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Original Article

# Evolution of pigments and their relationship with skin color and sensory profile in date fruits (*Phoenix dactylifera* L.)

## Evolução dos pigmentos e sua relação com a cor da casca e o perfil sensorial em frutos de tâmaras (*Phoenix Dactylifera* L.)

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**Abstract**

Fresh dates of seventeen varieties and khalts from Southern Morocco were analysed for their colour, pigments content, and sensory profile. The results showed significant differences between the sensory profiles of the samples due to the variability of the genotype and their different origin. Fresh date varieties and khalts were a good source of β-carotene (0.49 - 10.86 µg of β-carotene /100 g FW). The results revealed that the date varieties and khalts were found to have an excellent functional composition and good sensory characteristics. Therefore, these varieties of Moroccan dates could be used for fresh consumption and in the processing industry, which will constitute a significant source of antioxidants.

**Keywords:** Morocco, sensory profile, carotenoids, khalt, *Phoenix dactylifera*.

**Resumo**

Tâmaras frescas de 17 variedades e khalts do sul do Marrocos foram analisadas por sua cor, conteúdo de pigmentos e perfil sensorial. Os resultados mostraram diferenças significativas entre os perfis sensoriais das amostras devido à variabilidade do genótipo e suas diferentes origens. Variedades de tâmaras frescas e khalts foram consideradas uma boa fonte de β-caroteno (0,49-10,86 µg de β-caroteno / 100 g FW). Na verdade, os resultados revelaram que as variedades de tâmaras e khalts apresentam uma boa composição funcional e boas características sensoriais. Portanto, essas variedades de tâmaras marroquinas podem ser usadas para consumo in natura e na indústria de processamento, que constituirá uma fonte considerável de antioxidantes.

**Palavras-chave:** Marrocos, perfil sensorial, carotenoides, khalt, *Phoenix dactylifera*.

## 1. Introduction

Dates (*Phoenix dactylifera* L.) are yielded mainly in the world's desert regions and are commercialized worldwide as a high-value fruit. The leading date producers in the world are located in the Middle East and North Africa, including Morocco.

Dates are an important fruit, especially in Africa, the Middle East, and Asia. In addition to its local and regional commercial value, the date palm has played an essential role in communities' diet and social life across the oases of the Middle East and North Africa for 4000 years (Anli et al., 2020).

Date palm tree and fruit have been appreciated for their many horticultural, nutritional, medicinal, economic, architectural, environmental, and multiple uses. In recent years, this fruit has also gained importance in world commerce. Over the past two decades, world-date production has more than doubled; this trend is expected to continue in line with FAO (Taghizadeh-Alisaraei et al., 2019). An increasing number of palms is widespread, with about 100 million trees cultivated worldwide and an annual yield of 7.5 million tons of dates (Ghnimi et al., 2018; Naushad And Lichtfouse, 2019).

During maturation, dates are subjected to various physiological, physicochemical, and biochemical changes. Among the phenomena associated with fruit, ripening is the change in the colour from green to yellow, or to orange, or sometimes to red. This change is due to carotenoid synthesis and chlorophyll degradation and is the first observable sign of maturation. During maturation, while the quantity of chlorophyll in fruit tissues decreases

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rapidly, the carotenoid content increases (Conesa et al. 2019). Chloroplasts, present in green fruits, are converted to chromoplasts by the degradation of chlorophylls and the synthesis of carotenoids during the maturation process (Sun et al., 2018). Carotenoids are the most common class of pigments in nature. Studies have shown that date fruits contain different classes of carotenoids; lutein, β-carotene, and neoxanthin (Boudries et al., 2007). In the Algerian fresh date varieties, β-carotene levels are reported to be 6.4, 3.3, and 2.5 µg / 100 g while lutein levels were 156, 28, and 33.6 µg / 100 g in Deglet Noor, Tantebouchte, and Hamraya, respectively (Boudries et al., 2007; Al-Farsi And Lee, 2008).

Carotenoids are found in all photosynthetic organisms and are responsible for the colour of most types of fruits (Cao et al., 2017). They are responsible for the colour of a wide range of vegetables (Nour et al., 2018). Carotenoids belong to natural fat-soluble pigments that give plants a bright colour. Because of their high content of provitamin A (Eggersdorfer And Wyss, 2018), they have a nutritional role and preserve the cell from the harmful effects of free radicals by acting as antioxidants (Weaver et al., 2018).

This research aimed to characterize the sensory profile and evaluate the skin colour of dates based on the chlorophyll degradation and carotenoid synthesis in seventeen varieties and khalts of dates.

## 2. Material and Methods

### *2.1. Plant material*

The assayed plant material included 17 date varieties and khalts; khalts are palm seedlings that grow naturally and spontaneously (hybrids with an unknown male parent). The prospecting of the site of interest was conducted during October 2018 during the harvest season. The average age of date trees is 80-85 years. The GPS coordinates of the site were 30°20' 59" N, the longitude of 5°50'06" W, and is located at an elevation of 731 m above the sea level and 0.76 Km far from the city of Zagora, Southern Morocco. The study area has been estimated to cover 39 hectares with a semi-arid climate and annual mean rainfall of 61 mm, and mean temperature of 22.9 °C. After the harvest at the Tamar stage, the fruits were picked, covered with dark polyethylene foil, transported in the laboratory, and immediately kept at – 20 °C until use. The following is a list of the varieties and khalts that have been studied:

BRR: Bourar ; MTN: Mentouj tissgharine ; BZG: Bouezgagh ; BST: Black bousthammi; KHL: Khalt iaach; LHD: Khalt Lohmadi ; ECT: Elahmer chetoui ; EED: Elasfer eljaid ; ZIE: Khalt zoubir ibn laouam ; HFL: Hak feddan laaneb ; IAS: Khalt iaissi ; EMS: Elmensoum ; IAH: Khalt abdelghani ; IKL: Iklane ; MEL: Mentouj lhaj lehbib ; KBN: Khalt bheir ngli ; KKL: Khalt khel.

### *2.2. Colour analysis*

The skin colour was analysed with a Minolta chromometer (CM-300, Minolta, Ramsey, NJ) and expressed in the colorimetric space CIE 1976 L* a* b*, where L* indicates the brightness from black (0) to white (100), a* green (-60) to red (60) and b* blue (-60) to yellow (60). The C* (Chroma = (a2 + b2) 1/2) values, which go from 0 (dull) to 60 (bright), were generally more abundant in the flesh than in the skin for the same variety. Hue angle (H◦ = tan – 1 (b / a)) is indicated in degrees: 0◦ (red), 90◦ (yellow), 180◦ (green) and 270◦ (blue). The correlation between skin colour, chlorophyll, and carotenoid content was investigated using system space coordinates L*, a*, b*.

