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Aroma characterization of ripe date fruits (*Phoenix dactylifera* L.) from Algeria

El Yamine MEZROUA[1,2*], AbdelNacer AGLI[2], Guido FLAMINI[3,4], Sofiane BOUDALIA[5] and Hayet OULAMARA[2]

[1]Département de Biologie, Faculté des Sciences de la Nature et de la vie et des Sciences de la terre et de l'univers, Université 8 Mai 1945, 24000, Guelma, Algeria.
[2]Laboratoire de Nutrition et Technologie Alimentaire, INATAA, Université des Frères Mentouri, 25000, Constantine, Algeria.
[3]Dipartimento di Farmacia, via Bonanno 6, 56126 Pisa, Italy.
[4]Interdipartimentale di Ricerca, "Nutraceutica e Alimentazione per la Salute", Università di Pisa, Italy.
[5]Département d'Ecologie et Génie de l'Environnement, Université de 8 Mai 1945, Guelma, Algeria.

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The headspace of eight Algerian date varieties with low market value were analyzed for their aroma compounds using solid phase micro extraction and gas chromatography combined with mass spectrometry. In this study, 61 identified compounds were categorized in various chemical classes on the basis of their functional groups, alcohols, esters, aldehydes, terpenoids, ketones, hydrocarbons, and ethers. Twenty specific volatiles were found to be representative of a single variety and four shared molecules were exclusively observed in all the studied dates. Some dates such as Bent Qbala, Litima, and Timjouhart were statistically different from the other varieties which presented on the contrary a significant similarity between them. In the present study, forty eight new volatile compounds were identified which could be useful for the characterization of the Algerian dates.

Key words: Date fruit, Algerian varieties, aroma, solid phase microextraction.

INTRODUCTION

The date (*Phoenix dactylifera* L.) is the most important agricultural product in arid regions, such as Southern Algeria, seeing its socio-economic value for the populations of oases. Several studies have shown the antioxidant activity of date (Benmeddour et al., 2013; Mansouri et al., 2005) and its technological aptitude for the manufacture of different products such as syrup, vinegar, etc. (Belguedj et al., 2015; Benamara et al., 2008). Date fruit has higher sensory quality which is due to its wonderful flavour. This characteristic is one of the critical point for consumer's acceptability and it draws the scientist and the investor attention. Consequently, it is important to determine molecules that constitute it (Biniecka and Caroli, 2011). About 360 compounds were detected in strawberry flavour, more than 600 in coffee and around 850 in wine (Crouzet, 1998). These

*Corresponding author. E-mail: lyamine_mezroua@yahoo.fr. Tel: (+213) 6 70 26 61 05. Fax: (+213) 31 60 02 51.

compounds belong to many chemical classes (Crouzet, 1998). Moreover, the climatic conditions such as sunlight and agricultural practices can influence the harvested product flavour (El Hadi et al., 2013). Likewise, some researchers showed the environment effect on raspberry aroma (Moore et al., 2002).

Only a few workers reported the volatile compounds of dates. Jaddou et al. (1984) studied the variety of Iraki Zahdi. Reynes et al. (1996) analyzed the volatiles of Tunisian varieties: Alligh, Deglet Nour, and Kentichi. Harrak et al. (2005) identified the volatiles of some Moroccan varieties such as Aziza, Boufeggous, Bouskri, Bousthammi Noire, Iklane, Jihel, Mejhoul, and Najda, and they detected 47 volatile compounds. These studies showed a great difference in the volatile composition of dates.

In Algeria, there are many varieties of dates which differ in colour, morphology, flavor, and geographical distribution which made them different from the dates of other countries.

The majority of date varieties suffer each season from very important crop loss, because of limited marketing of these dates. Their crop is destined for animal feeds with low prices causing huge economic losses for the farmers. These conditions push the scientist to search new opportunities to use and transform these date varieties into high-value products to valorize them. Fruit aroma is in much demand in food industry for aromatized products. Dates aroma can add to new flavour for the dairy product processors, because in Algeria the dates are often eaten with milk or fermented milk.

To the best of our knowledge, all the researches carried out on the dates from Algeria studied their physico-chemical composition and their potential for transformation into various products; no previous research was performed on the volatile compounds of Algerian dates which are different from others in the geographical location and organoleptic characteristics. Therefore, the aim of this study is to identify, for the first time, the aroma compounds of eight varieties of Algerian date palm fruit that have a low market value so as to characterize their flavour. This work can be of interest to processors to produce processed products based on dates or flavour extracts from low market varieties to valorize them. The determination of these chemicals was carried out using a recent method, solid phase microextraction (SPME) to sample the headspace around the fruits, and gas chromatography/mass spectrometry (GC/MS) for separation and identification of the sampled compounds.

MATERIALS AND METHODS

Collection and storage of date samples

Eight varieties of date palm fruit (*Phoenix dactylifera* L.) were collected according to their availability during the 2013 harvest season in three regions of Southern Algeria as follows: Biskra region: Ghars, Litima, Houbales and Hamraia; El Oued region: Tinicine and Tantbouchet; Ghardaia region: Timjouhart and Bent Qbala.

