currently adopted by the EU (EC Reg. 796/02).

Each attribute is calculated, and the median value of each is used to classify the oil according to the median of the defect perceived with greatest intensity and the median for “fruity”. It is important to remember that the value of the robust variation coefficient for this negative attribute must be no greater than 20%.

The classification of olive oils, according to sensory attributes, has also undergone evolution. According to EC Reg. 796/2002, oils are classified as:

- a. extra virgin olive oil: the median of the defects is 0, and the median for “fruity” is above 0;
- b. virgin olive oil: the median of the defects is above 0, but not above 2.5 and the median for “fruity” is above 0;
- c. ordinary virgin olive oil: the median of the defects is above 2.5, but not above 6.0, or the median of the defects is not above 2.5 and the median for “fruity” is 0;
- d. lampante virgin olive oil: the median of the defects is above 6.0.

Since November 2003, categories c) and d) have been replaced by (c) “lampante olive oil”: the median of defects is above 2.5, or the median of the defects is not above 2.5 and the median for “fruity” is 0.

EC Reg. 640/08 introduced a new upper limit of defect for discriminating between virgin and defective oils: in particular, the evaluation of the median defect (‘2.5’) was replaced by ‘3.5’. An important innovation of Reg. 640/08 was also the grouping in only one negative attribute of two different defects: fusty and muddy sediment.

A revised method for the organoleptic assessment of VOO was adopted by the IOOC in November 2007 (Decision No DEC-21/95-V/2007, 16 November 2007) and adopted by the European Community with EC Reg. 640/2008. This revision updated the descriptions of the positive and negative attributes of VOO and the method. It also amended the maximum limit for the perception of defects in VOO. The IOOC’s revised method for the organoleptic assessment of VOO also specifies the conditions for the optional use, on labels, of certain terms and expressions relating to the organoleptic characteristics of VOO (optional terminology for labelling purposes).

The most recent change is Decision No Dec-23/98-V/2010 of the IOOC, which defined a new method for assessing the organoleptic properties of VOO and to establish its classification on the basis of those characteristics (IOOC/T.20/Doc. No 15/Rev. 3).

3.2 The method for assigning commercial class: The official profile-sheet and expression of results

The organoleptic assessment of VOO is officially regulated in Europe by a Commission Regulation (EC Reg. 640/2008). This regulation describes the procedures for assessing the organoleptic characteristics of VOOs, the method for classification according to sensory characteristics, the specific vocabulary for sensory analysis of VOOs, including positive and negative attributes, and the optional terminology for labelling purposes. The selection, training and monitoring of skilled VOO tasters, the skills and responsibilities of the panel leader, the specific characteristics of the glass for oil tasting and the test room were also considered, according to previous regulations and IOOC documents (IOOC, 2007 and 2010).

The official profile sheet intended for use by tasters, shown in Figure 3 (EC Reg. 640/08), is quite simple and is formed by an upper section for evaluation of the intensity of defects, and

Profile sheet for virgin olive oil

INTENSITY OF PERCEPTION OF DEFECTS

Fusty/muddy sediment

|

→

Musty-humid-earthly

|

→

Winey-vinegary — acid-sour

|

→

Metallic

|

→

Rancid

|

→

Other (specify)

|

→

INTENSITY OF PERCEPTION OF POSITIVE ATTRIBUTES

Fruity

|

→

greenly ☐ ripely ☐

Bitter

|

→

Pungent

|

→

Name of taster:

Sample code:

Date:

Comments:

Fig. 3. Profile sheet for VOO assessment currently adopted by the EU (EEC Reg. 640/08).

a lower part for the evaluation of the three most important positive sensory attributes (fruity, bitter, pungent). Tasters have to smell the sample, taste the oil (overall retronasal olfactory, gustatory and tactile sensations) and evaluate the intensity with which they perceive each of the negative and positive attributes on the 10-cm scale. If a taster identifies greenly or ripely as fruity attributes, the correct options must be indicated in the profile sheet. Green fruitiness is a characteristic of the oil which is reminiscent of green olives, dependent on the variety of the olive and coming from green, sound, fresh olives. Ripe fruitiness is reminiscent of ripe fruit. If any negative attributes not listed in the upper section of the profile are perceived, the taster records them under the "others" heading, using the descriptors among those in the specific vocabulary for the sensory analysis of olive oils (IOOC/T.20/Doc. 4/rev.1).