### *2.3. Pigment analysis*

After measuring the colour variables, the fruits (with the skin) were cut into small pieces before being crushed and frozen in liquid nitrogen and stored at -40°C until analysis. The extraction of chlorophylls from fruit samples was carried out by the De-Kok And Graham (1989) method with slight modifications: 5 g of the ground material was homogenized in 20 ml of 80% acetone for 5 min. The homogenate was centrifuged (10 min, 7 000 times Earth's gravitational force, 4°C).

The absorbance (A) of the supernatants was measured successively at 663 nm and 645 nm for Chl-a and Chl-b. The following standard Equations 1-3 were used to determine the parameters:

$$\text{Ch1-a} = -12.72(A663) - 2.69(A645) \quad (1)$$

$$\text{Chl} - \text{b} = -22.9(A645) - 4.68(A663) \quad (2)$$

$$\text{Total Ch1} = 20.2(A645) + 8.02(A663) \quad (3)$$

For the carotenoid analysis, 1 g of each sample was homogenized in a 1/1/2 solution of ethanol/acetone/n-hexane. The mixture was then well agitated. The extract was left at room temperature for about 30 minutes. The absorbance of the upper hexane layer was quantified using a spectrophotometer at 450 nm for a total carotenoid analysis described by Kuti (2004). The total carotenoid content was calculated using an extinction coefficient of β-carotene $E^{1\%}$ 2592 and expressed as mg of β-carotene/ 100g (F.W).

The hexane phase was dried and evaporated at 30°C under partial vacuum until a dry residue was obtained. The residue was dissolved in 5 ml of acetone, and the resulting extract was analyzed by HPLC using the Grimplet (2004) method. Samples of 20 µl of extracts were analyzed using an HPLC system equipped with a Eurospher II 100-5 C18 column (250 × 4.6 mm) protected by a pre-column containing the same stationary phase UV-vis detector with PDA photodiode array (Shimadzu), Tokyo, Japan.

The elution was performed at a solvent flow rate of 1 ml/min, and the data was acquired at 450 nm. The mobile phases consisted of both HPLC quality water (A) and acetone (B). After conditioning the system with Milli-Q water, we started the injection according to the gradient program. Carotenoid compounds were quantified based on the UV-vis (β-carotene) spectrum. Carotenoid concentrations of date varieties and khalts were evaluated by comparing their "peak area" values at 450 nm with standard stock solutions and expressed as micrograms per 100 g of fresh weight (F.W).

The provitamin A values expressed as retinol equivalents (RE) were calculated according to Nas-Nrc (1989), for which 6 μg of β-carotene corresponds to 1 μg of retinol equivalents (RE). Considering that the only pro-vitamin A precursor carotenoid present in date palm fruit is β-carotene, the following expression was used: 1 retinol equivalent = 6 μg β-carotene.

### *2.4. Sensory profile*

Date samples were analyzed for their sensory characteristics by a panel of 30 untrained members (graduated students) using a hedonic scale (0 = extremely low intensity, 5 = medium intensity, and 10 = extremely high intensity). The panelists scored for different parameters with a maximum score of 10.

The sensory descriptors consist of 4 attributes and 19 descriptors (as shown in Table 1). Date varieties and khalts were evaluated for colour, hardness (by Holding the whole fruit between the peduncle and the bottom, squeezing it, and assessing its firmness), skin hardness (The degree of force required for the initial bite of date until it breaks or bursts), flesh cohesion, herbaceous odor, dates flavor, fruity flavor, floral flavor, chewiness, elasticity, gumminess, hardness (taste), cohesiveness during biting, springiness, adhesiveness, resilience, and sweetness. The samples were positioned on white plates and identified with three-digit random numbers. The panelists valued the samples in the analysis area with good light and were asked to rinse their mouths with water after each sample analysis to minimize residual effects (Singh et al., 2015).

### *2.5 Statistical analysis*

The results were statistically evaluated by a one-way analysis of variance (ANOVA). The three replicates' measurements' means and standard deviations values were calculated for the different variables analyzed. The average data were compared using the least significant difference (LSD) and statistical differences with P values. Under a P-value of 0.05, the differences were considered significant. A principal component analysis (PCA) was performed using factor analysis of (Xlstat, 2014) statistical software version 2014. The relationships between all attributes were also evaluated by Pearson's product-moment correlation at $P \leq 0.05$.

## 3. Results

### *3.1. Colour evaluation*

The colour characterization of dates (as shown in Table 2) showed the presence of significant differences ($p < 0.05$) between the varieties and khalts analyzed. The measurement of colour of the fruit allowed us to have more information about the staining profile among the varieties and khalts tested. The assessment of variance exhibits a variability of the colour components between dates varieties and khalts. Values of the variables a* and b* make the main difference between date varieties and khalts. The values of lightness L* varied from 24.67 to 46.31. Whereas the values of a* ranged from -1.00 to 9.846. We noticed that the values of b* and C* increased in brown khalts (EED, EMS, ZIE, IAH, and MEL) compared to other varieties and khalts. The hue angle value was elevated in clear dates (EED, EMS, and ZIE).

### *3.2. Pigment analysis*

Pigment analysis (as shown in Table 3) indicated that date varieties and khalts were remarkably different ($p < 0.05$). It appeared that the quantity of chlorophyll compounds (Chl-a and -b) was low in all date fruits while carotenoid compounds level was high. The level of chlorophyll in date varieties and khalts ranged from 2.01 to 4.66 μg/g FW. The clear varieties and khalts were rich

**Table 1.** Sensory attributes of date khalts and varieties evaluated by panelists.

| Attributes | Descriptors (Singh et al., 2015) | Attributes | Descriptors (Singh et al., 2015) |
|---|---|---|---|
| Colour | Unblush colour | Odor / Flavor | Herbaceous odor |
| | Blush colour | | date flavor |
| | Flesh colour | | Fruity flavor |
| | | | Floral flavor |
| Texture | Hardness | Taste | chewiness |
| | Skin hardness | | Elasticity |
| | | | Gumminess |
| | | | Hardness (taste) |
| | | | Cohesiveness during biting |
| | | | Springiness |
| | | | Adhesiveness |
| | Flesh cohesion | | Resilience |
| | | | Sweetness |