These regions are characterized by arid climate. The mean temperature is 21.8, 21.0 and 21.8°C in Biskra, Ghardaia and El Oued, respectively. The rainfall remains always limited; 141 mm in Biskra, 68 mm in Ghardaia, and 74 mm in El Oued.

Ripe fruits free of defects and without any disinfestation or other treatment were stored at -20°C in glass bottles, immediately after harvesting until analysis. The maturation of dates is empirically determined by date palm farmers based on date characteristics such as: size and shape, skin colour, flesh colour, and flesh firmness.

Aroma compounds analysis

A small quantity of date flesh (5 g) was put into a 25-ml glass vial. After the equilibration time for 30 min, the headspace of date flesh was sampled by Supelco (Bellefonte, PA, USA) SPME devices which were coated with polydimethylsiloxane (PDMS, 100 µm). SPME sampling was performed using the same new fibre, preconditioned according to the manufacturer instructions, for all the analyses. Sampling was accomplished in an air-conditioned room (22±1°C) to guarantee a stable temperature.

After the equilibration time, the fibre was exposed to the headspace for 50 min. Once sampling was finished, the fibre was withdrawn into the needle and transferred to the injection port of the GC-MS system. All the SPME sampling and desorption conditions were identical for all the samples. Furthermore, blanks were performed before each first SPME extraction and randomly repeated during each series. Quantitative comparisons of relative peaks areas were performed between the same chemicals in the different samples.

GC-Electron Impact Mass Spectrometry analyses were performed with a Varian (Palo Alto, CA, USA) CP 3800 gas chromatograph equipped with a DB-5 capillary column (30 m × 0.25 mm × 0.25 µm; Agilent, Santa Clara, CA, USA) and a Varian Saturn 2 000 ion trap mass detector.

The analytical conditions were as follows: injector and transfer line temperatures were 220 and 240°C, respectively; oven temperature was programmed from 60 to 240°C at 3°C min^{-1}; helium at 1 mL min^{-1} was used as the carrier gas; splitless injection.

Aroma compounds identification

The identification of the constituents was based on a comparison of the retention times with those of authentic samples, comparing their linear retention indices (LRI) relative to a series of *n*-hydrocarbons, and on computer matching against commercial (NIST, 2000; Adams, 2007) and home-made library mass spectra and MS literature data (Stenhagen et al., 1974; Adams, 2007). The home-made library was implemented using the function of the NIST software using both measurements from pure compounds or known mixtures subjected to GC-MS analysis.

Statistical analysis of data

The results were analyzed using Minitab software (Minitab® version 16, Minitab Ltd, United Kingdom). To study the similarities between the date varieties, a hierarchical clustering of date varieties was performed on the basis of the presence or absence of number of aroma compound in each variety of date. A factorial correspondence analysis (FCA) was executed to reveal relationships that would not be detected in the varieties of pairs of hierarchical clustering.

RESULTS AND DISCUSSION

Aromatic profile of date samples

The headspace analyses of the eight Algerian date varieties permitted to characterize 61 volatile compounds (Table 1) among them 48 specific compounds were identified only in these Algerian date varieties and could characterize them. The volatiles can be sorted into eight chemical classes: alcohols, esters, aldehydes, terpenoids, ketones, saturated hydrocarbons, unsaturated hydrocarbons, and ethers. Comparison with previous studies of Jaddou et al. (1984) and Reynes et al. (1996) revealed that some similarities were observed with our date samples (Table 1; footnotes c,d, and e): four aldehydes, two saturated hydrocarbons, three alcohols, two ketones, one terpenoid and one ester, that is, hexanal, octanal, nonanal, decanal, *n*-hexadecane, *n*-heptadecane, 1-hexanol, 1-octen-3-ol, 1-octanol, 6-methyl-5-hepten-2-one, 2-undecanone, limonene, and ethyl acetate. None of unsaturated hydrocarbons and ethers which were identified in the volatile profile of Algerian dates were found in the precedent studies.

Analysis of aroma compounds of Algerian date (Table 2) showed that there were only four shared compounds in all the studied varieties: ethyl acetate, nonanal, decanal, and (*E*)-geranyl acetone. Other shared volatiles by seven varieties (Table 1) were isopentyl alcohol, 2,3-butandiol, 6-methyl-5-hepten-2-one, *n*-tetradecane, *n*-pentadecane and *n*-hexadecane. If we consider only six varieties, the shared compounds extend also to octanal, (*E*)-2-nonen-1-ol, and dodecanal. Some volatiles were only identified in two varieties, such as 2-pentyl furan, ethyl hexanoate, limonene, phenylethyl alcohol, 1-nonanol, 1-decanol, ethyl nonanoate, (*Z*)-2-tridecene, 1-pentadecene, methyl dodecanoate, methyl tetradecanoate and ethyl tetradecanoate. The difference in volatile composition of varieties may be due to the presence or absence of precursors and their content as well as to maturation conditions, which controls the biosynthesis of aroma compounds. Yu et al. (2017) found the candidate genes in the biosynthesis of fruit aroma, notably terpenoid molecules. Volatile compounds of fruit aroma were derived from various molecules including phytonutrients such as carotenoids, phenols, fatty acids, terpenoids and amino acids (Goff and Klee, 2006). β-Ionone and β-cyclocitral resulting from the degradation of β-carotene and lycopene during maturation stage (Crouzet, 1998). Saturated hydrocarbons may be produced from lipids. The mechanism of alcohols formation may involve the decomposition of hydroperoxides of the unsaturated fatty acids and some may also form the reduction of carbonyl compounds which are present in date flavour (Jaddou et al., 1984). Volatile esters are formed by esterification of alcohols by alcohol acetyltransferase, normally using a CoA moiety or CoA-ester as the acyl donor during the ripening of many fruits (Beaulieu, 2006). Ethyl acetate was also formed from carbohydrate fermentation by microorganisms. Aldehydes arise from the enzymatic degradation of lipid and/or are produced from free fatty acids, such as linoleic and linolenic acids, via the lipoxygenase activity of amino acids such as acetaldehydes from alanine (Grechkin et al., 2006). Furthermore, some of these compounds may be produced by the plant as a response to different biotic and abiotic stress in the growth habitat. A number of shared compounds were noted between Tinicine and Hamraia and between Tinicine and Litima (19 in both cases).

