Sensory and Volatile Profiles of Monovarietal North Tunisian Extra Virgin Olive Oils from ‘Chétoui’ Cultivar

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Abstract: The quality of olive oil is defined as a combination of characteristics that significantly determine its acceptance by consumers. This study was carried out to compare sensorial and chemical characteristics of sixty ‘Chétoui’ extra virgin olive oils (EVOOc) samples from six northern areas in Tunisia (Tebourba (EVOOT); Other regions (EVOON): Mornag, Sidi Amor, El Kef, Béjà and Jendouba). Trained panel taste detected ten sensory attributes. EVOOT and EVOON were defined by ‘tomato’ and ‘grass/leave notes, respectively. Twenty one volatile compounds from EVOOc were extracted and identified by Headspace Solid-Phase Microextraction followed by Gas Chromatography- Flame Ionization Detector. Principal component and cluster analysis of all studied parameters showed that EVOOT differed from EVOON. Sensory and volatile profiles of EVOOc revealed that the perception of different aromas, in monovarietal olive oil, was the result of synergic effect of oils’ various components, whose composition was influenced by the geographical growing area.

Key words: geographical effect, ‘Chétoui’ from Tebourba, sensory proprieties, sensory evaluation index (SE), volatile compounds

1 INTRODUCTION

Olive oil has been used for thousands of years in the countries surrounding the Mediterranean Sea. The dynamic increase on the demand for Virgin Olive Oils (VOO) cannot only be explained by their health properties, but also by their organoleptic properties1. The fine flavor (aroma and taste) and color of VOO distinguish it from other edible vegetable oils, giving it a superior quality that is traditionally appreciated by the consumers in Mediterranean countries and now all over the world. Nowadays the quality of olive oil reflects nutritional, sensory and commercial aspects and is regulated by European legislation (EC), the International Olive Council (IOC) and also the Codex Alimentarius. Aroma and taste are the only parameters that consumers can appraise directly, while other quality features (e.g. chemical composition) are not always labelled on the bottle.

Sensory characteristics are used to define VOO quality.

In fact, VOO is characterized by a unique flavor, which represents one of the most important qualitative aspects of this vegetable oil, and plays a major role in consumer approval. A full description of the organoleptic characteristics of the oil is only obtainable through sensory analysis. Moreover, the quali-quantitative determination of the volatile compounds can provide very useful information on product quality.

Volatiles mainly contribute to the flavor (smell and taste), and are the principal components responsible for the positive fruity attribute, characteristic of the oil from healthy, fresh fruits, both ripe or unripe2. Recent works reviewed the several factors influencing aromatic quality of VOO, i.e. biogenesis and composition of volatiles, relationships with sensory notes, possible influence of agronomic and processing factors, and oil oxidation3,4. Other researchers found that the different volatile composition in four Tunisian oils was affected by the cultivar, showing also
a close relation to the enzymatic profiling that is genetically determined\textsuperscript{8}. In 2007, other peculiar differences in the composition of volatile in Tunisian and French from Protected Designation of Origin (PDO) oils were found\textsuperscript{9} demonstrating that the building up of metabolites in oils from different cultivars was related to genetic origin. Different studies on chemical composition of extra virgin olive oils (EVOO) revealed, also, the influence of growing areas\textsuperscript{10}. So, the olive production area is greatly responsible for the specific characteristics of olive oil. Over the past decades, there has been an increasing interest in the geographical identification of EVOO, as a reliable criterion for its quality and authentication. As far as this point is concerned, there has been a remarkable proliferation of research works focused on the development of suitable methods (chro-
mamotographic, spectroscopic/ spectrometric and DNA-
based techniques) to classify and discriminate among olive oils from different geographical origins\textsuperscript{8-10}. Others have conducted studies in order to establish geographical origin of the selected olive oils (‘Picholine marocaine’) by the assessment of different chemical components as geographical markers in combination with chemometric tools\textsuperscript{11}.