**Table 2.** Colour values of the dates varieties and khalts (Reflectance Measurements L*, a*, b*, H◦, and C*).

| Dates khalts | L* | a* | b* | C | H◦ |
|---|---|---|---|---|---|
| KBN | 31.4± 3.2e | 7.2± 1.9b | 14.4± 4.4g | 16.4± 4.0f | 61.6± 7.5f |
| BRR | 40.2± 4.2c | 3.9± 1.4cd | 26.1± 4.1cd | 26.5± 3.9cd | 80.7± 3.9cde |
| BST | 24.8± 1.6h | 4.9± 1.5c | 4.4± 1.9ij | 6.9± 1.8i | 41.1± 14.2gh |
| BZG | 26.6± 1.7gh | 9.8± 1.8a | 7.5± 3.3hi | 12.7± 3.1gh | 34.7± 10.4i |
| ECT | 28.8± 2.4fg | 5.0± 1.4c | 10.2± 2.9h | 11.5± 3.1gh | 62.8± 7.4f |
| EED | 46.3± 5.5a | -1.0± 2.6h | 35.2± 6.2a | 35.3± 6.2a | 90.8± 4.2a |
| EMS | 43.8± 3.1b | 0.9± 2.7fg | 31.1± 5.0b | 31.3± 4.9b | 87.4± 5.1abc |
| HFL | 37.2± 3.9d | 2.5± 1.4ef | 22.2± 5.2ef | 22.5± 4.9e | 82.0± 5.5bcde |
| IKL | 24.7± 1.4h | 8.2± 1.9b | 4.1± 1.5ij | 9.4± 2.2hi | 26.3± 7.7j |
| IAS | 36.0± 4.1d | 1.4± 3.5efg | 22.0± 5.5ef | 22.4± 5.4e | 83.8± 9.3abcde |
| IAH | 40.6± 2.7c | 2.3± 1.7ef | 28.6± 4.4bc | 28.7± 4.3bc | 85.1± 3.9abcd |
| KHL | 35.4± 2.7d | 2.9± 1.4de | 20.6± 5.3f | 20.9± 5.2e | 80.8± 4.7cde |
| KKL | 25.3± 0.8h | 1.3± 0.6efg | 1.7± 1.2j | 2.4± 0.9j | 46.8± 23.2g |
| LHD | 27.2± 2.4fgh | 8.4± 1.8b | 6.9± 2.5hi | 10.9± 2.6gh | 37.7± 7.0i |
| MEL | 41.1± 3.7c | 0.3± 1.4gh | 24.4± 6.4de | 24.5± 6.3de | 88.4± 4.0ab |
| MTN | 29.3± 1.6ef | 2.3± 1.1ef | 13.7± 3.7g | 14.0± 3.7fg | 79.5± 6.1de |
| ZIE | 40.2± 3.9c | 5.0± 1.9c | 28.6± 5.6bc | 29.2± 5.2bc | 78.8± 5.8e |

Values are means ± standard deviation (SD) of three replications. Data followed by different letters are significantly different from each other ($P < 0.05$) according to the LSD test. BRR: Bourar ; MTN: Mentouj tissgharine ; BZG: Bouezgagh ; BST: Black bousthammi; KHL: Khalt iaach; LHD: Khalt Lohmadi ; ECT: Elahmer chetoui ; EED: Elasfer eljaid ; ZIE: Khalt zoubir ibn laouam ; HFL: Hak feddan laaneb ; IAS: Khalt iaissi ; EMS: Elmensoum ; IAH: Khalt abdelghani ; IKL: Iklane ; MEL: Mentouj lhaj lehbib ; KBN: Khalt bheir ngli ; KKL: Khalt khel.

**Table 3.** Mean of chlorophylls and carotenoids components contents of different date fruits.

| Khalts | Chlorophyll b | Chlorophyll a | Total chlorophyll | Luteoxanthin | Β-carotene | Provitamin A | Total Carotenoids |
|---|---|---|---|---|---|---|---|
| EMS | 1.3±0.1bcde | 2.9±0.5a | 4.3±0.5ab | 0.6±0.0k | 4.6±0.0g | 0.8±0.0g | 1.6±0.0g |
| MEL | 0.9±0.0def | 1.4±0.0efg | 2.3±0.0fg | 0.8±0.0i | 5.1±0.0e | 0.8±0.0e | 3.5±0.1bcd |
| BST | 1.2±0.1cdef | 1.6±0.2def | 2.8±0.1defg | 1.9±0.0c | 5.6±0.0d | 0.9±0.0d | 2.4±0.4f |
| BZG | 1.1±0.1cdef | 1.7±0.8cdef | 2.8±0.8defg | 0.4±0.0n | 7.1±0.0c | 1.2±0.0c | 3.8±0.3 abc |
| EED | 1.8±0.1ab | 2.9±0.3ab | 4.7±0.4a | 0.7±0.0e | 0.5±0.0n | 0.1±0.0n | 1.7±0.0 a |
| ECT | 0.8±0.0f | 1.2±0.0fg | 2.0±0.0g | 1.2±0.0j | 10.9±0.0a | 1.8±0.0a | 4.1±0.3 g |
| KBN | 1.0±0.0def | 1.3±0.1efg | 2.3±0.1efg | 2.2±0.0a | 5.1±0.0e | 0.8±0.0e | 3.4±0.1bcd |
| HFL | 0.8±0.0f | 1.6±0.2cdef | 2.4±0.1defg | 0.1±0.0o | 0.5±0.0o | 0.1±0.0o | 3.5±0.3abcd |
| MTN | 1.1±0.1def | 1.6±0.0cdef | 2.8±0.0defg | 0.3±0.0d | 8.6±0.0b | 1.4±0.0b | 4.0±0.5 ab |
| IAS | 1.0±0.0def | 1.7±0.0cdef | 2.78±0.1defg | 0.8±0.0h | 1.9±0.8i | 0.3±0.1i | 3.5±0.1abcd |
| IAH | 1.6±0.6bc | 1.4±0.0efg | 2.9±0.6cdef | 0.5±0.0m | 2.4±0.0h | 0.4±0.0h | 3.3±0.3cde |
| KHL | 1.3±0.3cdef | 1.8±0.2cdef | 3.0±0.3cdef | 0.6±0.0j | 0.9±0.0l | 0.2±0.0l | 2.9±0.0 de |
| KKL | 2.1±0.0a | 0.6±0.0g | 2.7±0.0defg | 0.9±0.0f | 4.9±0.0f | 0.8±0.0f | 2.3±0.1f |
| LHD | 0.9±0.1def | 1.3±0.2fg | 2.2±0.1fg | 0.9±0.0g | 0.9±0.0m | 0.1±0.0m | 3.6±0.1abc |
| BRR | 1.4±0.2bcd | 2.3±0.6abcd | 3.7±0.4bc | 0.1±0.0p | 1.6±0.0k | 0.3±0.0k | 3.8±0.3 abc |
| IKL | 1.0±0.2def | 2.2±0.1bcde | 3.2±0.1cde | 0.5±0.0l | 1.7±0.0j | 0.3±0.0j | 3.4±0.1bcd |
| ZIE | 0.9±0.1ef | 2.4±0.5abc | 3.3±0.4cd | 2.1±0.0b | 4.6±0.0g | 0.8±0.0g | 2.8±0.1ef |