Moreover, twenty specific aroma compounds (Table 2) were identified; 1-butanol in Tantbouchet, 2-octen-1-ol, 1-octanol, methyl octanoate, 2-ethyl-3-hydroxyethyl 2-methylpropanoate, (*Z*)-2-octenal, (*E*)-2-octenal, 2-undecanone and (*E*)-β-ionone in Litima, isopentyl acetate, ethyl heptanoate, ethyl dodecanoate, 2-phenylethyl acetate and styrene in Bent Qbala, (*Z*)-4-heptenal in Timjouhart, (*E*)-2-nonenal and 2-methyl tetradecane in Hamraia, (*E*)-2-decenal and *n*-dodecane in Ghars, *cis-threo*-davanafuran in Tinicine. It was clear that Litima and Bent Qbala were the richest varieties in specific volatile compounds (8 and 5, respectively). These results may be due to the presence of enzymes and precursors responsible for the biosynthesis of specific aroma compounds in these varieties. This explains the clear separation of these varieties observed in the dendrogram (Figure 3).

Chemical classes of volatile compounds

The molecules responsible for the flavour consist of a hydrocarbon skeleton which can be linear, cyclic or aromatic. Almost all the chemical functions carried by these chains are represented: alcohols, aldehydes, esters, ethers, phenols, sulphur derivatives, and heterocycles (Fernandez and Cabrol-Bass, 2007).

The total amounts of the different chemical classes of volatile compounds identified in the eight varieties of Algerian dates are as shown in Figure 1. It is apparent that the Bent Qbala variety had the high amount of alcohols and esters, while the Tantbouchet variety was distinguished by the high amount of aldehydes. Important levels of terpenoids and ketones were evidenced in the Ghars variety, while hydrocarbons were essentially observed in Hamraia one. Finally, the Tinicine variety was characterized by ethers.

The Hierarchical Cluster Analysis (Figure 2), revealed the existence of two varieties clusters (Distance = 0.53). The first one was formed by Ghars, Hamraia, Houbales, Tinicine and Tantbouchet, whereas Litima, Timjouhart and Bent Qbala contribute to the second cluster. A great similarity was noted between Ghars and Hamraia varieties, which was rich in alcohols, aldehydes and saturated hydrocarbons. Analogously, Litima and

Table 1. Major and minor aroma compounds[a] of Algerian date varieties and its linear retention indices and detection threshold of some compounds.

