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Valorization of date palm biodiversity: Physico-chemical composition, phenolic profile, antioxidant activity, and sensory evaluation of date pastes

Malika Tassoult[1], Djamel Edine Kati[1], Mostapha Bachir-bey[1*], Ali Benouadah[2], Guillermo Rodriguez-Gutierrez[3]

[1]Laboratoire de Biochimie Appliquée, Département des Sciences Alimentaires, Faculté des Sciences de la Nature et de la Vie, Université de Bejaia, 06000 Bejaia, Algeria

[2]Caracterisation and Valorization of Natural Resources Laboratory – University of BBA, Les ruisseaux, BBA 34000, Algeria

[3]Instituto de la Grasa, Consejo Superior de Investigaciones Científicas (CSIC), Avda. Padre García Tejero n° 4, Sevilla 41012, Spain

* Corresponding author: Mostapha Bachir bey

E-mail address: bachirbeymustapha@gmail.com

Institution: University of Abderrahmane Mira - Bejaia, Targa Ouzemour Street, 06000, Bejaia, Algeria

Tel: +213 34 21 47 62

Orcid: https://orcid.org/0000-0002-9987-1505

Abstract

This work is a contribution to the valorization of the Algerian date palm agrobiodiversity by studying some nutraceutical properties of date pastes from less important cultivars. A commercial date paste, prepared from *Ghars* variety, was compared to two date pastes prepared from the secondary cultivars *Tamjouhert* and *Tazarzeit*. Physico-chemical characteristics, phenolic profile (HPLC-DAD), and antioxidant activity were assessed for both date fruits and pastes. The sensory evaluation of date pastes was conducted through triangular, ranking, and hedonic tests. The results revealed that the transformation of date fruits into pastes caused a significant increase in phenolic content and antioxidant capacity, a decrease in sugar content in parallel with the appearance of hydroxymethylfurfural and furfural. The elaborated date pastes were characterized by a relatively low level of sugar (72.17-74.14 mg/100g), a high amount of phenolic compounds (>290 mg/kg DW), and a potent antioxidant activity. Seventeen phenolic compounds were identified by HPLC with global quantities for date fruits of 113 (*Tamjouhert* cv.) and 100 mg/kg DW (*Tazarzeit* cv.) and that were increased twofold after transformation to date pastes. The sensory analysis for the obtained date pastes indicated high scores of acceptability in comparison with the commercial paste. The obtained results showed clearly that these secondary cultivars possess several potentialities; this may help to valorize them by turning a part of their production into several added-value products such as date past.

Keywords Agrobiodiversity; Date Paste; Physico-chemical Composition; Phenolic Profile; Antioxidant Activity; Sensory Evaluation.

Introduction

Apart from the nutritional point of view; date fruits (*Phoenix dactylifera* L.) represent one of the most important commercial crops worldwide by an annual world production of 8.16 million tons [1]. Thereby, this high production has recently opened new opportunities to turn the surplus traditionally and/or industrially into a wide range of products and by-products; counting: alcohol, yeast, juice, jam, flour, mayonnaise, polyol, syrup, jelly, vinegar, and date paste [2]. The increasing interest in date fruit and its derived products is due to their highly nutritious composition that is rich in sugar, vitamins, minerals as well as fibers [3, 4]. On the other hand, it contains low amounts of fat and protein with no starch [5]. Moreover, these fruits are rich in phenolic compounds possessing several biological properties; including antimicrobial, antioxidant, and anti-inflammatory activities [3, 5, 6].

Among all the processed dates listed above, date paste is the most widespread considering its profitability, simplicity of preparation, and wide use. Date paste was initially prepared in order to conserve soft date fruits that were steamed and mixed to get a paste that can be stored for more than two years [7-9]. This paste is commonly used in bakery and confectionery; it can be also incorporated in several food preparations; precisely bologna-type meat, fruit bars, and muffin [10-13]. Admittedly, date pastes possess many nutraceutical properties since date fruits, used as raw material, are rich in essential nutrients and bioactive compounds [1, 4-6, 14]. Interestingly, it constitutes a novel and attractive vehicle of probiotics [15].

Indeed, date paste had been poorly studied; to our knowledge, limited data is available regarding their phenolic content [16]. However, their phenolic pattern and antioxidant activity had not been studied. The existing works focused on their physico-chemical composition [17, 18], microbial, technological, rheological, and textural characteristics [7, 16, 19, 20]. Harrak *et al*. [19] evaluated and improved the traditional process of making date paste by focusing on physic-chemical, sensory (texture; flavor, color, taste, and acceptability), and microbial characterization of the obtained paste. Abekhti *et al*. [7] described the dynamic changes of microbial and chemical parameters (pH, water content) of dates during transformation to paste and its storage. On the other hand, many recent works focused on the potential use of date paste as sugar substitute in several food preparations including muffin [12] and fruit bars [13],

jam [21], bread [22], and yogurt [23]. The fortified foods were then analyzed for their nutraceutical and organoleptic properties.