Values are means ± standard deviation (SD) of three replications. Data followed by different letters are significantly different from each other ($P < 0.05$) according to the LSD test. BRR: Bourar; MTN: Mentouj tissgharine; BZG: Bouezgagh; BST: Black bousthammi; KHL: Khalt iaach; LHD: Khalt Lohmadi ; ECT: Elahmer chetoui ; EED: Elasfer eljaid ; ZIE: Khalt zoubir ibn laouam; HFL: Hak feddan laaneb; IAS: Khalt iaissi; EMS: Elmensoum ; IAH: Khalt abdelghani ; IKL: Iklane ; MEL: Mentouj lhaj lehbib; KBN: Khalt bheir ngli; KKL: Khalt khel.

in chlorophylls, EED (4.66 µg/g FW), EMS (4.29 µg/g FW), and KHL (3.03 µg/g FW), they were especially rich in Chl-a, which was more abundant compared to Chl-b. This study identified a strong relationship and significant correlation between chlorophyll content and date colour. Two carotenoids were identified on chromatograms (Figure 1) in typical HPLC runs using date fruit extracts: luteoxanthin and β-carotene.

Analysis of carotenoids (Table 3) showed a notable variability between the varieties and khalts tested. Among the 17 dates varieties and khalts, the total carotenoid levels ranged from 1.64 mg/100 g FW (EMS variety) to 4.12 mg/100 g FW (ECT variety). The concentration of β-carotene varied from 0.49 µg/100 g FW (HFL variety) to 10.86 µg/100 g FW (ECT variety). Luteoxanthin content varied from 0.09 µg/100 g FW (BRR variety) to 2.23 µg/100 g FW (KBN variety). The variations in these concentrations between varieties and khalts showed an effect of clone on the synthesis of pigments. The coloured khalts contained a high quantity of carotenoids. The red khalt ECT was the richest in total carotenoids (4.12 mg/ 100 g FW), it was rich in β-carotene (10.86 µg/100 g FW), and Provitamin A (1.81 µg/100 g FW). The red khalt MTN recorded high total carotenoids (4.01 mg/100 g FW), followed by the red khalt BZG with abundant total carotenoids (3.81 mg/100 g FW). However, dates with a clear colour (EED and EMS) exhibited a low carotenoid content (1.64 mg / 100 g FW). A high amount of chlorophylls characterized them. These results presented a relationship between pigment content and the skin colour of the variety and khalt.

*3.3. Sensory profile*

The results of the sensory tests for each variety and khalts were summarized on a radar map (Figure 2). Significant variability was detected between sensory attributes related to analyzed varieties and khalts. Among date varieties and khalts, significant differences were identified between studied variables except for herbaceous note and fruity note.

The panelists' evaluation proved that date varieties and khalts had good characteristics for fresh consumption because of their high intensities of multiple key attributes, especially fruity flavor (7.03) for EMS and sweetness (8.97) for KKL. Different patterns were found regarding all varieties and khalts, and different attribute levels were obtained for the tested date varieties and khalts.

Comparing the results of the sensory profiles of the varieties and khalts, it may be concluded that IKL and MEL khalts were the most appropriate date for consumption. Some varieties and khalts studied showed a good date flavor (> 5) regarding flavor notes. The same profile was found for a fruity flavor. Regarding dates' sweetness, we noticed that all dark date fruits (brown, red, and black dates) except for BST were characterized by a sweety note. This latter was noted for the dark khalts (KKL) followed by red khalts.

ZIE khalt was highly aromatic, tasteful, and therefore the most appreciated, followed by EMS, BZG, and LHD. In summary, experimental sensory data demonstrated a wide variability among the organoleptic parameters between the different studied cultivars: appearance, texture, sweetness, etc. The cultivars with soft texture and sweety note were the most appreciated by the Moroccan consumer. The soft texture of some of the cultivars may be responsible for their short shelf life and makes them more appropriate for direct consumption after harvest. In addition, their sweety note could be useful in the food processing industry.

