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Olive oil volatile compounds, flavour development and quality: A critical review

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Abstract

The unique and delicate flavour of olive oil is attributed to the volatile compounds that develop during and after oil extraction from the olive fruit. The formation of these volatile compounds and the fruit characteristics that affect the formation are examined in this review. The role of extraction time -temperature interactions in volatile development and other factors that impact volatile development, such as fruit storage prior to oil extraction, are also considered. The volatile compounds that develop during extraction become less dominant during oil storage with the emergence of volatile compounds from chemical oxidation. The presence or absence of particular volatile compounds partly explains quality differences in olive oils.

Keywords: Sensory attributes; Odour threshold values; Fruit ripeness; Cultivar differences; Processing conditions

1. Introduction

Olive oil quality depends on market preferences and is based upon consumer perceptions of aroma, taste and colour, which may change over time and with location. Objectionable aroma and taste may lead to product rejection. The absence of sensory defects in olive oil is necessary for the oil to be classified as "extra virgin", whereas the presence and intensity of sensory defects is used to categorise oils of other qualities (Angerosa, 2000). Both positive attributes and sensory defects in olive oil can be associated with volatile compounds.

Volatile compounds in olive oil are mainly produced by oxidation of fatty acids. It is generally agreed that endogenous plant enzymes, through the lipoxygenase pathway, are responsible for the positive aroma perceptions in olive oil whereas chemical oxidation and exogenous enzymes, usually from microbial activity, are associated with sensory defects. Both the processing and storage of the fruit and the oil contribute greatly to the flavour and overall quality of olive oil (Angerosa, 2002; Venkateshwarlu, Let, Meyer, & Jacobsen, 2004).

An understanding of the stages at which volatile compounds are formed can be used to control the volatile composition of olive oil, allowing the production and consumption of better quality oils. Selection of premium olive fruit at optimum ripeness and optimum processing conditions are factors that can be used to control the process of volatile compound formation. This review discusses the influence of volatile compounds on olive oil quality and reviews the changes in volatile compound composition of both the fruit and oil that occur during processing and storage.

2. Olive oil quality

There are several ways of defining quality and perhaps there is no single universal definition that adequately satisfies all situations. In general terms, quality is defined as "The combination of attributes or characteristics of a product that have significance in determining the degree of acceptability of that product by the user" (Gould, 1992).

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Olive oil quality may be defined from commercial, nutritional or organoleptic perspectives (Duran, 1990). The nutritional value of olive oil arises from high levels of oleic acid and minor components, such as phenolic compounds, whereas the aroma is strongly influenced by volatile compounds (Angerosa, 2002; Kiritsakis, 1998). Nutritional value and pleasant flavour have contributed to an increase in consumption of olive oil which has fostered cultivation of olives outside the traditional olive oil producing region of the Mediterranean and into newer areas where cultivar adaptability, different climatic conditions and different agronomic practices may alter olive quality (Patumi et al., 2002).

The International Olive Oil Council (IOOC, 2001) and the EEC (EC, 1991) have defined the quality of olive oil, based on parameters that include free fatty acid (FFA) content, peroxide value (PV), UV specific extinction coefficients (K_{232} and K_{270}) and sensory score. In particular, the quantity of FFA is an important factor for classifying olive oil into commercial grades (Boskou, 1996; Rossell, 1986). The general classification of olive oils into different commercial grades is based on FFA (Table 1) and sensory characteristics (taste and aroma). The commercial grades separate oil obtained from the olive fruit solely by mechanical or physical means (virgin) from the other oils that contain refined oils.