Algeria is among the first date-producing countries (1.09 million tons) with a high agrobiodiversity potential but not all the date cultivars were evaluated for their performance and quality. *Deglet-Nour* and *Ghars* cultivars are widely cultivated in Algeria due to their high commercial values, which cause the biodiversity erosion of other cultivars. Hence, paste production from secondary cultivars could be viewed as an interesting way to contribute to the date palm agrobiodiversity preservation. In this context, by studying date pastes preparation, the current study was initiated in the framework of the valorization of two endemic cultivars, *Tamjouhert* and *Tazarzeit* grown in M'zab valley oases compared with *Ghars* cultivar mainly used for date paste production in Maghreb (Algeria, Morocco, and Tunisia). Thus, our work reports the proximate composition, the antioxidant activity, and the phenolic profile of two date fruits and pastes; as well as sensory evaluation of the prepared pastes compared to an industrial one. In addition, the effect of the preparation process on the composition and antioxidant activity evolution from fruit to the paste was assessed. All these issues are considered as a challenge with high nutritional, social, environmental, and economic stakes.

Materials and methods

Chemicals

Acetone (99%, CAS: 67-64-1), petroleum ether (99.9%, CAS: 64742-49-0), and methanol (99.80%, CAS: 67-56-1) were from VWR Prolabo (Fontenay-sous-Bois, France). Sodium carbonate ($NaCO_3$ 99.5%, CAS: 497-19-8), sodium nitrate ($NaNO_3$ 99.0%, CAS: 7631-99-4), aluminium chloride ($AlCl_3$ 97.0%, CAS: 7446-70-0), sodium hydroxide (NaOH 97.0%, CAS: 1310-73-2), potassium ferricyanide ($K_3(Fe(CN)_6)$ 99.0%, CAS: 13746-66-2), iron trichloride ($FeCl_3$ 98.0%, CAS: 7705-08-0); iron II chloride ($FeCl_2$ 98.0%, CAS: 13478-10-9), and trichloroacetic acid (TCA 98.0%, CAS: 76-03-9) were from Biochem Chemopharma (Georgia, USA). Folin-Ciocalteu's reagent was from Biochem Chemopharma (Montreal, Quebec). 2,2-Diphenyl-1-picrylhydrazyl (DPPH 90%, CAS:1898-66-4), hydrogen peroxide (H_2O_2, CAS: 7722-84-1), and ferrozine (98%, CAS: 63451-29-6) were from Sigma-Aldrich (Sternheim,

Germany). Gallic (99.5%, CAS: 149-91-7), *p*-coumaric (98%, CAS: 501-98-4), ferulic (99%, CAS: 537-98-4), and caffeic acids (98%, CAS: 331-39-5), rutin (94%, CAS: 207671-50-9), luteolin (98%, CAS: 491-70-3), isoquercetrin (97%, CAS: 482-35-9), quercetrin (95%, CAS: 522-12-3), and quercetin (98%, CAS: 117-39-5) were from Sigma-Aldrich Co (Saint-Louis, USA).

Plant material

The study was carried out on two local date fruit cultivars: *Tamjouhert* (DFT) and *Tazarzeit* (DFZ); collected from M'zab Valley, Ghardaia, Algeria (32°29′N 3°41′E). Full ripe fruits (1 Kg) with uniform size, free of physical damage, insect injury, and fungal infection were selected.

Preparation of date pastes

The preparation of the date paste was carried out according to the modified method of Ahmed *et al*. [17]. Two date pastes were aseptically prepared from *Tamjouhert* (DPT*)* and *Tazarzeit* (DPZ) cultivars following the industrial procedure. Briefly, about 500g of pitted dates were cooked under steam for 15 minutes. After cooking, the whole paste was mixed with 5 ml of sunflower oil and 5 ml of orange blossom water and then blended at speed 2000 rotations per minute (rpm) for 4 min (Fig. 1A). Three replicates were prepared of each cultivar. In addition to these two pastes, a third date paste, freshly prepared from *Ghars* cultivar (DPG) in accordance with the preparation process used for the preparation of DPT and DPZ, was obtained from an Algerian producer and was also studied as a standard for comparison. The use of a commercial date paste as a reference will make it possible to compare the two other elaborated date pastes (DPT and DPZ) with a marketed product and to get closer to the consumer, especially concerning the sensory perception, and the samples (Fig. 1B) were conserved in sterilized glass jars at 4°C for further analyses.

Physico-chemical composition

The physico-chemical characterization was performed on both date fruits and date pastes. The pH was measured according to Abekhti *et al*. [7] using a pH meter (Inolab, Munich, Germany) at 20°C. The moisture content was determined by drying two grams (2 g) of each sample in a vacuum oven (Memmert GmbH + Co.KG, Schwabach, Germany) at 70 ± 2 °C for 48h [24]. The total ash was measured according to El Arem *et al*. [25], One gram of each sample was incinerated in a muffle furnace (Nabertherm GmbH,

Lilienthal, Germany) at 530°C for 5h. Total sugar content was determined spectrophotometrically by phenol-sulfuric acid reaction [26]. Total nitrogen was determined by Kjeldahl method, which is used to determine protein content using a conversion factor of 6.25 [24]. The lipid fraction was extracted with petroleum ether at 60°C for 6 h using Soxhlet apparatus (Velp Scientifica, Milan, Italy). The solvent was finally removed using a rotary evaporator (Buchi, Flawil, Switzerland) for determining the fat content [27]. All the analyses were carried out by triplicates and the results were expressed as mg/100g of dried weights.