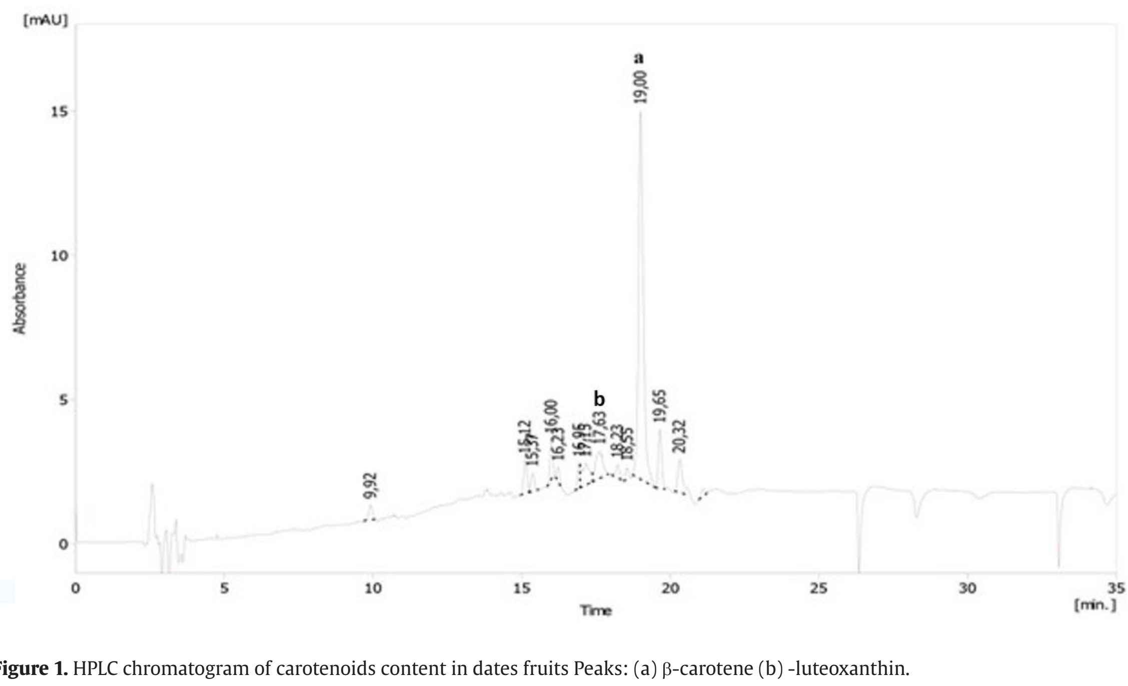


**Figure 1.** HPLC chromatogram of carotenoids content in dates fruits Peaks: (a) β-carotene (b) -luteoxanthin.

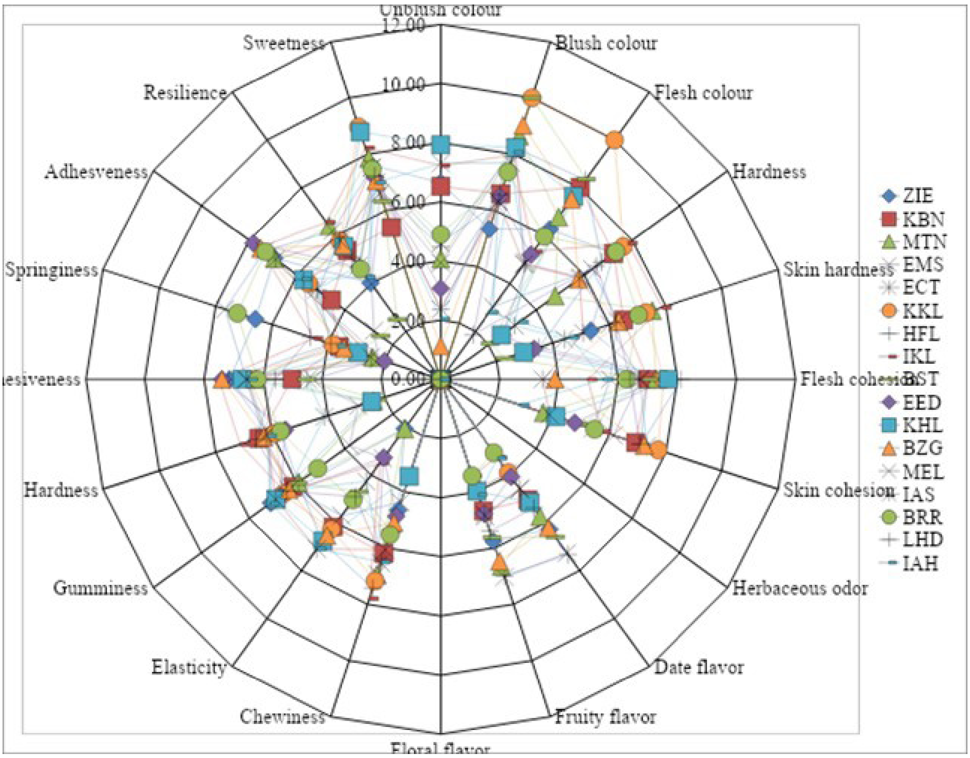


**Figure 2.** Radar maps of sensory profiles of date varieties and khalts as evaluated by the sensory panelists. BRR: Bourar / MTN: Mentouj tissgharine /BZG: Bouezgagh / BST: Black bousthammi/ KHL: Khalt iaach / LHD: Khalt Lohmadi / ECT: Elahmer chetoui / EED: Elasfer eljaid / ZIE: Khalt zoubir ibn laouam / HFL: Hak feddan laaneb / IAS: Khalt iaissi / EMS: Elmensoum / IAH: Khalt abdelghani / IKL: Iklane / MEL: Mentouj lhaj lehbib / KBN: Khalt bheir ngli / KKL: Khalt khel.

### *3.4. Correlation between variables*

Correlation analysis was carried out to analyze the strength of the relationship between the colour parameter groups, sensory profile, and pigments. Pearson correlation coefficients were calculated between sensory profile, colour parameters values (L*, a*, b*, Chroma (C*), hue (H◦)), Chl-a, Chl-b, total chlorophyll, β-carotene, luteoxanthin, provitamin A and total carotenoids (Table 3). Different correlations were detected between the tested variables, in particular for the variables L*, a*, b*, and C* with the chlorophylls and carotenoids contents. A negative correlation was found among chlorophyll pigments and the carotenoid components (r = -0.684). Chlorophyll was positively correlated with L* (r = 0.615), b* (r = 0.648) and C* (r = 0.702) while it was negatively correlated with chlorophyll b and total carotenoid content, r = - 0.458; -0.592 respectively.

The results obtained from the evaluation of colour pigments revealed that lightness L* was negatively correlated with the angle a* (r = -0.656). In contrast, it was positively correlated with all other colour variables, chlorophyll a and total chlorophyll. In addition, H◦ was highly correlated (r = 0.882; 0.894; 0.831) with L*,b* and C* respectively and negatively correlated with a* (r = -0.791). On the contrary, high correlation (r > 0.99) was found between the parameters b* and C*; they were positively correlated with the total chlorophyll (r> 0.594) but negatively correlated with carotenoids content (r < -0.321), a* was found to be correlated with carotenoids content (r=0.468).

Regarding the sensory attributes, hardness (touch) was noticed to be inter-correlated with skin cohesion (r = 0.526), hardness (taste) (r = 0.628) and springiness (r = 0.543). Furthermore, while skin hardness was positively correlated with resilience (r = 0.540), a negative correlation was found between elasticity and chlorophyll b (r = -0.531).

