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Review

Quality of olives: A focus on agricultural preharvest factors

Luis Rallo[a], Concepción M. Díez[a], Ana Morales-Sillero[b], Hristofor Miho[a], Feliciano Priego-Capote[c], Pilar Rallo[b,*]

[a] Departamento de Agronomía, Universidad de Córdoba, Campus de Rabanales, Carretera, Madrid, km 396, 14071 Córdoba, Spain
[b] Departamento de Ciencias Agroforestales, Universidad de Sevilla, Carretera. Utrera km 1, 41013 Sevilla, Spain
[c] Departamento de Química Analítica, Universidad de Córdoba, Campus Universitario de Rabanales, Carretera Madrid-Cádiz, Km. 396-A, 14071 Córdoba, Spain

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ABSTRACT

More than 11 million ha of olives (*Olea europaea* L.) are currently grown worldwide, 98% of which are localized in the Mediterranean Basin, with olives being one of the most important fruit trees in the area. The olive fruit is a very particular drupe since it not may be directly consumed but must instead be processed. Table olives and virgin olive oil are the two main processed products derived from olive fruits. Both are considered staple foods of the Mediterranean Diet and have been produced in the area for centuries, presumably since olive domestication occurred approximately 6.000 years ago. Despite their long history and economic importance, the focus on quality is quite recent. The presence of various and copious amounts of bioactive compounds, some of which are exclusive to olives, is drawing attention to the nutraceutical value of these products. This review aims to integrate the available information regarding the quality of table olives and olive oil with a focus on how preharvest factors may affect quality. The first part of the review describes the main quality attributes considered for each product from different perspectives, including the legal, organoleptic and nutritional points of view, among others. The physiological mechanisms involved in fruit development and ripening, which significantly affect the quality of the fruits, i.e., the raw material for obtaining both products, are also discussed. The review also addresses the potential of both the considerable number of traditional olive cultivars and recent olive breeding programs to obtain products with distinct quality attributes (in terms of sensorial profile and bioactive compounds). Finally, the most recent literature concerning the effect of environmental (soil and climate) and agronomical factors (irrigation, fertilization, canopy management and harvesting) is extensively reviewed.

1. Introduction

Olive growing has been traditionally localized in the Mediterranean Basin for thousands of years. According to the International Olive Council (IOC, http://www.internationaloliveoil.org/), there are more than 11 million ha of olive trees in more than 47 countries. The majority of this surface (97.9%) is localized in the Mediterranean countries. However, new intensive orchards have been planted in the Mediterranean and in new regions, such as Australia, North and South America, over the last 20 years. The mentioned expansion and intensification of olive growing as well as the perception of olive oil and table olives as healthy foods have largely increased both the production and demand of these products.

The olive fruit is a drupe that comprises the exocarp, the fleshy mesocarp (the edible portion) and the stony endocarp. Unlike other well-known drupes (peaches, apricots, cherries, and plums) olive fruit cannot be directly consumed but must instead be processed to eliminate their strong bitter taste, which is caused by the presence of oleuropein, a secoiridoid glucoside (the predominant phenolic compound), in the mesocarp. Other particularities of the olive fruit is its low sugar content (3.5-6%) and the high amount of oil accumulated during maturation (14–30% oil content).

The concept of quality in fruit products is wide, complex and dynamic. It implies a large number of attributes with different significance according to the interest and expectations of the different stakeholders of the chain, from producers to consumers (See Kyriacou and Rouphael, 2017). In the case of the olive, two main products are obtained from olive fruits: virgin olive oil (the juice of the fruit) and table olives; both are staple foods of the Mediterranean Diet. The quality attributes that are considered for each product largely differ from one another; thus,

Abbreviations: DAFB, days after full bloom; EEC, European economic community; EFSA, European food safety authority; EVOO, extra virgin olive oil; FA, free acidity; FAEEs, fatty acid ethyl esters; FATH, fruit abscission threshold; FR, fruit ripening; IOC, International Olive Council; LDL, low-density lipoprotein; MI, maturity index; MUFA, monounsaturated fatty acid; PL, phospholipids; PUFA, polyunsaturated fatty acid; RDI, regulated deficit irrigation; VOO, virgin olive oil

* Corresponding author.
E-mail address: prallo@us.es (P. Rallo).

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they are addressed separately in the first part of the review. Nevertheless, legal definition according to regulatory standards, chemical and nutritional attributes and organoleptic properties are reviewed in both products.

Preharvest factors directly affect the quality of the "fresh" olive fruits, i.e., the raw material for both table olives and olive oil; therefore, the final quality of both products depends largely on the cultivar, ripening stage and management in the field (olive orchards). Similarly, the processing required to obtain both products has an important effect on the final quality of table olives and olive oil. Nevertheless, in this review, only preharvest factors, including the physiology of ripening, genetics, and environmental and agronomic conditions, are discussed.

2. Olive quality

2.1. Table olive quality attributes

2.1.1. Legal definition of table olives and types

For commercial trading, olive fruits must conform to obligatory standards that mainly refer to fruit appearance and uniformity in addition to the presence of different defects. Quality standards for table olives were issued by the International Olive Council (IOC, 2004). According to this standard, table olives are defined as the product with the following characteristics:

(a) prepared from the sound fruits of varieties of the cultivated olive tree (*Olea europaea* L.) that are chosen for their production of olives whose volume, shape, flesh-to-stone ratio, fine flesh, taste, firmness and ease of detachment from the stone make them particularly suitable for processing;
(b) treated to remove its bitterness and preserved by natural fermentation, or by heat treatment, with or without the addition of preservatives;
(c) packed with or without covering liquid.