Compound	l.r.i.[b]	BQ	GH	HA	HO	TAN	LI	TIN	TIM	Average	Detection threshold (µg/kg)[f]
Major volatiles											
(E)-Geranylacetone	1455	1.0	40.1	31.6	27.2	18.4	13.1	30.1	14.9	22.05	-
Ethyl acetate[e]	614	22.7	10.8	7.3	14.2	6.3	7.8	4.6	18.2	11.49	8.5
Isopentyl alcohol	763	29.3	-	3.3	6.3	5.8	11.6	12.0	9.8	9.76	-
Decanal[d]	1206	0.3	11.3	12.0	10	11.9	4.4	9.8	10.8	8.81	-
2-Propanol	516	27.1	-	-	3.3	-	14.4	-	19.3	8.01	-
Minor volatiles											
6-Methyl-5-hepten-2-one [d.e]	987	-	10.3	2.5	6.5	5.7	2.6	5.5	3.2	4.54	-
Nonanal[c.d.e]	1102	0.2	4.9	3.7	6.0	9.8	1.8	5.4	4.3	4.51	-
2,3-Butandiol	789	0.2	2.7	3.5	4.2	2.7	0.8	2.8	-	2.11	-
n-Tetradecane	1400	-	1.0	4.4	1.6	3.3	1.4	2.4	1.2	1.91	-
Undecanal	1308	-	2.1	1.5	-	5.3	-	1.9	1.0	1.48	-
n-Pentadecane	1500	-	0.5	4.0	1.7	2.1	1.8	0.6	0.7	1.43	-
Octanal[c.d.e]	1003	0.3	1.0	0.7	0.6	5.6	-	-	0.8	1.13	-
n-Hexadecane [c]	1600	-	0.8	0.9	1.1	2.2	0.8	2.3	0.5	1.08	-
Ethyl decanoate	1395	3.7	-	-	-	-	2.1	0.7	1.5	1.00	-
Ethyl octanoate	1195	3.6	-	-	-	-	1.7	-	2.6	0.99	-
(E)-2-nonen-1-ol	1171	-	1.3	1.3	1.0	1.5	-	1.1	1.4	0.95	-
1-Octen-3-ol[d]	980	-	0.7	-	-	1.6	2.5	2.1	-	0.86	1.4 - 10
1-Hexanol[d.e]	873	0.4	-	0.5	-	-	3.9	-	1.5	0.79	2.5
n-Heptadecane[c]	1700	-	0.9	1.6	0.8	-	1.3	1.7	-	0.79	-
3-Ethyl-1-hexanol	1033	-	-	0.5	0.8	3.9	-	0.6	-	0.73	-
Phenylethyl alcohol	1110	2.9	-	-	2.9	-	-	-	-	0.73	-
Dodecanal	1409	-	0.8	1.9	1.0	-	0.5	1.1	0.4	0.71	-
Hexanal[c.d.e]	804	-	-	1.2	-	2.0	0.6	1.3	0.5	0.70	4.5×10^{-3}
1-Pentadecene	1492	-	-	3.7	-	-	-	1.5	-	0.65	-
Methyl decanoate	1327	0.4	-	0.9	-	-	3.4	-	-	0.59	-
1,3-Butandiol	788	-	0.7	1.5	1.1	0.2	-	0.6	-	0.51	-
(Z)-2-Octenal	1048	-	-	-	-	-	4.0	-	-	0.50	-
β-Cyclocitral	1222	0.2	-	0.4	0.5	-	1.8	1.0	-	0.49	-
n-Tridecane	1300	-	1.5	-	1.1	-	-	-	0.7	0.41	-
Limonene[e]	1032	-	0.6	-	-	2.6	-	-	-	0.40	0.01
(E,E)-Farnesyl acetate	1843	-	-	-	-	-	1.1	1.4	0.7	0.40	-
2-Methyltetradecane	1462	-	-	2.9	-	-	-	-	-	0.36	-
1-Butanol	659	-	-	-	-	2.6	-	-	-	0.33	0.5
Isobornyl acetate	1287	0.2	-	-	-	-	0.5	1.3	-	0.25	-
Methyl dodecanoate	1526	0.2	-	-	-	-	1.8	-	-	0.25	-
n-Octadecane	1800	-	-	-	0.7	-	0.7	0.6	-	0.25	-
(Z)-2-Tridecene	1304	-	-	-	1.3	-	0.6	-	-	0.24	-
Methyl tetradecanoate	1727	-	-	1.3	-	-	0.6	-	-	0.24	-
1-Decanol	1273	-	-	-	-	-	-	0.8	0.8	0.20	-
Ethyl nonanoate	1297	1.1	-	-	-	-	-	-	0.5	0.20	-
Ethyl tetradecanoate	1796	1.1	-	-	-	-	-	-	0.5	0.20	-
Ethyl hexanoate	998	0.5	-	-	-	-	-	-	0.8	0.16	-
Methyl octanoate	1127	-	-	-	-	-	1.1	-	-	0.14	-
(E)-β-ionone	1486	-	-	-	-	-	1.0	-	-	0.13	7×10^{-6}
Isopentyl acetate	878	0.9	-	-	-	-	-	-	-	0.11	-
(E)-2-Octenal	1063	-	-	-	-	-	0.9	-	-	0.11	-
2-Ethyl-3-hydroxyethyl-2-methylpropanoate	1372	-	-	-	-	-	0.9	-	-	0.11	-

Table 1. Contd.

1-Octanol[c,d,e]	1072	-	-	-	-	-	0.8	-	-	0.10	-
2-Pentyl furan	993	0.2	-	-	-	-	0.5	0.7	-	0.09	-
2-Octen-1-ol	1071	-	-	-	-	-	0.7	-	-	0.09	-
1-Nonanol	1174	0.3	0.4	-	-	-	-	-	-	0.09	-
2-Undecanone[c]	1293	-	-	-	-	-	0.7	-	-	0.09	-
cis-threo-Davanafuran	1415	-	-	-	-	-	-	0.7	-	0.09	-
n-Dodecane	1200	-	0.6	-	-	-	-	-	-	0.08	-
(E)-2-Nonenal	1162	-	-	0.5	-	-	-	-	-	0.06	8×10^{-5}
2-Phenylethyl acetate	1258	0.5	-	-	-	-	-	-	-	0.06	-
(E)-2-Decenal	1266	-	0.5	-	-	-	-	-	-	0.06	-
Ethyl dodecanoate	1596	0.5	-	-	-	-	-	-	-	0.06	-
Styrene	898	0.4	-	-	-	-	-	-	-	0.05	-
(Z)-4-Heptenal	902	-	-	-	-	-	-	-	0.4	0.05	-
Ethyl heptanoate	1097	0.2	-	-	-	-	-	-	-	0.03	-
Total	-	98.4	93.5	93.6	93.9	93.5	94.2	93.9	97.0	-	-