The panel leader collects the profile sheets and elaborates the results by a statistical approach. In particular, the medians of the greatest perceived defect and fruity attribute are calculated. According to these two parameters, the oil can be graded in different quality categories. Such values are expressed to one decimal place, and the value of the robust coefficient of variation which defines them shall be no greater than 20%. As already mentioned, the classification of the oil is carried out by comparing the medians of the defects and the fruity attribute with the reference ranges established by EC Reg 640/08 for the different categories:

1. Extra virgin olive oil: the median of the defects is 0 and the median of the fruity attribute is above 0;
2. Virgin olive oil: the median of the defects is above 0, but not more than 3.5, and the median of the fruity attribute is above 0;
3. Lampante olive oil: the median of the defects is above 3.5, or the median of the defects is not more than 3.5 and the median of the fruity attribute is 0.

The panel leader can also state that the oil is characterized by greenly or ripely fruity attributes if at least 50% of the panel agrees.

Actually the most important result for sensory analysis of VOO is to identify the presence of defects instead of evaluating the positive attributes, in agreement with the aim of such an analysis, which is essentially to classify the product in different commercial classes.

3.2.1 Optional terminology for labelling purposes

Upon request, the panel head may certify that an oil complies with the definitions and ranges that correspond to the following adjectives, according to the intensity and perception of attributes:

- a. for each of the positive attributes mentioned (*fruity* – whether *green* or *ripe* – *pungent* or *bitter*):
 - i. the term “intense” may be used when the median of the attribute is greater than 6;
 - ii. the term “medium” may be used when the median of the attribute is between 3 and 6;
 - iii. the term “light” may be used when the median of the attribute is less than 3;
 - iv. the attributes in question may be used without the adjectives given in points (i), (ii) and (iii) when the median of the attribute is 3 or more;

- b. the term “well balanced” may be used when the oil does not display a lack of balance, which is defined as the smell, taste and feel that the oil has when the median of the *bitter* and/or *pungent* attributes is two points higher than the median of its *fruitiness*;
- c. the term “mild oil” may be used when the medians of the *bitter* and *pungent* attributes are 2 or less.

3.3 Method for organoleptic assessment of EVOO to assign designation of origin: Sensory profile and data processing

In 2005, the IOOC issued a document on methods to be used for the organoleptic assessment of EVOO for granting designation of origin (D.O.) status (IOOC/T.20/Doc. no 22). This document declared that the D.O. authority shall select the characteristic descriptors of the designation of origin (10 at the most) from those defined and reported in Table 1, and shall incorporate them into the profile sheet of the method.