Determination of bioactive compounds

Extraction of bioactive compounds

The extraction of bioactive compounds was carried out according to Al-zoreky and Al-tahar [28] with slight modifications. Briefly, four grams of each date fruit or date paste were homogenized with 20 ml of methanol: water (65:35, v:v) for 2 min using an ultra-turax T25 homogenizer (IKA-labortechnik, Breisgau, Germany). The extracts were then centrifuged at 4000g (Sigma 2-16K, Osterode, Germany) for 5 min, paper filtered, and finally stored at 4°C for further analyses.

Determination of total phenolic content

The date fruits and date pastes total phenolic content (TPC) were determined according to Hachani *et al*. [6] by using the Folin-Ciocalteu spectrophotometric method. Two hundred microliters of each extract were mixed with 1.5 ml of Folin-Ciocalteu reagent (1:10). After 5 minutes, 1.5 ml of sodium carbonate (Na_2CO_3 7.5%) was added. The reaction mixture was incubated at room temperature in dark for one hour. The absorbance was measured at 760 nm. Results were expressed as milligrams of gallic acid equivalent per 100g of dried weight (mg GAE/100g DW).

Determination of flavonoid content

Total flavonoids content (TFC) of both date fruits and date pastes were measured calorimetrically according to Al Juhaimi *et al*. [29]. Extract (500 µL) was added to 150 µL $NaNO_2$ (5%) and 300 µL $AlCl_3$ (10%), respectively. After incubation at room temperature for 5 min, 1 ml of NaOH (1 M) was added. The absorbance was measured at 510 nm. Results were expressed as milligrams of quercetin equivalent per 100g of dried weight (mg QE/100g DW).

Determination of phenolic profile

To determine the date fruits and date pastes phenols, twenty microliters (20 µL) of each extract was injected into HPLC-DAD (Teknokroma, Barcelona, Spain). The Analytical separation was carried during 55 min out on a reversed phase equipped with C18 column (Teknokroma Tracer Extrasil ODS-2, 250 mm-4.6 mm, i.d. 5 µm) in gradient system (eluent A: water/TCA 0.01%, eluent B: acetonitrile). The flow rate of the mobile phase was 1 ml/min [12]. The identification of compounds was done by comparing their retention times and UV spectra to standards as well as by running the samples after the addition of pure standards. The quantification of the tentatively identified phenolics was done using standard calibration curves [30]. The results were expressed as milligrams per kilogram referred to dry weight (mg/kg DW). The same protocol was also used for the determination of the two sugar degradation products (SDP): hydroxymethylfurfural (HMF) and furfural.

Determination of antioxidant activity

Prior to determining the antioxidant activity (AOA), the obtained methanolic extracts were evaporated using N_2 and then diluted in water and finally filtered. The resultant extracts were used to assess antioxidant activity through different tests:

Ferric reducing power (FRP)

The FRP was carried out using the method of Oyaizu [31]. Five hundred microliters of each extract were added to 1.25 ml of potassium ferricyanide (1%) and 1.25 ml of phosphate buffer (0.2 M, pH 6.6). The solution was incubated at 50°C for 20 min, and then 1.25 ml of TCA (10%) was added. The mixture (1.25 ml) was combined with 1.25 ml of distilled water and 0.25 ml of $FeCl_3$ (1%) before the absorbance recording at 700 nm. The results were expressed as milligrams gallic acid equivalent per 100g (mg GAE/100g DW).

DPPH radical scavenging capacity

The free radical scavenging capacity was carried out as described by Al Juhaimi *et al*. [29]. Sixty microliters of each extract were added to 1.5 ml of DPPH solution (6 10^{-5} M). The mixture was incubated in the dark for 30 min at room temperature. The absorbance was recorded at 515 nm. The DPPH radical inhibition was determined using the following formula:

$I\ \% = [(A_0 - A_1) / A_0] * 100$

I %, inhibition percentage; A_0, absorbance of the control; A_1, absorbance of the sample extract.

Ferrous ion chelating capacity (FIC)

The FIC was determined as reported by Ramchoun *et al*. [32]. Each extract (250 µL) was mixed with 25 µL of $FeCl_2$ (2 mM) and 800 µL of distilled water. The mixture was left for 5 min at room temperature then 50 µL of ferrozine (5 mM) were added, mixed, and left another 5min. The absorbance was measured at 562 nm. The ability of the sample to chelate ferrous ion was calculated using the following formula:

$CE\ \% = [1 – (A_1 – A_2) / A_0] * 100$

CE, chelating percentage; A_0, absorbance of the control; A_1, absorbance of the sample extract; A_2, absorbance of the sample without ferrozine.

Sensory analysis

The sensorial characterization of the three date pastes was realized according to ISO 4120 [33], which requires that n/3 should be greater than 5. Triangular, ranking, and hedonic tests were carried out, each one, on eighteen (18) panelists, aged from 18 to 60, and randomly selected among the students and the staff of the University.

The three tests were realized according to Watts *et al*. [34].To make it easier and to reduce the tasters' confusion, we avoided the discussion about the samples but we explained to them the method and the protocols that must be used. We also recommended them not only to avoid using products with strong odors (soaps, lotions, and perfumes) but also to avoid eating, drinking, or smoking at least 30 minutes before proceeding to the tests. We provided them a survey that everyone had to fill in. Just one tasting session has been done. However, the different tests were done separately with a time difference of one hour; during which we presented the samples, explained the test, distributed the survey, and answered the questions asked by the tasters. Moreover, samples re-tasting was allowed for all three tests. The three date pastes submitted for these analyses were labeled as follows:

- "A": The reference date paste prepared from *Ghars* variety (DPG).
- "B": The date paste prepared from *Tamjouhert* variety (DPT).
- "C": The date paste prepared from *Tazarzeit* variety (DPZ).