BQ: BentQbala; GH: Ghars; HA: Hamraia; HO : Houbales; TAN: Tantbouchet; LI: Litima; TIN: Tinicine; TIM: Timjouhart. -Not identified, [a]Percentages obtained by FID peak area normalization (HP-5 column). [b]Linear retention indices (DB-5 column). [c]Found previously in Zahdi variety. [d]Found previously in Alligh. Deglet Nour and Kentichi varieties. [e]Found previously in Aziza, Boufeggous, Bouskri, Bousthammi noire, Iklane, Jihel, Mejhoul and Najda varieties. [F]threshold detection determined in water at 20°C.

Table 2. Aroma compounds availability in Algerian date varieties.

Aroma compound	Variety number
Ethyl acetate; nonanal; decanal; (*E*)-geranylacetone	8
Isopentyl alcohol; 2,3-butandiol, 6-methyl-5-hepten-2-one; *n*-tetradecane, *n*-pentadecane; *n*-hexadecane	7
Octanal; (*E*)-2-nonen-1-ol; dodecanal	6
1,3-Butandiol; hexanal; β-cyclocitral; undecanal; *n*-heptadecane	5
2-Propanol; 1-hexanol; 1-octen-3-ol; 3-ethyl-1-hexanol; ethyl-decanoate	4
Ethyl octanoate; isobornyl acetate; *n*-tridecane; methyl decanoate; *n*-octadecane; (*E,E*)-farnesyl acetate	3
2-Pentyl furan; ethyl hexanoate; limonene; phenylethyl alcohol; 1-nonanol; 1-decanol; ethyl nonanoate, (*Z*)-2-tridecene; 1-pentadecene; methyl dodecanoate; methyl tetradecanoate; ethyl tetradecanoate	2
1-Butanol; isopentyl acetate; styrene; (*Z*)-4-heptenal; (*Z*)-2-octenal; (*E*)-2-octenal; 2-octen-1-ol,1-octanol; ethyl heptanoate; methyl octanoate; (*E*)-2-nonenal; *n*-dodecane; 2-phenylethyl acetate; (*E*)-2-decenal; 2-undecanone; 2-ethyl-3-hydroxyethyl 2-methylpropanoate; *cis-threo*-davanafuran; 2-methyltetradecane; (*E*)-β-ionone; ethyl dodecanoate	1

Timjouhart mainly produced alcohols and esters. On the contrary, a great distance was evidenced between Bent Qbala and Tantbouchet varieties, probably because of their different content of esters.

The aroma compounds identified in this study were obtained through several mechanisms. The volatile compounds of food were formed by four different pathways: biosynthesis, direct enzymatic, indirect enzymatic (oxidative), and pyrolytic pathway (Crouzet, 1998). Esters are generally produced by the enzymatic way, starting from acyl-CoA and alcohols. The aldehydes reduction leads to primary alcohols and the acids derive by an enzymatic oxidation. Biosynthesis of monoterpenes was localized in the plastids, whereas that of sesquiterpenes takes place in the cytosol (Bouvier et al., 2005). However, both were synthesized starting from isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP), which were condensed into immediate precursors of terpenes, geranyl pyrophosphate (GPP) and farnesyl pyrophosphate (FPP), by a group of enzymes collectively known as short-chain isoprenyl diphosphate synthases (IDSs) (Wang and Ohnuma, 2000). Thermal degradation of β-carotene also leads to apocarotenes. Heating in aqueous medium of lycopene leads to the formation 6-methyl-5-hepten-2-one (Crouzet, 1998).