Olive oil is Tunisia’s main agricultural export, accounting for about 60\%, and has a fundamental importance for the country, employing within the sector about a million indirectly. Tunisia’s diverse olive varieties and cultivation systems are categorized by region. In the north, 100 feet per hectare of land is principally planted with ‘Chétoui’, ‘Sayali’ and ‘Jarboui’ olive trees. In the center of the country, on 50-60 feet per hectare are cultivated ‘Chemlali’ and ‘Oualatil’. The south consists of 17 feet per hectare of Zalmati, Zarrazi, and Chemlali\textsuperscript{12}. Over the olive crop season from 2014 to 2015, olive oil production in Tunisia has increased fourfold, making it the second largest producer after Spain. However, the challenge for Tunisia’s olive oil industry is not just to find ways to increase production but also to export less oil in bulk and more bottled and branded products. More than 75\% of the country’s output is exported in bulk to Italy and Spain, where it is mixed with local oil before being bottled and marketed as a product of those countries.

In the context of improving olive oil quality, since 2010, the Quality Department in the Tunisian Olive Oil Board has set a goal of establishing Protected Geographical Indication (PGI) labeled products. ‘Chétoui’ extra virgin olive oils (EVOOc) from Tebourba region were chosen thanks to its particular fatty acids composition and specific flavor. Therefore, the aim of this research study was to perform a physicochemical and compositional characterization of Tebourba olive oil as well as to determine its sensorial propri-
eties. Collaborating with Jaén University, some data are already available concerning this oil overall composition and quality, demonstrating the possibility of using phenolic compounds as ‘authentic markers’ to discriminate among EVOOc from Tebourba and other five north Tunisian regions.

The work described here constitute another step which, also, contributes to the establishment of PGI for Tebourba EVOO. The study of volatile profiles and sensory notes of oils produced in this region. A deep evaluation remains necessary to demonstrate the singularity of EVOOc from Tebourba and differentiate it from others EVOOc produced outside Tebourba regions.

2 MATERIALS AND METHODS

2.1 Oils samples

Sixty samples of EVOOc from different regions from the north of Tunisia (Tebourba (EVOOT); North (EVOON): Mornag, Sidi Amor, El Kef, Béja and Jendouba) and producers were used in this research. Over the olive crop seasons from 2010/2011 to 2013/2014, olive fruits (Olea europaea L.) were harvested at the same ripeness stage with the Ripening Index 2.90 and transformed into oil within 24 h in a modern mill. The oils samples were analyzed as soon as they arrived to the lab.

2.2 Free acidity, peroxide value and UV spectrophotometric index

Free acidity (FA), expressed as percent of oleic acid (% C18:1), peroxide value (PV), given as milliequivalents of active oxygen per kilogram of oil (meq. O₂ kg⁻¹) and UV absorption characteristic at 270 nm (K270) were determined according to the method of the Official Journal of the European Communities\textsuperscript{13}.

2.3 Sensory characterization

In the case of the characterization/valorization of monovarietal, protected designation of origin (PDO) and protected geographical indication (PGI)\textsuperscript{14, 15}, it is firstly necessary to verify that the sample has the characteristics provided in the extra virgin category using current methods\textsuperscript{2}, and to subsequently analyze it according to the old profile sheet\textsuperscript{13} to verify the presence of characteristic descriptors. The sensory characterization was performed by a fully trained analytical taste panel, composed of eight assessors, members of staff of ‘the Tunisian Board of Olive Oil’ (ONH). Each taster observed, smelled and tasted the oil under consideration in order to access the visual, olfac-
tory, gustatory and tactile or kinesthetic sensations. Knowing that samples have the same color (green), ten attributes were evaluated: seven during olfactory phase (fruity green/ ripe, grass/leaves, tomato, artichoke, almond, apple and banana), and three during the gustatory phase (bitter, astringent and pungent). Attributes were assessed on an oriented 10 cm line scale and quantified measuring the location of the mark from the origin. The data obtained
for the 10 descriptors were used to define the sensory profile for each sample (average values and their standard deviations). The quantitative sensory evaluation (SE) was the final global score attributed to each sample and ranged from 0 - 10.