Triangular test

The triangular test is commonly used to determine the ability of tasters to distinguish the differences in the appearance, smell, flavor, or texture of foods [34]. We presented simultaneously three samples, among which one was repeated, and the trained participants were asked to determine the unrepeated one. The pastes were submitted according to the following positions: (A-A-B), (A-A-C), (B-B-A), (B-B-C), (C-C-A), (C-C-B), (A-B-A), (A-C-A), (B-A-B), (B-C-B), (C-A-C) and (C-B-C) in identical sample containers coded with 3-digit random numbers. All three code numbers on the samples presented to each panelist were different, even though two of the samples are identical.

Two triangular proofs were carried out, the first relating to the external aspect and the second to the taste. These proofs use a binomial approximation that is based on calculating a "μ" value as follows:

$\mu = (| 3x - n | - 1.5) / \sqrt{2n}$

N, number of tasters; x, number of correct answers; the statistical decision is taken considering the following possibilities: if $\mu > 1.64$: Differences are significant at 5%; if $\mu > 2.33$: Differences are significant at 1%; if $\mu > 2.81$: Differences are significant at 1 ‰.

Ranking test

The ranking test aims to determine the degree to which the consumer accepts a product and therefore its real consumption. We submitted the three samples simultaneously in independent sample containers, labeled A, B, and C, then we asked the trained tasters to evaluate them singly by giving them rank from one to three ascendingly according to their acceptance, taking into account that equality is not accepted. The sample that has the lowest rank sum is the most preferred and vice versa. Three classification criteria were used: consistency, sweetness, and aroma.

The ranks assigned to each sample were summed and then the differences between all possible pairs in the summed rankings are compared to a critical value, cited in the table of critical absolute rank sum differences for "all treatments" comparisons at 5% [35].

Hedonic test

This test is done to establish a sensory profile for each sample, based on descriptors mainly: the texture (sliceable, spreadable, brittle, or liquid), the taste (bitter, sweet, salty, and acid), the color, and the smell.

Samples were submitted separately and the untrained tasters were asked to taste them and to give each one a score from 0 to 9 depending on the intensity of each descriptor mentioned above. The simultaneous presentation of the samples was adopted to allow re-evaluating the samples if desired and make comparisons between the samples.

Statistical analysis

All analyses were carried out in triplicate and the results were expressed as means ± standard deviation. Statistical analyses were performed using XLSTAT 7.1 (Addinsoft, USA) and the differences at $p< 0.05$ were considered statistically significant. The Student-t test was performed to compare the results of two fruit samples. Analysis of variance (ANOVA_T-Tuky) followed by Dunnett test was used to determine the differences between the elaborated date pastes and the reference one. The Principal Component Analysis (PCA) served to visualize the correlation between the physico-chemical parameters and the sensory profile as well as between bioactive compounds and antioxidant capacity of the samples.

Results and discussion

Physico-chemical characterization

The proximate composition of the analyzed samples is given in Table 1. The two date fruits presented globally the same physic-chemical characteristics. The transformation to date pastes was accompanied by some modifications particularly a significant ($p<0.05$) augmentation of pH and moisture and fat contents well sugar level was decreased. Carbohydrates were the predominant components with concentrations varying between 66.10 and 74.14 mg/100g DW in date pastes and from 79.82 to 82.53 mg/100g DW in date fruits. Moisture content ranged from 10.63 (DFZ) to 17.17 mg/100g DW (DPG). Both date fruits and pastes were characterized by low amounts of proteins and fat. Some SDP such as HMF (27.14 - 45.82 mg/kg) and furfural (0.57 - 1.31 mg/kg) were also detected in pastes.

It was observed that the fat and the moisture contents increased significantly in date pastes in comparison with fruits, with about 47 and 30%, respectively. Moreover, the transformation caused a slight increase of pH (4.3%). On the other hand, the sugar content diminished considerably (10%) while protein and ash contents remain stable.

The physico-chemical composition of the analyzed fruits is within the previously published values. Rahman *et al*. [24] highlighted that Omani date fruits are slightly acid (5.6 - 5.8) while their sugar fraction is around 62%. Chibane-Amellal [8] reported that water and protein contents of Algerian cultivars are ranging from 13.03 and 2.18% (*Mech Degla*) to 14.80 and 3.50% (*Frezza*), respectively. All the other studies reported that fat and ash contents do not exceed 2%.

Regarding the proximate composition of the date pastes, Sánchez *et al*. [16] reported similar protein, fat, and mineral contents (2%); lower sugar content (53%), and higher moisture content (34%). On the other hand, the pastes analyzed by Abekhti *et al*. [7] are characterized by nearby water contents (9.09-11.58%) and slightly acidic pH (5.45-5.84).

The same trend of variation in the physico-chemical composition after transformation of date fruits into pastes was reported in the literature. Abekhti *et al*. [7] reported also a significant increase in pH and moisture contents by 2.51, 1.83, 4.02, and 4.95, 4.32, 4.04%, respectively in *Lmaiz*, *Abani*, and *Mtafra* Algerian date pastes after transformation of the fruits. With regard to fat content, Parn *et al*. [13] highlighted an average increase of 2.54% in fruit bars made with date paste. In their studies about Tunisian date pastes, Mrabet *et al*. [18] reported also the diminution of the sugar fraction by 25%.