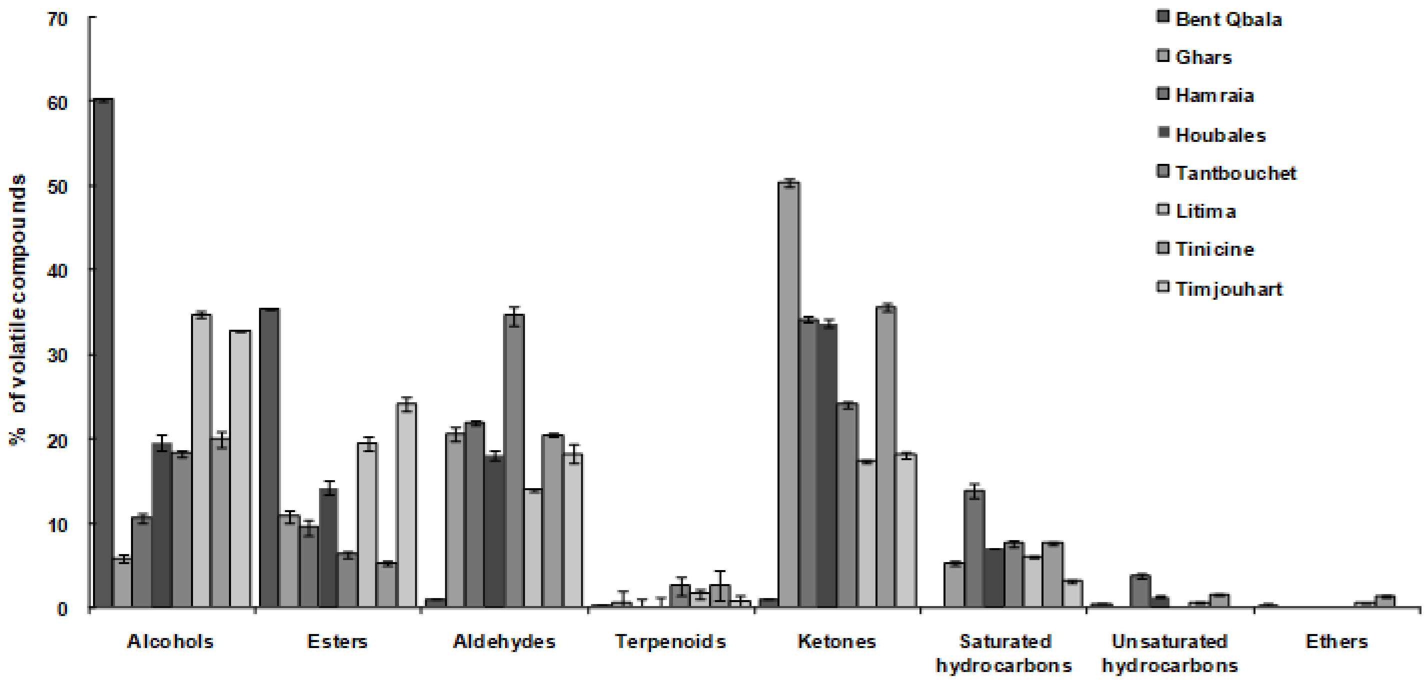

Figure 1. Evolution of each group of volatile compounds in Algerian date variety.

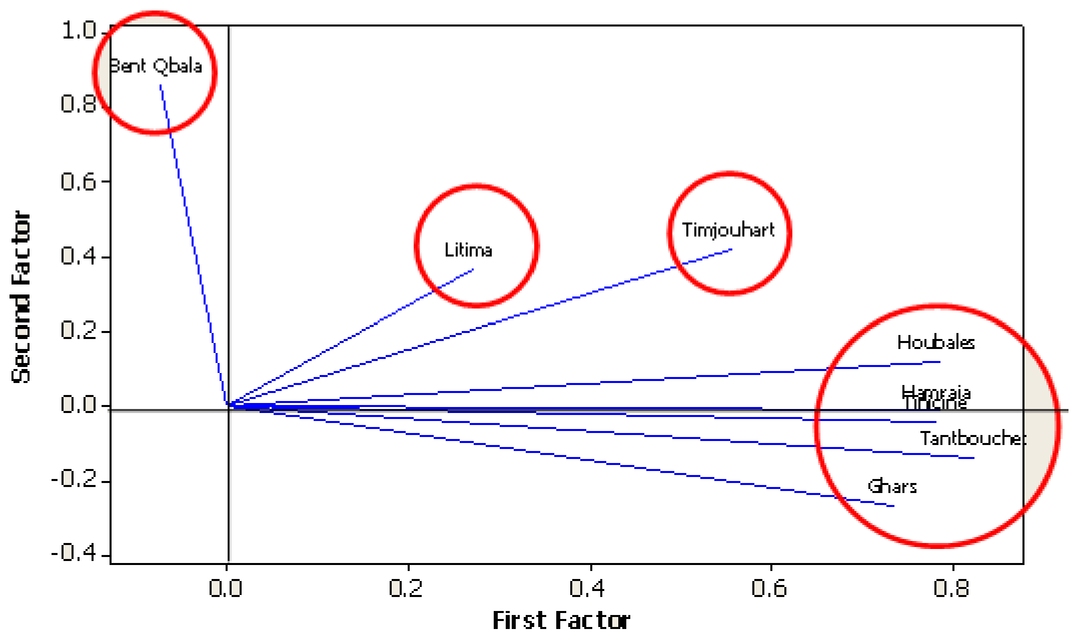

Figure 2. Factorial correspondence analysis based on the presence-absence of volatile compounds in Algerian date varieties.

Moreover, the volatile compounds do not participate in the same degree to the fruit aroma; there are some key compounds which strongly contribute to the final aroma. Alcohols, alkanes, acids and aldehydes were responsible for the *Dialium guineense* characteristic aroma note (Pélissier et al., 2001). However, linalool, limonene, 4-hydroxy-2,5-dimethyl-3(2H)-furanone, nonanal, and *(Z)*-3-hexenal caused the significant differences in odour