Principal components analysis (PCA) was used to evaluate the relationships among varieties and khalts and determine the correlations between sensory attributes, colour parameters, and color pigments. The analysis was conducted by selecting two factors (F1 and F2) to explain the significant variability and minimize variables to only the highly correlated ones. More than 40.65% of the total variance was observed and defined by the factors F1 and F2 (Figure 3). The first component, F1 explained 22.61% of the total variability; it showed clone effect on the colour of variables, on sensory profile, and the difference between studied varieties and khalts. The F2 component explained 18.04% of the total variance.

The correlation circle (Figure 3a) represents the correlation between the variables tested. Three important groups of components were found. The first group corresponds to the group that showed a correlation between chlorophyll a, chlorophyll b, total chlorophyll and L*,b*,c*,

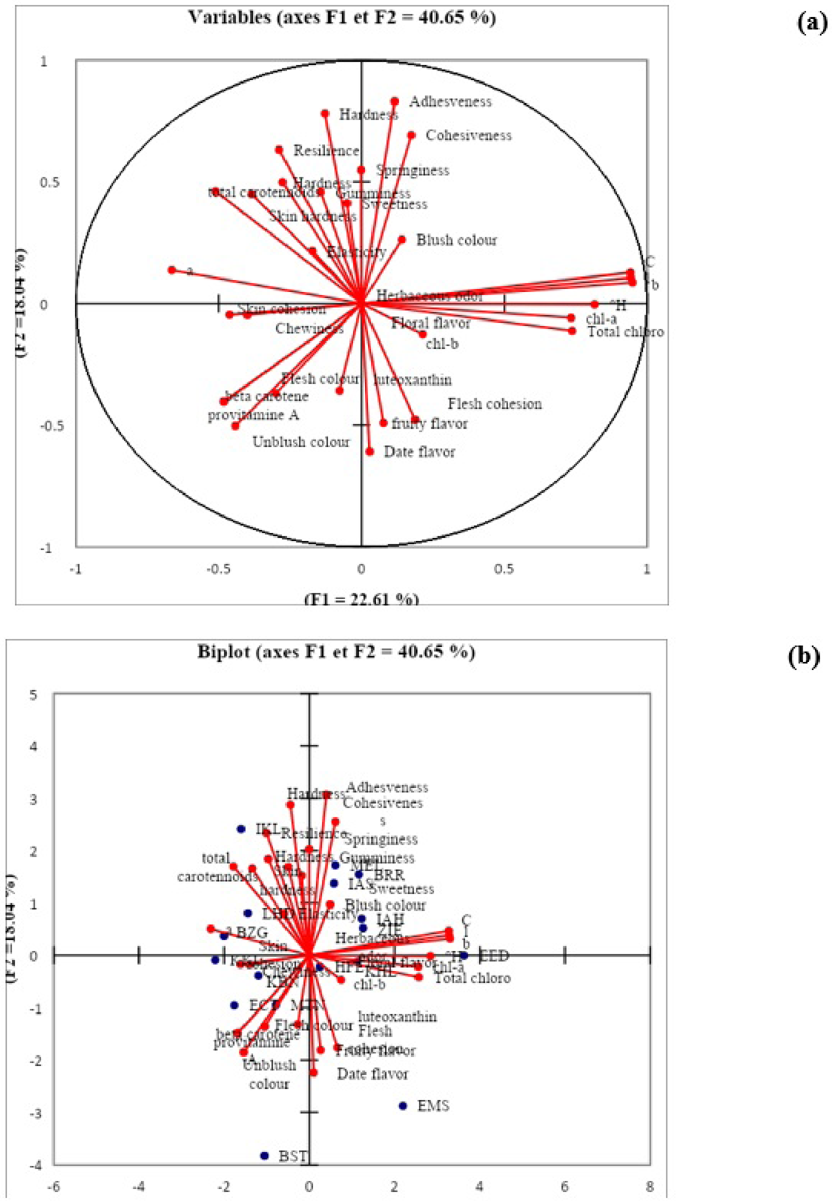

**Figure 3.** Representation of dates varieties and khalts according to the different parameters. (a) Representation of variables related to PCA. (b) Segregation of 17 dates varieties and khalts according to their pigments and sensory attributes.

and H°. The second group was composed of the colour parameter a*, which correlated with total carotenoids and some sensory attributes (skin cohesion, chewiness, and skin hardness). The third group displayed a strong correlation between carotenoid components (β-carotene, provitamin A and luteoxanthin). The statistical analysis showed a dispersion of studied parameters and therefore a significant variability of the investigated samples due to the effect of cultivar. The representation of varieties and khalts on plot (Figure 3b) showed the description of each variety and khalt based on the attributes of the variables. It was observed that the three groups of variables clearly differentiated the three types of tested dates varieties and khalts (clear, red and brown). Clear dates (EED, KHL, and HFL) were linked to the first group of variables defined by the L* value and chlorophyll content (a and b). Brown dates (IKL, LHD) were rich in carotenoids and characterized by a brown colour which was well explained by the high values of the parameters a*. In addition, the two red khalts (ECT and MTN) were rich in β-carotene and provitamin A.

## 4. Discussion

Generally, the L*, a*, b*, C*, and H◦ parameters are commonly used for colour description in fruits (Caliskan et al., 2017). The variation of colour parameters (L*, a*, b*, C*, and H◦) showed the presence of the clone effect. These results were in line with those obtained by Hasnaoui (2011) and Ayour et al. (2016), who mentioned that the colour of fruit varied based on genotypes.

The results obtained revealed that the variable a is responsible for the generation of the yellow (clear) colour for EED, IAS, KHL, HFL, and MEL khalts, brown colour for khalts IAH and KBN, red colour for ECT, BZG, and MTN and dark colour for KKL and BST. The increase of a* in parallel with the decrease of L* manifested in the darkening of dates was due to the pigment variation during the development and maturation of dates and especially by carotenoid accumulation. The variation of pigmentation in dates may be explained by the variability of the varieties and khalts, mainly by environmental factors (very hot climate); the hot climate characterizes the Gulf countries and promotes a more intense browning. According to Achour And Bagga (2005), the loss of the initial colour of dates packaged in different oxygen concentrations and at different temperatures has been explained more by an increase in ambient temperature than by the variation in oxygen concentration in the storage medium. Colour degradation is believed to be caused by non-enzymatic and oxidative enzymatic Browning.

The poor clarity of these dates can be explained by the intensity of the browning phenomenon (Maillard reactions) favored by their high-water content and activity. Indeed, water can accelerate browning by facilitating the mobilization of substances or reduce it by diluting reactive substances. Mobilization of substances predominates at high water activity values (aw). Consequently, browning accelerates with an increasing water activity (Nugroho et al., 2020).