2.4 Overall Quality Index

The Overall Quality Index (OQI) introduced by the International Olive Council was used to express EVOO quality numerically. The scale ranges from 0 to 10 and considers 4 quality parameters: the score of SE, FA, \( K_{270} \) and PV according to the following equation:

\[
OQI = 2.55 + 0.91\ SE - 0.78\ FA - 7.35\ K_{270} - 0.066\ PV
\]

2.5 Extraction of the volatile compounds

Volatile fractions of the extra-virgin olive oils were analyzed according to a modified method. Solid-phase microextraction (SPME) followed by GC-FID were used. Olive oil samples were conditioned to room temperature and then placed in a vial heater at 40°C. After 10 min of equilibration time, volatile compounds from headspace were adsorbed on a SPME fiber DVB/Carboxen/PDMS 50/30 µ (Supelco Co., Bellefonte, PA). Sampling time was 50 min at 40°C. Desorption of volatile compounds trapped in the SPME fiber was done directly into the GC injector. Volatiles were analyzed three times in duplicate experiments using a HP-6890 gas chromatograph equipped with a DB-Wax capillary column (60 m × 0.25 mm i.d., film thickness = 0.25 µm; J&W Scientific, Folsom, CA). Operating conditions were as follows: \( N_2 \) as carrier gas; injector and detector at 250°C; column held for 6 min at 40°C and then programmed at 2°C min\(^{-1}\) to 128°C. Quantification was performed using individual calibration curves for each identified compound by adding known amounts of different compounds to redeteriorated high-oleic sunflower oil. Compound identification was carried out on a HRGC-MS Fisons series 8000 equipped with a similar stationary phase column and two different lengths, 30 and 60 m, matching the Wiley/NBS Library, and by GC retention time against standards (Kovats indices are given in brackets): \( \langle E \rangle \)-hex-3-enal[1137], \( \langle Z \rangle \)-hex-3-enal[1156], \( \langle Z \rangle \)-hex-2-enal[1218], \( \langle E \rangle \)-hex-2-enal[1233], \( \langle E \rangle \)-hex-3-enol[1364], \( \langle Z \rangle \)-hex-3-enol[1383], \( \langle E \rangle \)-hex-2-enol[1399], hexanal[1074], hexan-1-ol[1355], pent-1-en-3-one[1018], \( \langle Z \rangle \)-pent-2-enal[1100], \( \langle E \rangle \)-pent-2-enal[1127], \( \langle E \rangle \)-pent-2-en-1-ol[1322], \( \langle Z \rangle \)-pent-2-en-1-ol[1327], pent-1-en-3-ol[1168], pentanal[980], pentan-1-ol[1261], hexyl acetate[1299], \( \langle Z \rangle \)-hex-3-en-1-yl acetate[1316], \( \langle E \rangle \)-hex-2-en-1-yl acetate[1337] and ethyl hexanone[1249].

Linoleic acid (LA), linolenic acid (LnA), soybean lipoxygenase (LOX), and reference compounds used for volatile identification were supplied by Sigma-Aldrich (St. Louis, MO, USA) except for \( \langle Z \rangle \)-hex-3-enal, which was generously supplied by S.A. Perlaron (Louvaine-La-Neuve, Belgium). Compounds such as \( \langle E \rangle \)-hex-3-enal, \( \langle Z \rangle \)-hex-2-enal, \( \langle Z \rangle \)-pent-2-enal, and pentene dimers were tentatively identified on the basis of mass spectra and their concentrations approximately quantified according to their available isomers. The 13-hydroperoxide derivatives from LA (13-HPOD) and LnA (13-HPOT) were prepared using soybean LOX. All chemicals used as standards and solvents had purity up to 99.0%. All the SPME operations were automated using a Combi Pal AutoSampler Varian (Walnut Creek, CA, USA).

2.6 Statistical analysis

All parameters were determined in triplicate for each sample. Analysis of variance (ANOVA) was applied in order to evaluate the influence of growing area conditions on ‘Chétoui’ olive oil (SPSS statistical package (Version 18.0 for Windows, SPSS Inc. Chicago, IL, 2009)). The results are reported as mean values and standard deviations. Significant differences among cultivars were determined by analysis of variance using a Duncan’s multiple tests. Differences were considered statistically significant when probability was greater than 99% (\( p < 0.01 \)). Pearson’s correlation coefficient was calculated in order to find relations between sensory attributes and volatile compounds. Principal components analysis (PCA) was applied to quality parameters, chemical and sensory data. PCAs were carried out for all raw data processed with a cross-validation method. Hierarchical cluster analysis (HCA) was used to obtain a dendrogram. Data were clustered by hierarchical complete-linkage clustering and squared Euclidean distance.