Moreover, the changes in the physico-chemical composition after transformation are certainly due to the preparation process. Indeed, the increase of pH may be attributed to blending during which organic acids (citric, malic, and oxalic acids) may be released [10]. Similarly, the increasing amounts of fat and water contents are due to the addition of sunflower oil and moisturization by steam, respectively. However, the diminution of sugar content could be explained by the cooking process which may cause their caramelization and Maillard reaction [5] as well as the degradation of a little fraction of carbohydrates to HMF and furfural [14]. Likewise, the diminution of ash and protein contents is probably due to the addition of the organic material from the sunflower oil and the orange blossom water and moisturization. The apparition of SDP in date pastes could be explained by the degradation of sugars under the thermal treatment applied when preparing them. According to Mrabet *et al*. [12], high amounts of HMF were found when using the steam treatment. The lowest amounts of furfural could be explained by its volatility [14].

Total Phenolic content

The results of total phenolic and flavonoid contents were summarized in Table 2. Date fruits presented similar levels on TPC and TFC. The transformation of date fruits to pastes was accompanied by a significant increase in TPC by about 10% but no effect was observed for TFC. Regarding elaborated date pastes, their TPC were higher than the reference (DPG) while their TFC were lower.

Very high polyphenol amounts were previously detected in Algerian cultivars that varied from 247 to 1394 mg GAE/100g [30, 36, 37, 38]. According to Ghnimi *et al*. [5], the variations observed between cultivars may be due to genetic, stage of ripening, storage conditions, and extraction procedure. Moreover, the phenolic fraction of our date pastes is higher than that reported by Sánchez *et al*. [16] who found only 225 mg GAE/100g. Regarding the effect of the transformation on the phenolics, its increase after heating and steaming was previously reported [14, 26]. Likewise, these findings were also detected for other fruits and vegetables such as tomato [39], eggplants [40], strawberry [41], and cocoa [42]. Actually, the hydrothermal treatment, employed during date paste preparation, helps to solubilize a higher quantity of phenols from date fruits [43]. In addition, heating of dates may facilitate the leakage of some phenols, mainly phenolic acids and anthocyanins [2].

Antioxidant activity

The antioxidant potential was assessed using FRP, DPPH, and FIC and the results were given in Table 2. As clearly shown in the table, all the samples exhibited a potent AOA, which varied significantly ($p<0.05$) among date fruits as well as among date pastes that exhibited the strongest antioxidant potential whatever was the test.

Date fruits of *Tamjouhert* cultivar demonstrated higher DPPH scavenging capacity and ferrous ion chelating capacity than the fruit of *Tazarzeit* cultivars. Whereas, this latter had a higher ferric reducing power than the first one. The elaborated date pastes presented higher significant antioxidant activity measured by FRP and FIC than corresponding date fruits, but DPPH scavenging activity remained stable after the transformation.

The Algerian date fruit cultivars are known to possess strong AOA as mentioned by several studies. The AOA ranges from 32.4 to 86%, from 25.29 to 41.67 mg EAG/100g, and from 170.4 to 948.1 mg EAA/100g respectively, as tested by DPPH scavenging capacity [28, 36, 37].

It was reported that antioxidant activity of thermally treated dates increased significantly compared to the date fruit [43-45]. However, these results disagree with those of Parn *et al*. [13] who reported a slow decrease of antioxidant capacity of date paste, as tested by DPPH scavenging capacity, upon its incorporation in fruit bars. Similarly, numerous studies established that heat treatment enhanced the antioxidant activity of tomato, eggplants, strawberry, and cocoa [39-42].

Admittedly, the strong AOA of date fruits is due to the presence of enzymatic antioxidants (catalase, peroxidase, and superoxide dismutase) and non-enzymatic antioxidants, mainly phenolic compounds [46]. Hence, it is admitted that these compounds are responsible for the antioxidant power of date paste especially, non-enzymatic activity. This is confirmed by the increase of the AOA in date pastes, compared to date fruits, in parallel with the increase of their phenols (TPC and changes in phenolic profiles).

This was confirmed by strong correlations between bioactive compounds (TPC and TFC) and AOA (DPPH, FRP, and FIC) of analyzed samples with coefficients of determination ranged from 0.70 to 0.95 (Table I, supplementary material). These results are in line with those of Mansouri *et al*. [47] and Biglari *et al*. [48] who reported that the antioxidant potential of date fruit is due to the presence of phenolic compounds and consequently their potent contribution to the antioxidant capacity of date pastes. Nevertheless, this activity may depend on the available concentration of an individual antioxidant compound or on the potential synergistic interaction that occurs in various constituents of plants [49, 50].

Phenolic profile

The phenolic profiles of date fruits and pastes were determined using HPLC-DAD and the results were presented in Table 3. All the analyzed samples shared quietly the same phenolic pattern. The main identified compound was gallic acid (2.44-29.36 mg/kg DW). *Tamjouhert* cultivar was distinguished by significantly high contents on fives compounds (catechin and vanillic, syringic, sinapic, and ferulic acids) than *Tazarzeit* cultivar. This latter exceeded DFT only in tyrosol content. The other phenolic compounds

were equal for the two date fruits. Interestingly, the transformation of date fruits to date paste caused a significant increase in almost all of the phenolic compounds, mainly gallic acid, PHBA, vanillin. In parallel luteolin decreased significantly, especially in DPZ with 80% loss. It can be seen also that the two elaborated date pastes were globally more concentrated on phenolics than the reference.