Ayour et al. (2021) stated that carotenoid level in apricot fruit is correlated with skin and flesh colour. Apricots with orange coloured flesh are found to be rich in carotenoids compared to those with clear coloured flesh. These results were similar to our findings; it was shown that the yellow and red colour varieties and khalts were closely correlated with the carotenoid content (EED, ECT).

The effect of variety and khalt was highly significant on the changes in pigment content. Previous studies on chlorophylls showed that its degradation was coupled with chromo-plastids synthesis during fruit ripening (Abaci And Asma, 2013; Park et al., 2018). Chlorophyll degradation during maturation arises parallel with the development and accumulation of other pigments, like carotenoids. We found that β-carotene was the main pigment quantified in date varieties and khalts. This finding is similar to the result reported by Al-Farsi et al. (2005), who found an abundance of β-carotene in dates. The Moroccan tested varieties and khalts were rich in β-carotene.

Regarding date varieties and clones, HFL, EMS, and BZG were the clones that showed qualitative potential among the varieties and clones of the dates studied. This variability of the different sensory attributes can explain the biochemical level of the fruit of dates. Red date fruits, especially for BZG (the sweetest and tastiest clone) and yellow dates (especially EED, IAS, KBN, and IAH), were characterized by good flavour and texture.

The PCA showed correlations between colour attributes and pigments. A negative correlation was noticed between the two classes of pigments analyzed. This may be due to chlorophyll degradation and carotenoid formation, which produces yellow, brown and red during ripening dates. The positive correlation between L*, H◦, and the chlorophylls highlights a relationship between the skin clarity and the chlorophyll amount particularly. The clearest dates are rich in chlorophyll. Moreover, the variables L* and H◦ are relevant in predicting these compounds.

The high correlation ($r > 0.9$) among b* and C*, their negative relationship with the total carotenoids, and their positive relationship with chlorophylls highlight the significance of these attributes in the evolution of colour pigments. The correlation circle and bi-plot highlight that the tested dates varieties and khalts were characterized by an interesting genetic diversity differentiating the three types (yellow khalt, red khalt, and dark khalt) of dates varieties and khalts and defining the three groups of parameters.

The different correlations identified between colour parameters and chlorophyll and carotenoid pigments might be used to predict these biochemical variables.

The textural attributes were plotted considering PC 2 (Figure 2). The khalts (KKL, BRR) on the left-hand side of the PCA plot include hard and chewy dates. On the opposite side of this Group, the dates (EED, KHL) are high in water, soft, low-chewy, and medium-gummy. Similarly, dates (BST and EMS) are high in water, soft, and no adhesive. In addition, KKL, KHL, and IKL are sweeter, while KBN is low sweet. This suggested that different brands of date fruits with variable levels of chewiness and gumminess could be classified based on the expected consumer preferences. These findings were similar to the results found by Singh et al. (2015).

## 5. Conclusion

The assessment of numerous quality parameters of the seventeen Moroccan varieties and khalts showed that they are rich in carotenoids, making them a good source of antioxidants. In addition, the sensory profile evaluated by the consumers does inform us that the most appreciated cultivars have a soft texture and high sweety note. Combining sensory and biochemical markers allow us to elucidate the overall fruit quality. Furthermore, the results showed a correlation between the sensory profile and pigments content variation. The colour parameters (a*, b*, and C*) correlate with the chlorophyll and carotenoids variables and might be used to predict the pigment profile of date varieties and khalts. Given all these quality properties, the Moroccan dates might be used to promote the dates' industry as fresh fruit (MTN, BZG, ECT, BST and MEL) or food processed products (LHD, EED, HFL, KHL, and BRR).

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## References

ABACI, Z.T. and ASMA, B.M., 2013. Examination of some physiological and biochemical changes based on ripening in fruits of different types of apricots. *Journal of Plant Sciences*, vol. 1, no. 1, pp. 6-10.

ACHOUR, M. and BAGGA, N., 2005. Effect of storage conditions on the color degradation of Tunisian Deglet Nour dates. *Fruits*, vol. 60, no. 1, pp. 41-46. http://dx.doi.org/10.1051/fruits:2005011.

AL-FARSI, M., ALASALVAR, C., MORRIS, A., BARON, M. and SHAHIDI, F., 2005. Comparison of antioxidant activity, anthocyanins, carotenoids, and phenolics of three native fresh and sun-dried date (*Phoenix dactylifera* L.) varieties grown in Oman. *Journal of Agricultural and Food Chemistry*, vol. 53, no. 19, pp. 7592-7599. http://dx.doi.org/10.1021/jf050579q. PMid:16159191.

AL-FARSI, M.A. and LEE, C.Y., 2008. Nutritional and functional properties of dates: a review. *Critical Reviews in Food Science and Nutrition*, vol. 48, no. 10, pp. 877-887. http://dx.doi.org/10.1080/10408390701724264. PMid:18949591.

ANLI, M., KAOUA, M.E.L., AIT-EL-MOKHTAR, M., BOUTASKNIT, A., BEN-LAOUANE, R., TOUBALI, S., BASLAM, M., LYAMLOULI, K., HAFIDI, M. and MEDDICH, A.2020. Seaweed extract application and arbuscular mycorrhizal fungal inoculation: a tool for promoting growth and development of date palm (*Phoenix dactylifera* L.) cv «Boufgous». *South African Journal of Botany*, vol. 132, pp. 15-21. http://dx.doi.org/10.1016/j.sajb.2020.04.004.

AYOUR, J., SAGAR, M., ALFEDDY, M.N., TAOURIRTE, M. and BENICHOU, M., 2016. Evolution of pigments and their relationship with skin color based on ripening in fruits of different Moroccan genotypes of apricots (*Prunus armeniaca* L.). *Scientia Horticulturae*, vol. 207, pp. 168-175. http://dx.doi.org/10.1016/j.scienta.2016.05.027.

AYOUR, J., ALAHYANE, A., HARRAK, H., NEFFA, M., TAOURIRTE, M. and BENICHOU, M., 2021. Assessment of Nutritional, Technological, and Commercial Apricot Quality Criteria of the Moroccan Cultivar "Maoui" Compared to Introduced Spanish Cultivars "Canino" and "Delpatriarca" towards Suitable Valorization. *Journal of Food Quality*, vol. 2021, pp. 2021. http://dx.doi.org/10.1155/2021/6679128.