Providing that the olive fruit is sound, at production most olive oil is extra-virgin. When the fruit quality is low, the oil is refined. The classification of olive oil is usually done just after production. However, stability to oxidation is an important requirement excluded in the regulation; such oxidation can lead to a subsequent loss of extra-virgin quality status (Monteleone, Caporale, Carlucci, & Pagliarini, 1998). Some parameters that are not included in the IOOC and EC standards (EC, 1991; IOOC, 2001), such as phenolic content, are known to have a significant effect on the stability and sensory characteristics of olive oil. The phenol profile can be followed from the fruit to the oil production and through storage, and may serve as a good indicator of olive oil quality. Indeed, there have been proposals to include phenols in the olive oil standard (Blekas, Psomiadou, Tsimidou, & Boskou, 2002; Psomiadou, Konstantinos, Blekas, Tsimidou, & Boskou, 2003; Ranalli, Ferrante, De Mattia, & Costantini, 1999).

Table 1
General classification of olive oils based on FFA

Olive oil classification	FFA limit (as oleic acid)%
Extra-virgin olive oil	0.8 (max)
Virgin olive oil	2.0 (max)
Ordinary virgin olive oil	3.3 (max)
Lampante virgin olive oil	3.3 (min)
Refined olive oil	0.3 (max)
Olive oil	1.0 (max)
Refined olive pomace oil	0.3 (max)
Olive pomace oil	1.0 (max)

In most cases quality parameters change by the time the oil reaches the consumer (Gutierrez & Fernandez, 2002). Olive oil is susceptible to both hydrolytic and oxidative reactions (Duran, 1990) that can adversely affect oil quality parameters. For instance, an increase in PV, K_{232} and K_{270} values and development or loss of certain volatile compounds is very common between extraction and consumption (Boskou, 1996; Gutierrez & Fernandez, 2002). The presence or absence of particular volatile compounds may also be a good indicator of olive oil quality changes.

3. Volatile compounds

Volatile compounds are low molecular weight compounds (less than 300 Da) which vapourise readily at room temperature. Some volatile compounds reach the olfactory epithelium, dissolve into the mucus and may bond with olfactory receptors to give an odour sensation (Angerosa, 2002). The aroma of olive oil is attributed to aldehydes, alcohols, esters, hydrocarbons, ketones, furans and, probably, other as yet unidentified volatile compounds. The major volatile compounds reported in virgin olive oils are the C6 and the C5 volatile compounds. Hexanal, *trans*-2-hexenal, hexan-1-ol and 3-methylbutan-1-ol are found in most virgin olive oils in Europe (Angerosa, 2002; Aparicio, Morales, & Alonso, 1997; Kiritsakis, 1998). A study of Italian, Spanish and Moroccan extra-virgin olive oil (Reiners & Grosch, 1998) confirmed the richness of C6 volatile compounds in Italian oils but showed that they were poor in fruity esters. The fruity esters, ethyl isobutyrate, ethyl butyrate, ethyl 2-methylbutyrate, ethyl 3-methylbutyrate, and ethyl cyclohexylcarboxylate were rich in Moroccan extra-virgin olive oils (Reiners & Grosch, 1998). It should be noted that the high concentration volatile compounds are not necessarily the major contributors of odour. For instance, Reiners and Grosch (1998) reported a concentration of 6770 μg/g for *trans*-2-hexenal with an odour activity value of 16 whereas 1-penten-3-one with a much lower concentration of 26 μg/g had a higher odour activity value of 36.

Volatile compounds, whether major or minor, are crucial to olive oil quality. Volatile compounds that occur in olive oil below their olfactory threshold, and make no direct contribution to the aroma, could be important in understanding the formation and degradation of the volatiles with significant contribution to aroma, and they may provide useful quality markers (Buttery & Takeoka, 2004). This fraction includes C5 carbonyl compounds, pentenols, hydrocarbons and minor compounds not derived from fatty acid transformations (Angerosa, Camera, D'alessandro, & Mellerio, 1998; Buttery & Takeoka, 2004).

Cultivar, geographic region, fruit maturity, processing methods and parameters influence the volatile composition of olive oil. Fruit from different cultivars grown under the same environmental conditions produce oils with different volatile compounds, as does fruit of the same cultivar grown in different geographic regions (Angerosa, Basti, &