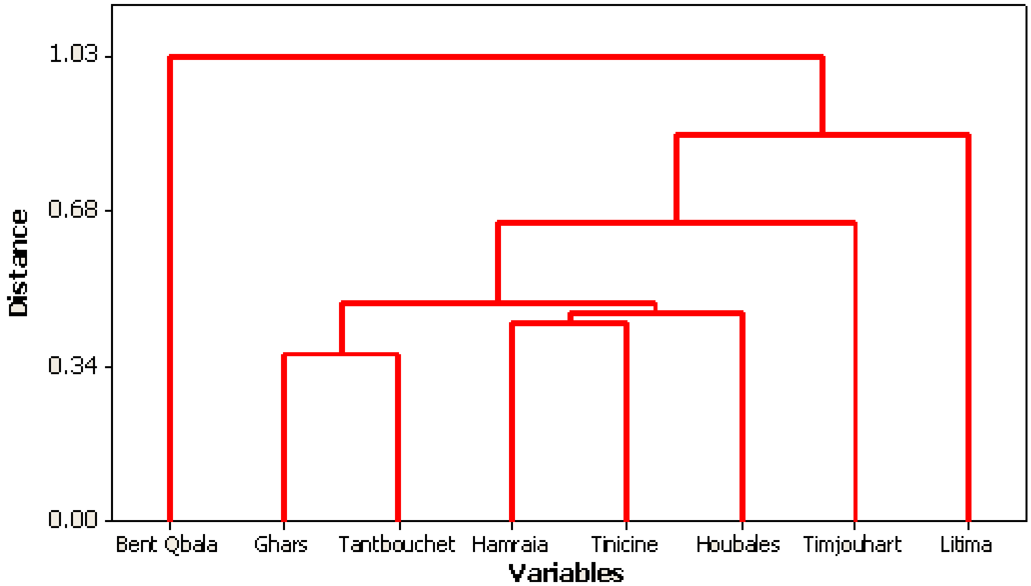

Figure 3. Hierarchical ascendant clustering dendrogram based on presence-absence of volatile compounds in Algerian date varieties.

profiles of different tamarinds (Lasekan and See, 2015). According to Kesen et al. (2013), aldehydes were found as the major aroma active compounds in olive oil, followed by alcohols such as: hexanal, octanal and guaiacol. The aliphatic hydrocarbons identified among the volatiles emitted by dates are probably only of secondary importance for their flavour (Jaddou et al., 1984). Furthermore, alcohols and carbonyl compounds such as, aldehydes and ketones are extremely important compounds involved in many odours such as fruity, floral, and lemon scents (Harrak et al., 2005).

Qualitative composition of Algerian date aroma

The factorial correspondence analysis based on the presence or absence of identified aroma compound in Algerian date varieties (Figure 2) separated the studied varieties into four groups. Three of them were formed by one variety only, that is, Bent Qbala, Litima, Timjouhart, while the fourth one grouped Houbales, Tinicine, Hamraia, Tantbouchet and Ghars. It is apparent that Bent Qbala was clearly separated from all the other varieties. The clustering analysis (Figure 3) tallied with the varieties' distribution in Figure 2 and showed that Bent Qbala variety was separated from other date varieties. This behavior is due to the presence of several esters, such as ethyl acetate, isopentyl acetate, ethyl hexanoate, ethyl heptanoate, ethyl octanoate, 2-phenylethyl acetate, ethyl nonanoate, methyl decanoate, ethyl decanoate, methyl dodecanoate, ethyl dodecanoate, ethyl tetradecanoate and to the lack of ketones and saturated hydrocarbons. The same observation was noted for Litima and Timjouhart varieties which were separated at a lower level, compared to Bent Qbala, from the other date varieties. Litima was characterized by the highest number of volatile compounds (35 out of 61; Table 1) and many esters (ethyl acetate, methyl octanoate, ethyl octanoate, methyl decanoate, 2-ethyl-3-hydroxyethyl 2-methylpropanoate, ethyl decanoate, methyl dodecanoate, methyl tetradecanoate and all the identified ketones (6-methyl-5-hepten-2-one, 2-undecanone, *(E)*-geranylacetone and *(E)*-β-ionone)). Furthermore, Timjouhart also emitted aldehydes (hexanal, *(Z)*-4-heptenal, octanal, nonanal, decanal, undecanal, dodecanal) and esters (ethyl acetate, ethyl hexanoate, ethyl octanoate, ethyl nonanoate, ethyl decanoate, ethyl tetradecanoate and did not produce ethers and unsaturated hydrocarbons.

The use of fruit aroma is frequent in the food, cosmetics and pharmaceutical industries to satisfy the different consumer requirements and improve the taste or smell of the product (Öğütcü et al., 2015; Janiaski et al., 2016) or else masking the undesirable impression such as the bitter taste of most drug in pharmaceutical industry. This study highlighted the aroma composition of some date varieties of low market value and may attract processors attention to exploit its flavour in different products. This field raises undoubtedly the market value of these dates and improves the economic yield of their farmers and encourages them to continue the planting of these varieties. The conservation of date fruit diversity is an important challenge to face the growing of commercial varieties planting which leads to extinction of other dates.

Conclusion

This study showed the aromatic compounds that are the origin of the superior sensory quality of some Algerian date varieties that have a low commercial value. Thirteen molecules were found in preceding studied dates and forty eight volatiles were identified for the first time and could distinguish the Algerian date from others previously studied. These data can aid processors to develop a new aroma and produce processed products from lower market varieties to valorize them. Further investigation is required to describe the key volatile compounds responsible for date characteristic aroma and to study the aromatic composition changes during maturation stages and storage time.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Adams RP (2007). Identification of essential oil components by gas chromatography mass spectroscopy. 4th Ed. Allured Publishing Corporation. 804p.

