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Physicochemical and sensory characteristics of virgin olive oils in relation to cultivar, extraction system and storage conditions

Kaouther Ben-Hassine [a,b,c], Amani Taamalli [d], Sana Ferchichi [e], Anis Mlaouah [f], Cinzia Benincasa [g], Elvira Romano [g], Guido Flamini [h], Aida Lazzez [b], Naziha Grati-kamoun [b], Enzo Perri [h], Dhafer Malouche [f,*], Mohamed Hammami [a]

[a] Biochemistry Laboratory, UR03/ES08 'Human Nutrition and Metabolic Disorders', USCR Mass Spectrometry Lab of Monastir Medicine University, Tunisia
[b] Institut de l'olivier, Unité Technologie et Qualité, BP 1087, 3018 Sfax, Tunisia
[c] National Institute for Applied Sciences and Technologies, Tunisia
[d] Laboratoire de Biotechnologie de l'Olivier, Center of Biotechnology of Borj Cedria, Tunisia
[e] Faculté des Sciences de Tunis, Université Tunis El Manar, Tunisia
[f] Engineering School of Statistics and Information Analysis, University of Carthage, Tunisia
[g] CRA Experimental Institute for Olive Growing, C. da Li Rocchi, 87036 Rende, CS, Italy
[h] Dipartimento di Chimica Bioorganica e Biofarmacia, via Bonanno 33, 56126 Pisa, Italy

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ABSTRACT

This research was carried out to evaluate the effects of variety, extraction system and storage conditions such as packaging type and temperature variation on the quality of virgin olive oil. Several parameters were studied, namely, quality indices, polyphenols, tocopherols, volatile compounds and sensory properties. Thus, two olive varieties Chemlali (Tunisia) and Coratina (Italy) were selected. The olive oils were extracted by different industrial processes (super press, dual and triple phase decanter) then stored in the established conditions (ambient and refrigerator temperature) in the following packaging materials: clear and dark glass bottles and metal bottles. The oils were analyzed before and after being stored for 9 months. Principal Component Analysis and Graphical Modeling were applied to fully explore the influence of the studied factors. Results revealed that among samples, oils from Coratina cultivar were the richest in γ-tocopherol while Chemlali oils contained the highest amount of Δ-tocopherol. Quality indices namely K232 and K270 values were mainly influenced by the storage date and packaging material. Meanwhile, free acidity and peroxide value were mainly influenced by the extraction system. Concerning tocopherols, α-tocopherol content was mainly influenced by the packaging material, β-tocopherol was mainly affected by the storage date, for γ-tocopherol content the main influencing factor was the cultivar whereas for Δ-tocopherol the main influencing factor was the extraction system. Regarding volatile compounds their amounts were influenced mainly by the storage date, that was influenced by the packaging material, where a considerable decrease was observed after storage which was reflected by the change of sensory characteristics of stored oils: loss of positive attributes fruitiness, bitterness and pungency and onset of defects which were mainly influenced by the storage date (fruity and bitter attributes), packaging material (pungent, rancid and fusty attributes) and extraction system (musty attribute).

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1. Introduction

Tunisia olive groves present several varieties among which Chemlali constitutes the bulk of the Tunisian olive cultivation. Grown in warm coastal and low steppe Chemlali groves occupy nearly 85% of the olive-growing area and contribute over 80% of national production in olive oil. To improve olive oil quality produced in Tunisia, some approaches have been considered among them the introduction of different new cultivars. During the last years, foreign cultivars which showed an excellent olive oil quality and perfect adaptation to modern intensive cultivation conditions in their original site, have been introduced in Tunisian environment by private Tunisian companies for their easy harvesting and more rapid return on investment (Allalout et al., 2009). One of the introduced varieties is the Italian Coratina. This variety is known for its good quality and richness in antioxidants such as polyphenols and tocopherols.