Table olive processing procedures are intended to remove oleuropein to reduce the bitterness distinctive to the olive fruit. The methods largely differ among the regions, cultivars and ripening stages of the olives. There are, however, according to the standards (IOC, 2004), four main trade preparations: "treated olives" (fruits undergo an alkaline treatment and are placed in a brine, where fermentation occurs), which includes the well-known Spanish-style green olives; "natural olives" (olive fruits are directly placed in a brine), with Greek-style black olives being the most prevalent preparation within the category; "olives darkened by oxidation" (olives are preserved in a brine and darkened by oxidation), which are also known as black ripe olives or Californian-style olives; and "dehydrated and/or shriveled olives" (fruits are preserved in brine or partially dehydrated in dry salt and/or by heating or any other process).

2.1.2. Fruit traits

The attributes of the olive fruit are key for table olives since the first perception of quality by the consumer relies in many of them: size, shape, color and the absence of damage.

Olive fruit size is expressed as unitary fruit weight and/or volume, although for commercial size grading, it is calculated as the number of fruits per kilogram. Table olives are preferred to be large (over 5 g per fruit) or medium-size (3–5 g per fruit) (Garrido Fernandez et al., 1997). Nevertheless, many table olive cultivars vary considerably in size (Barranco et al., 2000). Fruit shape is usually measured as the ratio between fruit length and width. Many different shapes may be found among table olives, but spherical rounded shapes are often preferred by consumers and by the industry since pitting them is easier. However, very appreciated table olives such as "Kalamata olives" are notably elliptical and asymmetrical (Tsantili, 2014). Having a high flesh-to-stone ratio is essential for table olive acceptance by the consumer. No "legal" minimum value is established, but a 5:1 ratio is acceptable. Stone morphology is also an important trait influencing quality. The surface of the pit should be smooth, and the flesh should be easily detached.

Regarding fruit surface color, chlorophylls and carotenoids are the main pigments responsible for the color of green olives. Consumers prefer the golden-yellow color characteristic of alkali-treated olives to the brownish colors that natural green olives (non-treated with alkali) usually develop (Ramirez et al., 2015). Anthocyanins are involved in the final color of natural black (Greek-style) olives, whereas the color of black ripe (California-style) olives is achieved by oxidation of hydroxytyrosol (Brenes et al., 1992). The dark color of black olives is one of the attributes that is most valued by consumers, but natural black olives do not usually reach the darkness and homogeneity of black-ripe olives (Romero et al., 2015). For green olives, color determination is based on the measured reflectance at wavelengths of 560, 590 and 635 nm (Sánchez Gómez et al., 1985). Alternative methods, primarily the CIE (Commission internationale de l'éclairage) L* (lightness), a* (redness) and b* (yellowness) parameters, are currently widely used for color determination for both fresh and processed table olives (Ramirez et al., 2015). In ripe and naturally black olives, the parameters proposed are the reflectance of the olive surface at 700 nm (Garrido Fernandez et al., 1997) in addition to the CIE L*, a* b* color space (Marsilio et al., 1990).

As mentioned above, fruit appearance is one of the most decisive factors influencing consumer's choice, and a long list of defects affecting olive fruit surface is included within the International Trade Standard for Table Olives (IOC, 2004). Among these defects, bruising is the most common type of mechanical damage, and its occurrence is mainly related to the impacts suffered by the olive fruit during harvesting. Bruising is generally associated with superficial browning (dark spots) on the fruit exterior, but internal damage within the mesocarp, including ruptured cells and a loss of cell wall thickness, has also been reported (Jimenez et al., 2016). Bruising assessment in commercial regulations (IOC, 2004) and, in most studies, is usually limited to a visual evaluation of external damage (Jimenez-Jimenez et al., 2013; Saracoglu et al., 2011). A recent methodology developed by Jimenez et al. (2016) is being employed to assess and quantify internal damage associated with bruising at the tissue level (Casanova et al., 2017; Jiménez et al., 2017).

2.1.3. Flesh texture

Flesh texture is a quality attribute of great importance for table olives. In fact, "abnormal texture", based on subjective appreciation, is considered a defect within the quality standard (IOC, 2004), and similarly, kinesthetic sensations (directly related to fruit firmness) have been included in the sensory analysis methodology (IOC, 2011). Nevertheless, no average values are specified, and no correlation with instrumental objective methods has yet been established (Sánchez Gómez and García, 2017).

There are no unified standard methodologies to assess the mechanical properties of the olive fruit, although different tests and instruments have been employed for the texture evaluation of table olives. Most methods are based on applying pressure or force to the fruit surface and measuring traits related to fruit consistency, such as fruit deformation (Kilickan and Guner, 2008; Lanza et al., 2010; Mafra et al., 2001), the compression force based on single or continuous measures (Cardoso et al., 2008; Catania et al., 2015), the puncture force required to penetrate the pulp (Cano-Lamadrid et al., 2015; Cardoso et al., 2008; Fadda et al., 2014; Mafra et al., 2001), and the shear force required to break it (Garcia-Garcia et al., 2014; Rejano Navarro et al., 2008). Instruments for physical measures include pressure testers or durometers, puncture testers or penetrometers and more sophisticated texturometers. Texture is related to the cell structure, the composition of the cell wall, particularly regarding polysaccharides, and the enzymes involved in cell degradation. Thus, indirect methods based on some of these aspects to determine the mechanical properties of the olive drupe