Beaulieu J (2006). Volatile changes in cantaloupe during growth, maturation and in stored flesh-cuts prepared from fruit harvested at various maturities. J. Am. Soc. Hortic. Sci. 131(1):127-139.

Belguedj N, Bassi N, Fadlaoui S, Agli A (2015). Contribution to industrialization through the improvement of the traditional process of local drink manufacturing based on dates « Rob ». J. New Sci. Agric. Biotechnol. (in French). 20(7):818-829.

Benamara S, Gougam H, Amellal H, Djouab A, Benahmed A, Noui Y (2008). Some technologic proprieties of common date (*Phoenix dactylifera* L.) Fruits. Am. J. Food Technol. 3(2):79-88.

Benmeddour Z, Mehinagic E, Le Meurlay D, Louaileche H (2013). Phenolic composition and antioxidant capacities of ten Algerian date (*Phoenix dactylifera* L.) cultivars: a comparative study. J. Funct. Foods 5(1):346-354.

Biniecka M, Caroli S (2011). Analytical methods for the quantification of volatile aromatic compounds. Trends Anal. Chem. 30(11):1756-1770.

Bouvier F, Rahier A, Camara B (2005). Biogenesis, molecular regulation and function of plant isoprenoids. Prog. Lipid Res. 44(6):357-429.

Crouzet J (1998). Food flavour. Techniques de l'ingénieur. F4100 :01-18. (in French).

El Hadi MA, Zhang FJ, Wu FF, Zhou CH, Tao J (2013). Advances in fruit aroma volatile research. Molecules 18(7):8200-8229.

Fernandez X, Cabrol-Bass D (2007). Flavour analysis.Techniques de l'ingénieur 3233:3201-3222. (in French).

Goff SA, Klee HJ (2006). Plant volatile compounds: sensory cues for health and nutritional value? Science 311(5762):815-819.

Grechkin AN, Bruhlmann F, Mukhtarova LS, Gogolev YV, Hamberg M (2006). Hydroperoxide lyases (CYP74C and CYP74B) catalyze the emolytic isomerization of fatty acid hydroperoxides into hemiacetals. Biochim. Biophys. Acta 1761(12):1419-1428.

Harrak H, Reynes M, Lebrun M, Hamouda A, Brat P (2005). Identification and comparison of volatile components of fruits of eight Moroccan date varieties. Fruits 60(4): 267-278. (in French).

Jaddou H, Mhaisen MT, Al-Hakim M (1984). Flavour volatile analysis of Zahdi dates by gas liquid chromatography. Date Palm J. 3(2):367-379.

Janiaski DR, Pimentel TC, Cruz AG, Prudencio SH (2016). Strawberry-flavored yogurts and whey beverages: What is the sensory profile of the ideal product? J. Dairy Sci. 99(7):5273-5283.

Kesen S, Kelebek H, Sen K, Ulas M, Selli S (2013). GC–MS–olfactometric characterization of the key aroma compounds in Turkish olive oils by application of the aroma extract dilution analysis. Food Res. Int. 54(2):1987-1994.

Lasekan O, See NS (2015). Key volatile aroma compounds of three black velvet tamarind (*Dialium*) fruit species. Food Chem. 168:561-565.

Mansouri A, Embarek G, Kokkalou E, Kefalas P (2005). Phenolic profile and antioxidant activity of the Algerian ripe date palm fruit (*Phoenix dactylifera*). Food Chem. 89(3):411-420.

Moore PP, Burrows C, Fellman J, Mattinson DS (2002). Genotye x environment variation in raspberry fruit aroma volatiles. Acta Hortic. 585:511-516.

National Institute of Standards and Technology (NIST) (2000). NIST mass spectral search program for use with Microsoft windows. http://chemdata.nist.gov/mass-spc/ms-search/docs/Ver20Man.pdf

Öğütcü M, Yılmaz E, Güneşer O (2015). Influence of storage on physicochemical and volatile features of enriched and aromatized wax organogels. J. Am. Oil Chem. Soc. 92:1429-1443.

Pélissier Y, Haddad C, Marion C, Milhau M, Bessière J (2001).Volatile constituents of fruit pulp of *Dialium guineense* Wild.(*Cesalpinaceae*). J. Essent. Oil Res.13(2):103-104.

Reynes M, Lebrun M, Shaw PE (1996). Identification of volatile date components and use for multivariate analysis to distinguish date varieties. J. Food Qual. 19(6):505-514.

Stenhagen E, Abrahamsson S, Lafferty MCFW (1974). Registry of Mass Spectral Data. Ed. Wiley. 4:3358.

Wang KC, Ohnuma S (2000). Isoprenyl diphosphate synthases. Biochim. Biophys. Acta 1529(1-3):33-48.

Yu Y, Bai J, Chen C, Plotto A, Yu Q, Baldwin E, Gmitter F (2017). Identification of QTLs controlling aroma volatiles using a Fortune x Murcott (*citrus reticulata*) population. BMC Genomics 18:646.