Unlike date fruits, date pastes' phenolic profile was poorly studied. In this context, more or less similar phenolic patterns have been listed for other date fruit varieties. Mansouri *et al*. [47] identified *p*-coumaric, ferulic, sinapic, and cinnamic acids; however, they have not been quantified. Similarly, Benmeddour *et al*. [30] identified and quantified some flavonoids including isoquercetin (13.33-51.03%), rutin (19.10% - 39.90%), quercetin (16.05- 53.78%), and luteolin (0.64- 4.49%). Likewise, Mrabet *et al*. [12] detected certain phenolic acids, namely gallic (major compound), protocatechuic, vanillic, and *p*-coumaric acids as well as tyrosol, while Hachani *et al*. [6] detected 23 phenolic compounds, most of them are hydroxycinnamic and formic acid derivatives. These authors did not detect gallic acid except in methanolic extracts while luteolin was only detected in acetone-aqueous extracts.

These results were in line with those of Allaith *et al*. [43] and Mrabet *et al*. [12] who indicated the increase of some date phenols after steam and heat treatments. In addition, Rubio-Sentent *et al*. [51] detected new phenols in thermally treated olive oil that were not present in the untreated reference sample. According to Homayouni *et al*. [2], the increasing level of phenolic acids is due to chain-breaking effect of heat treatment, the breakdown of cell walls, and hydrolysis of linkages between bound acid and lignin or arabinoxylans caused the release of phenolic acids. On the other hand, Ghnimi *et al*. [5] explained the diminution of some phenols by their destruction under high temperatures because they are heat-labile. Nevertheless, Mrabet *et al*. [12] reported that gallic acid contents decrease in thermal extracts at very high temperatures (180 – 200°C).

Sensory analysis

Triangular test

The statistical decisions and μ values for both the external appearance and the taste of the three date pastes were given in Table II (supplementary material). It is indicated that DPG (A) had an external appearance that was significantly different from that of DPZ (C), regardless of its position of presentation.

On the other hand, its external appearance was significantly different from that of DPT (B), especially when it was presented after. However, DPT (B) and DPZ (C) had similar external appearances.

Regarding the taste, sample "A" had a taste that is significantly different from that of sample "C", regardless of its position of presentation. On the other hand, its taste was significantly different from that of DPT (B) only when it was presented before. Finally, the DPT (B) and DPZ (C) had similar tastes (Sensory records of the triangular test were given in table III of supplementary material).

Ranking test

The participants ranked the three samples according to their consistency, sweetness, and aroma, and the attributed ranks were presented in Table 4. For the three sensory descriptors, the panelists assigned the first rank to DPZ (C) followed by DPT (B) while the sample DPG (A) is ranked the last one.

In parallel, the differences between the paired rank totals (A – B), (A – C), and (B – C) were calculated and the results were mentioned in Table 5. According to Friedman's table, the critical value for 18 tasters and 3 samples is 15. Thus, differences between the pairwise classification totals (D) show that there is no significant difference (D <15 differences) between the consistencies of the pairs (DPT-DPZ) and (DPG-DPT). For the other pair (DPG-DPZ), the difference was significant (D ≥15). In terms of sweetness and aroma, the three samples show no significant differences since the differences between the total paired ranks were all less than 15 (Sensory records of the ranking test were given in table IV of supplementary material).

Hedonic test

Sensory profile

The obtained results, presented in Fig. 2, showed that panelists perceive that sensory attributes describing texture and color were the most intense in contrast with those describing smell and taste where a low intensity was noted for each of their descriptors, except the sweet taste. Indeed, DPZ had a sliceable and spreadable texture and a considerable sweetness. On the other hand, DPT had a brittle texture, low spreadability, and the best color, while DPG had a semi-solid texture, an acid taste and best smell.

The statistical analysis showed significant differences ($p< 0.05$) between the three samples. The Dunnett test mentioned clearly that the texture, taste and the smell of DPT and DPZ were significantly ($p< 0.05$)

different from those of the reference; except for the liquid texture. Unlike the salty taste, DPG and DPZ share the same color, which was significantly different from that of DPT. Furthermore, the mean classification test (T-Tukey) reveals their separation into two heterogeneous groups. The first group includes the sample “A” while the second group includes the samples “B” and “C”. This means that DPG was significantly different from DPT and DPZ, which were similar in terms of almost all the studied descriptors (Sensory records of the hedonic test were given in table V of supplementary material).

Correlation between the sensory profile and the proximate composition

The PCA allows visualizing the correlation between physico-chemical parameters and sensory attributes. The obtained results (Fig. 3) showed that they are closely correlated as it was clearly appearing that the sweety taste was positively correlated with the sugar content (r = +0.958). Admittedly, carbohydrates were the main molecules that were responsible for the food’s sweetness. Being the major components of the date fruit, sugars render the date paste very sweet.