BOUDRIES, H., KEFALAS, P. and HORNERO-MÉNDEZ, D., 2007. Carotenoid composition of Algerian date varieties (*Phoenix dactylifera*) at different edible maturation stages. *Food Chemistry*, vol. 101, no. 4, pp. 1372-1377. http://dx.doi.org/10.1016/j.foodchem.2006.03.043.

CALISKAN, O., BAYAZIT, S., ILGIN, M. and KARATAS, N., 2017. Morphological diversity of caprifig (Ficus carica var. caprificus) accessions in the eastern Mediterranean region of Turkey: potential utility for caprification. *Scientia Horticulturae*, vol. 222, pp. 46-56. http://dx.doi.org/10.1016/j.scienta.2017.05.008.

CAO, S., LIANG, M., SHI, L., SHAO, J., SONG, C., BIAN, K., CHEN, W. and YANG, Z., 2017. Accumulation of carotenoids and expression of carotenogenic genes in peach fruit. *Food Chemistry*, vol. 214, pp. 137-146. http://dx.doi.org/10.1016/j.foodchem.2016.07.085. PMid:27507458.

CONESA, A., MANERA, F.C., BROTONS, J.M., FERNANDEZ-ZAPATA, J.C., SIMÓN, I., SIMÓN-GRAO, S., ALFOSEA-SIMÓN, M., MARTÍNEZ NICOLÁS, J.J., VALVERDE, J.M. and GARCÍA-SANCHEZ, F., 2019. Changes in the content of chlorophylls and carotenoids in the rind of Fino 49 lemons during maturation and their relationship with parameters from the CIELAB color space. *Scientia Horticulturae*, vol. 243, pp. 252-260. http://dx.doi.org/10.1016/j.scienta.2018.08.030.

DE KOK, L.J. and GRAHAM, M., 1989. Levels of pigments, soluble proteins, amino acids and sulhydryl compounds in foliar tissue of Arabidopsis thaliana during dark-induced and natural senescence. *Plant physiology and biochemistry (Paris)*, vol. 27, no. 2, pp. 203-209.

EGGERSDORFER, M. and WYSS, A., 2018. Carotenoids in human nutrition and health. *Archives of Biochemistry and Biophysics*, vol. 652, pp. 18-26. http://dx.doi.org/10.1016/j.abb.2018.06.001. PMid:29885291.

GHNIMI, S., AL-SHIBLI, M., AL-YAMMAHI, H. R., AL-DHAHERI, A., AL-JABERI, F., JOBE, B., & KAMAL-ELDIN, A., 2018. Reducing sugars, organic acids, size, color, and texture of 21 Emirati date fruit varieties (*Phoenix dactylifera*, L.). *NFS Journal*, 12, 1-10. https://doi.org/10.1016/j.nfs.2018.04.002.

GRIMPLET, J., 2004. *Génomique fonctionnelle et marqueurs de qualité chez l'abricot*. Toulouse: Institut National Polytechnique de Toulouse, 253 p. Thèse de doctorat.

HASNAOUI, A., 2011. *Valorisation de la production dattière de la palmeraie de Figuig : Evaluation de la qualité des dattes, extraction et caractérisation des fibres des écarts de tri des dattes des principaux cultivars*. Faculté des sciences d'Oujda, Thèse de Doctorat.

KUTI, J.O., 2004. Antioxidant compounds from four Opuntia cactus pear fruit varieties. *Food Chemistry*, vol. 85, no. 4, pp. 527-533. http://dx.doi.org/10.1016/S0308-8146(03)00184-5.

NAS-NRC, 1989. Food and nutrition board, national academy of sciences-national research council. Revised recommended dietary allowances. *Journal of the American Dietetic Association*, vol. 89, pp. 1748-1752.

NAUSHAD, M., & LICHTFOUSE, E., 2019. *Sustainable agriculture*. USA: Springer.

NOUR, V., CORBU, A.R., ROTARU, P., KARAGEORGOU, I. and LALAS, S., 2018. Effect of carotenoids, extracted from dry tomato waste, on the stability and characteristics of various vegetable oils. *Grasas y Aceites*, vol. 69, no. 1, pp. 238. http://dx.doi.org/10.3989/gya.0994171.

NUGROHO, R.W.N., OUTINEN, M., TOIKKANEN, O., HEINO, A., SAWADA, D. and ROJAS, O.J., 2020. Effect of water activity on the functional, colloidal, physical, and microstructural properties of infant formula powder. *Journal of Colloid and Interface Science*, vol. 586, pp. 56-66. PMid:33143850.

PARK, M.H., SANGWANANGKUL, P. and BAEK, D.R., 2018. Changes in carotenoid and chlorophyll content of black tomatoes (*Lycopersicone sculentum* L.) during storage at various temperatures. *Saudi Journal of Biological Sciences*, vol. 25, no. 1, pp. 57-65. http://dx.doi.org/10.1016/j.sjbs.2016.10.002. PMid:29379358.

SINGH, V., GUIZANI, N., AL-ZAKWANI, I., AL-SHAMSI, Q., AL-ALAWI, A. and RAHMAN, M.S., 2015. Sensory texture of date fruits as a function of physicochemical properties and its use in date classification. *Acta Alimentaria*, vol. 44, no. 1, pp. 119-125. http://dx.doi.org/10.1556/AAlim.44.2015.1.12.

SUN, T., YUAN, H., CAO, H., YAZDANI, M., TADMOR, Y. and LI, L., 2018. Carotenoid metabolism in plants: the role of plastids. *Molecular Plant*, vol. 11, no. 1, pp. 58-74. http://dx.doi.org/10.1016/j.molp.2017.09.010. PMid:28958604.

TAGHIZADEH-ALISARAEI, A., MOTEVALI, A. and GHOBADIAN, B., 2019. Ethanol production from date wastes: adapted technologies, challenges, and global potential. *Renewable Energy*, vol. 143, pp. 1094-1110. http://dx.doi.org/10.1016/j.renene.2019.05.048.

WEAVER, R.J., WANG, P., HILL, G.E. and COBINE, P.A., 2018. An in vivo test of the biologically relevant roles of carotenoids as antioxidants in animals. *The Journal of Experimental Biology*, vol. 221, no. Pt 15, pp. jeb.183665. http://dx.doi.org/10.1242/jeb.183665. PMid:29941616.

XLSTAT, 2014. *XLSTAT, Addinsoft TM*. XLSTAT.