3 RESULTS AND DISCUSSION

3.1 Physicochemical parameters

The physicochemical quality parameters \( FA, K_{270} \) and PV of olive oils from the studied cultivars are represented in Table 1. All the analyzed oils showed very low values for the regulated physicochemical parameters valued (\( FA \leq 0.8\%, K_{270} \leq 0.220 \) and PV \( \leq 20\) meq. O₂.Kg\(^{-1}\)). All of them belonged to the ranges established for “extra virgin olive oil” (EVOO) category, as required by the European Community Regulation. No significant differences \( (p > 0.01) \) were detected on these parameters from an area to another. These results were consistent with the findings of other authors. They reported that, cultivar or origin area had no significant influence on these analytical parameters. However olive fly attacks, improper systems of harvesting, carriage and storage of olives, and technological treatments may favor the hydrolysis of triglycerides which will increase free fatty acid concentration and have the most influence on quality parameters.

Oils from different areas presented significant differenc-
Astringent Tunisian authors made up of primary and secondary varieties, as well as area olive oils from different cultivars but produced in the same flavor of factor. The influence of this parameter on the variation of the oils characteristics according to geographical growing areas was reached the highest level in EVOOT. The obtained results from sensory characterization showed that the intensities of the three positive descriptors (fruity, bitter and pungent) varied from one harvest to another. RDO from PA showed higher levels of fruity, bitter and pungent than RDO from C. The first fruity analogical descriptor for RDO from PA, the most often cited by tasters, was 'artichoke'. In the case of RDO from C, the olive oils were characterized by high intensity of 'fresh almond' note. This research made on French oils demonstrates that, even, olive oils produced in the same area (Provence-Alpes-Côte d’Azur) from different varieties present different sensory characteristics, so different flavors. In this sense, another study was carried in Italy, in order to demonstrate variety influence on virgin oil flavor. The research was made, for 4 years, on oil samples obtained from 18 ('Baia', 'Casaliva 1', 'Casaliva 2', 'Cornaloi', 'Favaroil', 'Francoil', 'Gargnà', 'Grignano', 'Leccino', 'Less', 'Maurino', 'Minioi', 'Mitria', 'Pendolino', 'Raza', 'Regina', 'Rossanello' and 'Trepp') cultivars grown in the same orchard in the western coast of the Garde Lake (northern Italy). The obtained results showed that the aromatic quality of virgin olive oil depends on genetic factor.

### 3.3 Aromatic compounds

The aim of increasing the quality standards for VOO is continuously stimulating the study of biochemical pathways related to organoleptic properties and the development of technological procedures to improve them. Volatile compounds are low-molecular weight compounds (less than 300 Da) that vaporize readily at room temperature. The major volatile compounds, usually found in extra virgin olive oil of high sensory quality, are the C5 and the C6 vola-

### Table 1

Physiochemical parameters and sensory evaluation of analyzed oils obtained from olives fruits grown in different areas.

<table>
<thead>
<tr>
<th>Areas</th>
<th>Tebourba</th>
<th>North</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters</td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Min</td>
</tr>
<tr>
<td>FA (% C18:1)</td>
<td>0.29</td>
<td>0.18</td>
</tr>
<tr>
<td>$K_{270}$</td>
<td>0.186±0.018a</td>
<td>0.159</td>
</tr>
<tr>
<td>PV (meq.O₂, kg⁻¹)</td>
<td>9.60</td>
<td>5.00</td>
</tr>
<tr>
<td>SE</td>
<td>7.83</td>
<td>7.28</td>
</tr>
<tr>
<td>OQI</td>
<td>7.54</td>
<td>7.45</td>
</tr>
</tbody>
</table>

Means within a row for each parameter marked with different lowercase letter (a and b) are significantly different ($p < 0.01$).

Note: FA - free acidity expressed as percent of oleic acid; $K_{270}$ - UV absorption characteristic at 270 nm; PV - peroxide value expressed as milliequivalents of active oxygen per kilogram of oil; SE - sensory evaluation ranged from 0 to 10; OQI - overall quality index ranged from 0 to 10.
method was established to determinate volatile compositions of olive oils. Therefore, in this study, the extraction of volatile compounds from oil samples was done by the modified method to detect, mainly, the aromatic components on C5 and C6 from LA and LnA.