The color had also a positive correlation with sugar content (r = +0.855). Indeed, in addition to pigments such as carotenoids, anthocyanins, and tannins, carbohydrates contribute to date color through Maillard and caramelization reactions [5]. Regarding texture, the spreadable texture and pH were positively correlated (r = +0.866). In fact, after heating, when the pH increased the protein-protein, protein-fat, and protein-water interactions increase. Hence, the product may have a soft and elastic texture [52].

On the other hand, the pH is negatively correlated (r = - 0.953) with the brittle texture. When the pH decreases, the friable texture could result from the weakness of protein-protein and protein-water interactions [53].

Likewise, a positive correlation (r = +0.782) is observed between the liquid texture and the moisture content. Actually, the decrease in moisture content causes poor protein hydration and results in a less elastic paste that is more susceptible to breaking forces [24]. Thus, this was explained by the plasticizing effect of water contained in dates fruit itself and that acquired during the steaming preparation of date paste.

Furthermore, the variations of the salty taste can be attributed to samples' ash content (r = +0.609), which presents a more intense salty taste with the increase in the mineral content, especially NaCl [54].

A similar trend of positive correlation was observed between odor and fat content (r = +0.951). Since volatile compounds responsible for the aroma were mainly lipophilic, it is recognized that the intensity of the flavor increased with the increase of fat content. In fact, the volatile compounds including alcohol, aldehydes, esters, terpenes, and ketones are the key volatiles determinants of the date aroma [55]. These flavor volatiles are derived from an array of compounds, via different pathways such as terpenes pathway and some of them (alcohols) are mainly generated as reaction products of lipid oxidation [25].

Conclusion

The preparation of date paste from date fruits resulted in a dough with higher bioactive compounds amounts and lower sugar content as well as appreciated texture, taste, color, and smell. In fact, both date fruits and pastes exhibited promising nutraceutical potentialities. The prepared date pastes showed high scores in consumer's acceptability and preference in comparison with the commercial paste. Relying upon the obtained results; the transformation of secondary date varieties, mainly *Tazarzeit* and *Tamjouhert*, into paste constitutes a useful boost for their valorization.

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Conflict of interest

The authors declare that there is no conflict of interest.

Availability of data and material

Not applicable

Code availability

Not applicable

Authors' contributions

Malika Tassoult: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing- Original draft, Visualization.

Djamel Edine Kati: Conceptualization, Methodology, Resources, Supervision; Project administration.

Mustapha Bachir bey: Software, Validation, Formal analysis, Visualization.

Ali Benouadah: Validation, Resources, Project administration.

Guillermo Rodriguez-Gutierrez: Conceptualization, Methodology, Resources, Supervision; Project administration.

References

1 FAOSTAT, http://www.fao.org/faostat/en/#data/QC Accessed 14 August 2020 (2018).

2 A. Homayouni, A. Azizi, A. K. Keshtiban, A. Amini, and A. Eslami, J. food sci. technol. **52**, 1872 (2015).

3 A. Mrabet, H. Hammadi, G. Rodríguez-Gutiérrez, A. Jiménez-Araujo, and M. Sindic, Food Sci. Technol. Res. **25**, 1 (2019).

4 A. Qadir, F. Shakeel, A. Ali, and M. Faiyazuddin, J. Food Sci. Technol. **57**, 1191 (2020).

5 S. Ghnimi, M. Al-Shibli, H. R. Al-Yammahi, A. Al-Dhaheri, F. Al-Jaberi, B. Jobe, and A. Kamal-Eldin, NFS J. **12**, 1 (2018).

6 S. Hachani, C. Hamia, S. Boukhalkhal, A. M. Silva, A. Djeridane, and M. Yousfi, NFS J. **13**, 10 (2018).

7 A. Abekhti, K. Zarour, A. Boulal, Z. Benmechernene, and M. Kihal, J. Microbiol. Res. **3**, 163 (2013).

8 H. Amellal-Chibane and S. Benamara, Am. J. Food. Nutr. **1**, 74 (2011).

9 N. Belguedj, N. Bassi, S. Fadlaoui, and A. Agli, J. new sci. Agric. Biotechnol. **20**, 818 (2015).

10 S. Ghnimi, S. Umer, A. Karim, and A. Kamal-Eldin, NFS J. **6**, 1 (2017).

11 A. Manickavasagan, M. M. Essa, and E. Sukumar, *Dates: production, processing, food, and medicinal values* (CRC Press, 2012).

12 A. Mrabet, A. Jiménez-Araujo, J. Fernández-Bolaños, F. Rubio-Senent, A. Lama-Muñoz, M. Sindic, and G. Rodríguez-Gutiérrez, Food Chem. **196**, 917 (2016).

13 O. J. Parn, R. Bhat, T. Yeoh, and A. Al-Hassan, Food Biosci. **9**, 20 (2015).

14 A. Mrabet, G. Rodríguez-Gutiérrez, F. Rubio-Senent, H. Hamza, R. Rodríguez-Arcos, R. Guillén-Bejarano, M. Sindic, and A. Jiménez-Araujo, LWT-Food Sci. Technol. **75**, 727 (2017).

15 M. S. Marcial-Coba, A. S. Pjaca, C. J. Andersen, S. Knøchel, and D. S. Nielsen, LWT-Food Sci. Technol. **99**, 197 (2019).