It is well established that olive oil quality is influenced by several factors such as variety, environmental conditions, cultural and harvesting practices and technological processes. Hence, one of the primary causes of loss of olive oil quality is oxidation. The oxidation is an inevitable process that starts after the virgin olive oil has been extracted and leads to a deterioration that always becomes more serious during oil storage.

* Corresponding author at: Ecole Supérieure de la Statistique Et de l'Analyse de l'Information, 6-Rue des métiers, BP 675, 1080 Tunis, Tunisia. Tel.: +216 24 67 10 97; fax: +216 70 838170.
E-mail address: dhafer.malouche@me.com (D. Malouche).

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Initially lipids are radically oxidized to hydroperoxides, which are odorless and tasteless (Frankel, 1985) and do not account for sensory changes. However, they are susceptible to further oxidation or decomposition into products of secondary reactions, which, conversely, are responsible for typical unpleasant sensory characteristics, identified on their whole as a rancid attribute.

Storage conditions are considered critical variables that influence the quality of olive oil and its shelf life which is attributable to lipid oxidation mechanisms which lead to rancidity (Vacca, Del Caro, Poiana, & Piga, 2006). Glass and metal bottles were used for packaging olive oils. The major function of packaging materials is related to their barrier properties against moisture, oxygen and light. It is known that these reactions are catalyzed by light and heat and are partly slowed down by compounds belonging to the unsaponifiable fraction. Polyphenols and tocopherols are the two main groups of compounds acting as primary antioxidants to inhibit oxidation in virgin olive oils. Many methods for phenol determination from different plants showed a variation of their concentrations which may be due to the exposure to several factors (Figueiredo-González, Simal-Gándara, et al., 2012; Pérez-Lamela, García-Falcón, Simal-Gándara, & Orriols-Fernández, 2007; Rodrigues, Pérez-Gregorio, Garcia-Falcon, & Simal-Gandara, 2009; Rodrigues, Pérez-Gregorio, García-Falcón, Simal-Gándarab, & Almeida, 2011) which could explain the significant difference between phenolic profiles from different plants. Regarding the great importance of the protective effect of virgin olive oil against cardiovascular, cancer, and neurodegenerative diseases, studying functional foods may be of great interest. Virgin olive oil is considered as an exceptional source of polyphenols, equalling all well-known polyphenol-rich plants such as green tea, pomegranate and date *Vitis vinifera* L. red grape varieties (Figueiredo-González, Martínez-Carballo, et al., 2012), onions (Pérez-Gregorio, Regueirob, Simal-Gándara, Rodrigues, & Almeida, 2013) and other plants.

The biological activities of olive oil phenolic compounds have prompted several studies on their potential activity in the prevention of cardiovascular diseases and cancer. However, a decrease in LDL oxidation was demonstrated with a greater ingestion of virgin olive oil phenolic compounds (Covas et al., 2006). In recent years, the anti-inflammatory and vascular protective properties of EVOO polyphenols have been extensively investigated (Fitó et al., 2008; Mc Geer, Mc Geer, & Schwab, 2009). This assumption has reinforced the proposed suggestions on phenolic compounds, which are able to interact with biological systems and act as bioactive molecules; in particular, they are important inhibitors of lipid peroxidation (Jemai, Bouaziz, Feki, El Fki, & Sayadi, 2008) and are believed to be effective through their free radical scavenging and metal-chelating properties. Despite the numerous studies that have shown the powerful antioxidant properties of olive oil, whether the effects really occur and the mechanisms responsible for these beneficial effects are not presently known. Polyphenols and tocopherols mainly act as chain breakers by donating a radical hydrogen to alkylperoxyl radicals formed during the propagation step of lipid oxidation and subsequently forming a stable radical tocopherols constitute the lipophilic antioxidant group and are noted for their effective inhibition of lipid oxidation in all vegetable oils (Velasco & Dobarganes, 2002).