Headspace solid-phase microextraction (SPME) followed by GC-FID were used to characterize the EVOOc volatile fractions. The detection of aroma volatile compounds emitted by EVOO was important for quality control of this product. Twenty one volatile compounds were identified in Fig. 2.

\((E)\)-hex-2-enal represented a main compound extracted from all examined samples. The means values for EVOOT and EVOON were respectively 13.4 and 9.4 mg / kg. Some researchers found that (E)-hex-2-enal was the dominant volatile in ‘Chétoui’ oils profiles\(^7\). This compound could be, also, considered the main contributor to green, fruity, bitter and astringent attributes\(^27\).

The other identified compounds were mainly (E)-hex-3-enol, (E)-hex-2-enol, (E)-pent-2-enal, (Z)-hex-3-enol, (Z)-pent-2-en-1-ol, hexanal and hexan-1-ol. The contents of (E)-hex-3-enol and (E)-pent-2-enal varied widely according to the production area. Tebourba oils showed the highest means values in (E)-hex-3-enol and (E)-pent-2-enal 6.2 and 3.7 mg / kg, respectively, whereas samples from the north recorded the lowest means values 3.2 and 1.3 mg / kg, respectively.

The highest means values of (Z)-pent-2-en-1-ol, (E)-hex-2-enol and hexan-1-ol were found in Tebourba oils increasing their proportion in C5 and C6 alcohols (Fig. 2). EVOON were more rich than EVOOT in (Z)-hex-3-enol and hexanal.

In overall quality of olive oil, the aroma plays an important role in directing consumer preference so it is important to determine, at least, the relative amounts of the aroma components of olive oils. Unfortunately, the unique and delicate EVOO flavor depends on the interaction of hundreds of compounds: aldehydes, alcohols, esters, hydrocarbons, ketones, furans and others\(^26\).

To characterize aroma profiles of studied oils, all identified compounds (Fig. 2) were regrouped in aldehydes, alcohols, esters and ketone. Means and boxplots for each monovarietal oils were represented in Fig. 3. Standardization of all values to mean zero and unit variance was necessary to display them on the same graph, enabling a helpful visualization of apparent differences and/ or similarities between groups.

C5 (Pentanal, (Z)-pent-2-enal and (E)-pent-2-enal) and C6 (Hexanal, (E)-hex-3-enal, (Z)-hex-3-enal, (Z)-hex-2-enal and (E)-hex-2-enal) aldehydes were the major fraction in ‘Chétoui’ analyzed oils profiles. The highest content was recorded in EVOOT (49.38%). However, in EVOON, aldehydes represented 47.72%. The contribution of these components is crucial to olive oil quality and is related to posi-

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**Fig. 1** Sensory profiles of extra virgin olive oils from ‘Chétoui’ cultivars grown in Tebourba (a), the other studied regions of the north of Tunisia (b).

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**Fig. 2** Identification of the volatile compounds from EVOOc with GC-FID.
Aldehydes are usually characterized by intense sensory descriptions associated with green, fruity and bitter sensory notes. Alcohols fraction were also important in EVOOc studied samples, in a range between 44.07 and 45.81. C5 (Pent-1-en-3-ol, Pentan-1-ol, (E)-pent-2-en-1-ol and (Z)-pent-2-en-1-ol) and C6 (Hexan-1-ol, (E)-hex-3-enol, (Z)-hex-3-enol and (E)-hex-2-enol) identified alcohols were abundant. As well known, C6 alcohols are derived from the lipoxygenase (LOX) pathway that involves a series of enzymes that oxidize, cleave (hydroperoxide lyase, HPL) and are reduced to alcohols (alcohol dehydrogenase, ADH).

The minor fractions in Chétoui analyzed oils profiles were esters (Ethyl hexanoate, hexyl acetate, (Z)-hex-3-en-1-yl acetate and (E)-hex-2-en-1-yl acetate) ranged between 2.37 and 6.89%, and ketone (pent-1-en-3-one) ranged between 1.02 and 1.62%. Esters are considered as important constituents of many fruits and linked to the positive fruity aroma of olive oil. Generally, the formation of volatile esters involves the alcohol acetyl transferase action. The presence of ketone in the aroma profile in EVOOc was probably related to the activity of indigenous microflora in the fruit. C5 Ketones are generally linked to positive sensory characteristics and proposed as markers of virgin olive oil quality.