Direct or retronasal aromatic olfactory sensations	
Almond	Olfactory sensation reminiscent of fresh almonds
Apple	Olfactory sensation reminiscent of the odour of fresh apples
Artichoke	Olfactory sensation of artichokes
Camomile	Olfactory sensation reminiscent of that of camomile flowers
Citrus fruit	Olfactory sensation reminiscent of that of citrus fruit (lemon,orange, bergamot, mandarin and grapefruit)
Eucalyptus	Olfactory sensation typical of Eucalyptus leaves
Exotic fruit	Olfactory sensation reminiscent of the characteristic odours of exotic fruit (pineapple, banana, passion fruit, mango,
Fig leaf	Olfactory sensation typical of fig leaves
Flowers	Complex olfactory sensation generally reminiscent of the odour of flours, also known as floral
Grass	Olfactory sensation typical of freshly mown grass
Green pepper	Olfactory sensation of green peppercorns
Green	Complex olfactory sensation reminiscent of the typical odour of fruit before it ripens
Greenly fruity	Olfactory sensation typical of oils obtained from olives that have been harvested before or during colour change
Herbs	Olfactory sensation reminiscent of that of herbs
Olive leaf	Olfactory sensation reminiscent of the odour of fresh olive leaves
Pear	Olfactory sensation typical of fresh pears
Pine kernel	Olfactory sensation reminiscent of the odour of fresh pine kernels
Ripely fruity	Olfactory sensation typical of oils obtained from olives that have been harvested when fully ripe
Soft fruit	Olfactory sensation typical of soft fruit: blackberries,raspberries, bilberries, blackcurrants and redcurrants
Sweet pepper	Olfactory sensation reminiscent of fresh sweet red or green peppers
Tomato	Olfactory sensation typical of tomato leaves
Vanilla	Olfactory sensation of natural dried vanilla powder or pods,different from the sensation of vanillin
Walnut	Olfactory sensation typical of shelled walnuts
Gustatory sensations	
Bitter	Characteristic taste of oil obtained from green olives or olives turning colour; it defines the primary taste associated with aqueous solutions of substances like quinine and caffeine
“Sweet”	Complex gustatory-kinaesthetic sensation characteristic of oil obtained from olives that have reached full maturity
Qualitative retronasal sensation	
Retronasal persistence	Length of time that retronasal sensations persist after the sip of olive oil is no longer in the mouth
Tactile or kinaesthetic sensations	
Fluidity	Kinaesthetic characteristics of the rheological properties of the oil, the set of which are capable of stimulating the mechanical receptors located in the mouth during the test
Pungent	Biting tactile sensation characteristic of oils produced at the start of the crop year, primarily from olives that are still unripe

Table 1. List of descriptors for D.O. of EVOO.

The characteristic descriptors are identified according to the round-table method: the panel supervisor leads a discussion based on a series of samples of known origin that display the most important specific characteristics of the VOO undergoing preparatory analysis. When the descriptor recognition stage is completed, the panel supervisor opens discussions with panel members to establish a list of all descriptors that are considered to be most important and characteristic of the designation that is undergoing preparatory analysis.

Validation should take into account the possible natural variations that may occur in the oil from one crop year to the next. When the profile sheet is completed, tasters shall assess the intensity of perception of the descriptors cited in the profile sheet on the 10-cm scale used for commercial grading of oils. The D.O. authority shall fix the maximum and minimum limits of the median for each descriptor included in the profile sheet and shall establish the limits for the robust coefficient of variation of each descriptor. It shall then enter these values in the *IOOC spreadsheet folder-profile* (software) accompanying this method to define the intervals of the characteristic sensory profile of the designation of origin.

Most of the specifications for the designation of origin of oils before 2005 or those that have not undergone revisions after this date, do not refer to the method IOOC just explained, but to the use of a previous procedure (EEC Reg. 2568/1991) for sensory evaluation of the oils. In Figure 1, the profile sheet according to the old regulation for the commercial grading is shown (EEC Reg. 2568/1991). This method provides a partial description of flavour: tasters are requested to define the fruity type, green or ripe, and recognize the presence of attributes such as grass, leaf, apple and other fruits. For each attribute, a discreet score from 0 to 5 is assigned (0: absence of perception; 1: intensity slightly perceptible; 2: intensity light; 3: average intensity; 4: great intensity; 5: extreme intensity), and there are many positive attributes to evaluate in addition to defects. Tasters rate the overall grading by using a 9-point scale: 9 for oils with exceptional sensory characteristics, and 1 for products with the worst qualities. The mean score identifies the category. An oil could be classified as EVOO if it obtains a final score (expressed as an average of the panel's judgement) of 6.5.

In the case of specifications for the designation of origin of some D.O oils, which have not yet been reviewed according to the new IOOC regulation (IOOC, 2005), it is firstly necessary to verify that the sample has the characteristics provided in the extra virgin category using current methods (EC Reg. 640/08), and to subsequently analyze it according to the old profile sheet (EEC Reg. 2568/1991) to verify the presence of characteristic descriptors. The final score for the D.O must be at least 7, but can be even higher.