Many studies on oxidation of virgin olive oils were based on accelerated test measurements (Aparicio, Roda, Albi, & Gutierrez, 1999; Baldioli, Servili, Perretti, & Montedoro, 1996; Gutierrez & Fernandez, 2002; Gutierrez, Villafranca, & Castellano, 2002; Krichene et al., 2010). In these studies, good correlations between changes in various components and stability were found. However, the extreme conditions in accelerated test high temperatures and with air bubbled into the oils do not simulate actual storage conditions and may lead to qualitative and quantitative changes to the oil that are not related to real-time storage. The main objective of our research is to investigate in depth how the extraction system and storage conditions affect the quality and composition of olive oil quality of two varieties: the Tunisian Chemlali and the Italian Coratina. To our knowledge, this is the first study of its kind that has applied the graphical modeling for full exploration of factors affecting olive oil physicochemical and sensory characteristics in a real-time shelf life study.

2. Materials and methods

2.1. Olive samples and oil extraction

Olive fruits (*Olea europaea*) of Coratina varieties were collected in an orchard in Calabria (South of Italy) while olives from Chemlali variety were collected in the orchard in Chaal (60 km away from Sfax in South East of Tunisia) and benefited both from the same cultural practices and the same ripeness index 3.5. We used for this study 900 kg of olives each from the two varieties, the orchard of 10 ha surface with trees planted at 24 × 24 m (17 trees/ha). Twenty marked trees of Chemlali variety were used to carry out this experiment knowing that each tree gave 45 kg of olives whereas for Coratina olives the orchard was of 400 trees/ha from which 30 marked trees were harvested each tree gave 30 kg. After homogenization and cleaning, fruits from both varieties were divided into three portions according to the extraction process used namely pressure system (SP) and centrifugation system with dual- (2P) and triple-phase (3P) decanters.

2.1.1. Pressure system

First, the olives are ground into an olive paste using large millstones. The olive paste generally stays under the stones for 45–50 min. After grinding, the olive paste is spread onto fiber disks, which are stacked on top of each other and then placed into the press. Traditionally, the disks were made of hemp or coconut fiber but nowadays they are made of synthetic fiber, which makes it easier to clean and maintain. These disks are then put on a hydraulic piston, forming a pile. Pressure is applied on the disks, thus compacting the solid phase of the olive paste and percolating the liquid phases (oil and vegetation water). The applied hydraulic pressure can go to 400 atm. The liquids are then separated by a standard process of decantation.

2.1.2. Centrifugation system

2.1.2.1. Triple-phase centrifugation system. Through this procedure, the olives were crushed to a fine paste. This paste was then malaxed for 50 min in order to allow the small olive droplets to coalesce. At this time, the paste was pumped into an industrial decanter to achieve the separation of the different constituents of the paste. During this process water was added to the paste in order to facilitate the separation of the three phases (oil, vegetation water and solids). The decanter is a large capacity-horizontal centrifuge rotating approximately 3000 rpm. The high centrifugal force created allows the phases to be readily separated according to their different densities (solids > vegetation water > oil). Inside the decanter's rotating conical drum is a coil rotating a few rpm (rounds per minute) slower pushing the solid materials out of the system. The separated oil and vegetation water are then rerun through a vertical centrifuge, working around 6000 rpm separating the small quantity of vegetation water still contained in oil and vice versa.

2.1.2.2. Dual-phase centrifugation system. The olives were crushed to a fine paste, then, olive paste was kneaded for 50 min at 22 ± 2 °C. Afterwards, the paste is pumped into a dual-phase industrial decanter where the liquid and solid phases were separated. Finally, the oil was separated from the obtained liquid phase by means of an automated discharge vertical centrifuge. After extraction, the olive oils were stored, in full filled bottles of three kinds of packaging: clear, dark glass and metal bottles, up to 9 months at temperatures of 8 °C and ambient temperature, and analyzed at the beginning of the experiment and again after 9 months of storage. Temperature conditions were chosen to simulate ideal and poor storage.

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