These results are in concordance those obtained by Tunisian researchers. They focused on the variation of volatile compounds profiles of Chétoui olive oils induced by growing area. The olives from Chétoui cultivar were collected in 14 different Tunisian regions: Amdoun, Testour, Bouarada, Goubellat, Lakouet, Gaafour, Amayem, Chuiogui, Fig. 2 Volatile contents in Chétoui extra virgin olive oils produced in Tebourba and different geographical areas from the north of Tunisia.

Fig. 3 Profiles of volatile compounds (%) of extra virgin olive oils from Chétoui cultivar grown in Tebourba and selected regions from the north of Tunisia.
Sensory and volatile profiles of ‘Chétoui’ extra virgin olive oils

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Slouguia, Elles, Sers, Borj El Anri, Jendouba, Zaghouan. The extraction of olive oils was processed by the laboratory mill. The application of SPME to analysis of virgin oil head-space allowed the detection of significant differences in the proportions of volatile constituents from oils of various geographical origins. This would probably affect olive oils flavors. As the harvesting period and extraction conditions were similar for all studied samples, the results indicate that genetic factor and environmental conditions influence the volatile production.

After assessing the chemical and sensorial characteristics of monovarietal olive oils, some considerations could be drawn about correlations between volatile compounds and sensorial attributes (Table 2).

For the olfactory descriptors, ‘grass/leave’ note was, especially, correlated with (Z)-hex-3-enol \( r = 0.891 \) which explains the dominance of ‘green’ note in EVOON. However, ‘tomato’ note was, especially, correlated to (E) -pent-2-enal \( r = 0.978 \). Therefore, this note characterized EVOOT. ‘Fruity’, ‘artichoke’, ‘almond’, ‘apple’ and ‘banana’ notes were, mainly, correlated to (E) -hex-3-enal \( r = 0.804 \), (E) -hex-3-enal \( r = 0.822 \), (E) -pent-2-enal \( r = 0.665 \), hexanal \( r = 0.683 \) and hexan-1-ol \( r = 0.862 \); respectively.

The taste notes of ‘astringent’, ‘bitter’ and ‘pungent’ were, mainly, correlated to (E) -hex-2-enal \( r = 0.658 \), pent-1-en-3-one \( r = 0.814 \) and pentan-1-ol \( r = 0.833 \); respectively.

In this way, many correspondences were found between sensory notes and chemical compounds, most of them in agreement with the literature \(^{3,4,31,32}\).

Most of the volatile showed an average content higher than odor and taste thresholds, explaining the correlations to sensory attributes. Other volatile compounds, correlated to sensory attributes, showed concentrations different from odor and taste thresholds: pentan-3-one had content lower than odor threshold; (E)-pent-2-enal showed concentration higher than odor, but smaller than taste threshold.

Some volatiles were correlated to the sensory notes even if their concentration was smaller than a given thresholds. This could be due to a synergic effect with other compounds for that specific sensory note. The odor threshold is possibly more effective than that taste.

The application of PCA algorithm to all collected data from olive oils samples showed two distinctive groups. The bi-plot graph for the Scores (Fig. 4a) and Loadings (Fig. 4b) were obtained.

The data distribution shown on the Scores graph (Fig. 4a) represented the influence of the geographical area on PC1. Thus, oils obtained from Tebourba were distributed on the top side of the graph, while the oils obtained from North of Tunisia (Sidi Amor, Mornag, Béjâ, Jendouba and El Kef) were distributed on the bottom side of the graph. In order to detect important variables, a two-dimensional scatter plot of loadings for the first two components from PCA was represented in Fig. 4b. The first two factors were sufficient to account for 93.48% of the total \( \rho_{PC-1} = 70.97 \% \); PC- 2: 22.51%. If the two graphs in Fig. 4 were compared, we observed that OQL; pentanal; (E)-hex-3-enol; (E)-pent-2-enal; tomato; fruity; banana; pentan-1-ol; almond; (E) -hex-2-enol; hexan-1-ol; (E) -hex-2-enol; apple, hexyl acetate; artichoke; bitter; SE; (E)-hexyl-2-en-1-yl acetate; pungent; (Z) -pent-2-enal; pent-1-en-3ol and (Z) -pent-2-en-1-ol were correlated with oils obtained from Tebourba.