4. Consumer acceptability of the sensory characteristics of VOO: An overview of literature data

As previously stated, a virgin oil that is not subjected to any subsequent technological refining has a sensory profile standardized by a rich/robust/harmonized regulatory environment (Conte & Koprivnjak, 1997) strongly linked to the quality of the starting olives. Any damage to drupes, which can lead to hydrolysis or fermentation, produces molecules that remain in the product and irreversibly affect its quality. There is no way of correcting

chemical and/or sensory defects in a virgin product. On the other hand, technological refining results in the loss of the superior quality of “extra virgin/virgin” oil, and the transition to a lower category with weaker sensory attributes. The difference in the overall quality between a virgin and a refined oil, the latter adjusted in both quality and the flavour, is not always correctly perceived by the consumer.

Generally, consumers appreciate what is familiar, what is strongly linked to the territory (tradition/origin) or to which they have a precise expectation (brand, other values) (Caporale et al., 2006, Costell et al., 2010). Furthermore, as demonstrated in a recent large study, people do not understand dietary fat, either the importance of the quality or the quantity needed for health and this generally results in consumers adhering to fat choices they are comfortable with (Diekman & Malcolm, 2009). In the case of EVOO, for a correct perception of the overall quality the fruity (green or ripe) and bitter and pungent attributes should be perceived by consumers as “healthy” indicators of quality and genuine taste, linked to the raw oil and its richness in pungent and bitter minor components (phenols) (Carluccio et al., 2003). To achieve this purpose, consumers should be made capable, by research dissemination, to appreciate bitterness (primary taste of oil obtained from green olives or olives turning colour) and pungency (biting tactile sensations characteristic of oils produced at the start of the crop year, primarily from olives that are still unripe) (COI/T.20/Doc. no 22) as healthy substances related attributes.

By law, the virgin oil “ideal” sensory profile is quite simple and easy, the fruity attribute is universally recognized as the primary sensory characteristic, and the bitter and pungent aspects are reported as positive attributes (*CODEX STAN 33-1981*). However, due to the superficial knowledge in terms of fat quality, technology (virgin and refined) and sensory characteristics, consumers do not appear to practice an informed/univocal consumption of EVOO. In this regard, research on consumer behaviour has intensified in recent years, and some of the more salient findings are provided below.

A study in Turkey (Pehlivan & Yilmaz, 2010) comparing olive oils originating from different production systems (continuous, organic, stone pressed, refined) declared that, for a sample of 100 consumers, hedonic values of the refined samples were close to the values of the virgin samples. Similar findings were previously reported by Caporale et al (2006), by which consumers are able to differentiate EVOO on their characteristic sensory attributes, but buying intentions (blind test) of the refined samples were as high as the values for the virgin samples. Again, the sensory attributes of EVOO, even if perceived, did not seem to be drivers to purchase it.

In Italy, Caporale et al. (2006) demonstrated that information about origin creates a favourable hedonic expectation, with regards to specific sensory attributes, such as pungency and bitterness. This means that, if familiar with bitter/pungent oils, consumers can have high and positive expectations of bitter and pungency attributes as distinguishing characteristics of typical olive oils (i.e. *Coratina* cv.). To confirm this physiological opportunity to perceive pungent as a positive attribute can be cited an interesting paper on the unusual pungency of EVOO (Peyrot des Gachons et al., 2011), sensed almost exclusively in the throat, suggesting that it is, therefore, perhaps no coincidence if phenols with potent anti-inflammatory properties (oleocanthale, ibuprofen) also elicit such a localized/specific

pungency. In this paper the authors ask what is the functional significance of the pungency to the human upper airways; they suggest that the posterior oral location of toxin and irritant detectors can protect against their intake either by inhalation or ingestion. But if the role of these ion channels, in general, is to protect tissue from harmful compounds, then it is a mystery how one (TRPA1-channel), mediating throat irritation of extra-virgin olive oils, came to be valued as a positive sensory attribute by those who consume them. The authors hypothesize that this pungency, distinguishing particularly good olive oils in the European Union standards, similarly to other common food irritants (e.g., capsaicin, menthol, and so forth), also important positive components in many cuisines, turns, from a usually negative taste-kinesthetic sensation into positive, because the molecules that elicit it have a body healthy action. This theory requires considerably more investigations to be demonstrated, but is true that many compounds eliciting pungency are also linked to decreased risks of cancer, degenerative and cardiovascular diseases (Boyd et al., 2006; Peng & Li, 2010).

In the case of EVOO, but this is a very general question, the authors suggest that people can transform an inherently unpleasant sensation into a positive one, commonly experienced around the world when consuming pungent EVOO, because it has beneficial health effects (Peyrot des Gachons et al., 2009). If this theory is correct, it means that this kind of pungency could be easily taught as a positive sensation quality-related, to the unfamiliar consumers.

In fact, it has been reported (Delgado & Guinard, 2011) in the USA, an emergent market, that in a study on 22 samples evaluated in blocks of 5, for the majority of 100 consumers bitterness and pungency were negative drivers of liking.

Descriptive analysis (Delgado & Guinard, 2011) has been proposed as a more effective method to provide a more detailed classification of EVOO; the final method consisted of 22 sensory attributes, some of which were original but infrequent (butter/green tea). But, in the case of EVOO, the challenge for the future does not appear descriptive analysis, which has had the most interesting developments for the characterization/valorization of monovarietal, PDO and PGI (Inarejos-García et al., 2010; Cecchi et al. 2011) with many targeted/robust attributes. Rather it concerns the fact that consumers are actually able to appreciate/perceive its fundamentals of sensory profile (fruity, bitter, pungent) as related to its quality.

Finally, the worldwide problem of two different qualities of EVOO, a high one (expensive) and a “legal” one (less flavour/cheaper), was also highlighted in a means-end chain study (Santosa & Guinard, 2011), explaining that the attributes associated with EVOO generally have high (more flavour, more expensive, smaller size) or, unfortunately, low (cheaper/on sale, big quantity/bulk size, less flavour) levels of product involvement.

5. Conclusion

Sensory analysis of EVOO has been used for classification for more than 20 years. Since 1987, the “COI Panel test” has undergone many revisions, became law in 1991 in Europe and actually COI/T.20/Doc. no. 15. is the method of analysis accepted by the Codex Alimentarius. Over the years, the profile sheet has undergone simplifications that have

restricted selected specific positive (fruity, bitter, pungent) attributes and defects (fusty/muddy sediment, winey-vinegary-acid-sour, metallic, rancid, others).

On the other hand, in 2005 the IOOC issued document COI/T.20/Doc. no 22 that provides specifics about the methods to be used for sensory assessment of EVOO when granting designation of origin (D.O.) status. The method contains a list of 23 direct or retronasal aromatic olfactory sensations, 2 (bitter, sweet) gustatory sensations, 2 tactile or kinesthetic sensations (fluidity/pungent) and a qualitative retronasal persistence. Even taking into account the recent development of sensory analysis, there is no other food that has such a rich/robust/harmonized regulatory environment regulated by the EU, International Olive Oil Council and, as any food, Codex Alimentarius (FAO-OMS).

At present, origin, tradition and habits, more than sensory profile, are purchase drivers for EVOO and the real challenge for the future is improving consumer education in appreciating the fundamental attributes: fruity, together with taste and tactile sensations of phenols, functional and healthy substances naturally present in EVOO, respectively, bitterness and pungency.

Therefore, nowadays, the key to provide the consumer a truly effective EVOO organoleptic knowledge is the worldwide dissemination of the three basic quality-related and “healthy” sensory attributes.

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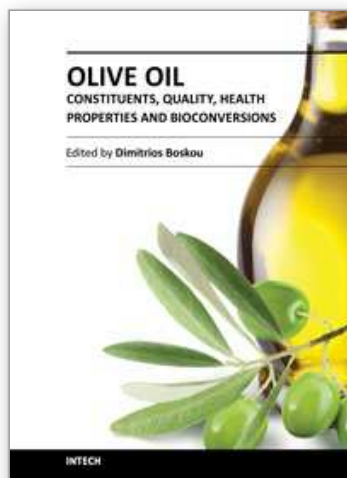
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The health-promoting effects attributed to olive oil, and the development of the olive oil industry have intensified the quest for new information, stimulating wide areas of research. This book is a source of recently accumulated information. It covers a broad range of topics from chemistry, technology, and quality assessment, to bioavailability and function of important molecules, recovery of bioactive compounds, preparation of olive oil-based functional products, and identification of novel pharmacological targets for the prevention and treatment of certain diseases.

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