<table>
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<th>Sensory descriptors</th>
<th>Volatile compounds</th>
<th>( r )</th>
<th>( \rho )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruity</td>
<td>(E)-hex-3-enal</td>
<td>0.804</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Hexan-1-ol</td>
<td>0.692</td>
<td>0.000</td>
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<td></td>
<td>Hexyl acetate</td>
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<td>0.003</td>
</tr>
<tr>
<td>Grass/leave</td>
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<tr>
<td></td>
<td>(E)-pent-2-en-1-ol</td>
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<td>Hexanal</td>
<td>0.683</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(Z)-hex-3-enol</td>
<td>0.539</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>(E)-pent-2-enal</td>
<td>0.512</td>
<td>0.005</td>
</tr>
<tr>
<td>Banana</td>
<td>Hexan-1-ol</td>
<td>0.862</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(Z)-pent-2-en-1-ol</td>
<td>0.800</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Hexanal</td>
<td>0.745</td>
<td>0.002</td>
</tr>
<tr>
<td>Bitter</td>
<td>Pent-1-en-3-one</td>
<td>0.814</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(E)-pent-2-enal</td>
<td>0.736</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(E)-hex-3-enol</td>
<td>0.608</td>
<td>0.004</td>
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<tr>
<td>Pungent</td>
<td>Pentan-1-ol</td>
<td>0.833</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Pent-1-en-3-one</td>
<td>0.828</td>
<td>0.000</td>
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<tr>
<td></td>
<td>Pent-1-en-3-ol</td>
<td>0.779</td>
<td>0.001</td>
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</tbody>
</table>

Significant correlation at \( \rho < 0.01 \).

J. Oleo Sci. 65, (7) 533-542 (2016)
while PV; $K_{C50}$; FA; (Z)-hex-2-enal; astringent; (Z)-hex-3-en-1-yl acetate; (Z)-hex-3-en-1-yl; hexanal; grass/leave; (E)-pent-2-en-1-ol; pent-1-en-3-one; ethyl hexanoate and (Z)-hex-3-enol were correlated with oils obtained from the north of Tunisia. So, the PCA applied to all collected data gave very good results showing high positive correlation between oils from Tebourba and fruity properties while oils from surrounding regions seem correlated with green properties. These results were consistent with those obtained in Fig. 2 and Table 2.

Similarly, HCA was performed to detect the influence of geographical areas on potential sample clustering (Fig. 5). The dendrogram indicated that, at rescaled distance of twenty, samples were clustered into two groups by geographical areas: Tebourba and North of Tunisia (Sidi Amor, Mornag, Béja, Jendouba and El Kef).

4 CONCLUSIONS

The current study demonstrated the influence of geographical origin of Tunisian ‘Chétoui’ extra virgin olive oils on their sensory and volatile profiles. Sensory characterization of ‘Chétoui’ oils samples led to the perception of ten sensory attributes. EVOOT presented high levels of ‘fruity’ and ‘tomato’ notes. Whereas, EVOON presented a high level of ‘grass/leave’ note. In terms of chemical composition, the aliphatic C6 compounds were the major volatile components detected in EVOOc. Concentrations of each C5 or C6 compound changed from one sample to another according to olive oils origins. These quantitative differences could notably modify the sensory perceptions on oils. In fact, calculating Pearson’s correlation revealed that the high content on (Z)-pent-2-en-1-ol was responsible for a perception of a high note of ‘tomato’ in EVOOT whereas a high content (Z)-hex-3-enol was responsible for a perception of a high note of ‘green grass’ on EVOON.

Chemometric evaluation of data, obtained through Panel test evaluation and headspace analysis, showed a correlation between oils aroma and olives growing areas. On the basis of the results, EVOOc were divided into two separated groups. EVOOT were classified as fruity oils, while the majority of EVOON were classified as oils with green properties. With the obtained results, it is possible to conclude that Tebourba region seems to produce olive oils with high physico-chemical standards of quality and particular sensory proprieties.

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J. Oleo Sci. 65, (7) 533-542 (2016)

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