16 E. Sánchez-Zapata, J. Fernández-López, M. Peñaranda, E. Fuentes-Zaragoza, E. Sendra, E. Sayas, and J. A. Pérez-Alvarez, Food Res. Int. **44**, 2401 (2011).

17 J. Ahmed, H. Ramaswamy, and A. Khan, J. Food Eng. **66**, 253 (2005).

18 A. Mrabet, M. Rejili, B. Lachiheb, P. Toivonen, N. Chaira, and A. Ferchichi, Ann. Microbiol. **58**, 453 (2008).

19 H. Harrak, A. Hamouda, and M. Nadi, Cahiers Agricultures **27**, 15001 (2018).

20 S. M. A. Razavi and H. Karazhiyan, International Journal of Food Properties **15**, 281 (2012).

21 S. Bhople, M. Ingle, and D. Bornare, Beverage and Food World **43**, 41 (2016).

22 D. Shinde, S. Popale, S. G. Salunke, and S. Kadam, Journal of Pharmacognosy and Phytochemistry **8**, 4489 (2019).

23 H. M. Haneen, Asian Journal of Applied science and Technology **3**, 234Y248 (2019).

24 M. S. Rahman and S. A. Al-Farsi, J. Food Eng. **66**, 505 (2005).

25 A. El Arem, E. B. Saafi, G. Flamini, M. Issaoui, A. Ferchichi, M. Hammami, A. N. Helall, and L. Achour, Inter J. Food Sci. Technol. **47**, 549 (2012).

26 S. Besbes, L. Drira, C. Blecker, C. Deroanne, and H. Attia, Food chem. **112**, 406 (2009).

27 H. M. Habib, H. Kamal, W. H. Ibrahim, and A. S. Al Dhaheri, Ind. Crop. Prod. **42**, 567 (2013).

28 N. S. Al-zoreky and A. Y. Al–Taher, Ind. Crop. Prod. **65**, 241 (2015).

29 F. Al Juhaimi, M. M. Özcan, O. Q. Adiamo, O. N. Alsawmahi, K. Ghafoor, and E. E. Babiker, J. Food Process. Preserv. **42**, e13584 (2018).

30 Z. Benmeddour, E. Mehinagic, D. Le Meurlay, and H. Louaileche, J. Funct. Foods. **5**, 346 (2013).

31 M. Oyaizu, Nippon Shokuhin Kogyo Gakkaishi **35**, 771 (1988).

32 M. Ramchoun, C. Alem, K. Ghafoor, J. Ennassir, and Y. F. Zegzouti, J. Saudi Soc. Agric. Sci. **16**, 257 (2017).

33 I. ISO, International Organization for Standardization: Geneva, Switzerland (2004).

34 B. Watts, G. Ylimaki, L. Jeffery, and L. Elias, Ottawa, ON, CA (1989).

35 G. Newell and J. MacFarlane, J. Food Sci. **52**, 1721 (1987).

36 F. Benkerrou, H. Louaileche, and M. Bachir bey, The Annals of the University Dunarea de Jos of Galati. Fascicle VI-Food Technology **42**, 9 (2018).

37 O. Djaoudene, V. López, G. Cásedas, F. Les, C. Schisano, M. B. Bey, and G. C. Tenore, Food funct. **10**, 4953 (2019).

38 F. Benkerrou, M. Amrane, and H. Louaileche, J. Food Meas. Charact. **12**, 1910 (2018).

39 V. Dewanto, X. Wu, K. K. Adom, and R. H. Liu, J. Agric. Food Chem. **50**, 3010 (2002).

40 A. Chumyam, K. Whangchai, J. Jungklang, B. Faiyue, and K. Saengnil, Sci. Asia **39**, 246 (2013).

41 G. Rodríguez-Gutiérrez, J. C. Cardoso, F. Rubio-Senent, A. Serrano, R. Borja, J. Fernández-Bolaños, and F. G. Fermoso, Inn. Food Sci. Emerg. Technol. **51**, 186 (2019).

42 C. Hernández-Hernández, A. Morales-Sillero, J. Fernández-Bolaños, A. Bermúdez-Oria, A. A. Morales, and G. Rodríguez-Gutiérrez, J. Sci. Food Agri. **99**, 325 (2019).

43 A. A. Allaith, S. H. Ahmed, and F. Jafer, Intern. J. Food Sci. Technol. **47**, 783 (2012).

44 S. Sirisena, K. Ng, and S. Ajlouni, Compr. Rev. Food Sci. Food Saf. **14**, 813 (2015).

45 Z.-X. Tang, L.-E. Shi, and S. M. Aleid, Braz. Arch. Biol. Techn. **57**, 706 (2014).

46 S. Al-Turki, M. A. Shahba, and C. Stushnoff, J. Food Agric. Environ. **8**, 253 (2010).

47 A. Mansouri, G. Embarek, E. Kokkalou, and P. Kefalas, Food chem. **89**, 411 (2005).

529 48 F. Biglari, A. F. AlKarkhi, and A. M. Easa, Food chem. **107**, 1636 (2008).
530 49 M. Alothman, R. Bhat, and A. Karim, Innov. Food Sci. Emerg. **10**, 512 (2009).
531 50 M. J. O. Wijekoon, R. Bhat, and A. A. Karim, J. Food Compos. Anal. **24**, 615 (2011).
532 51 F. t. Rubio-Senent, G. Rodríguez-Gutíerrez, A. Lama-Muñoz, and J. Fernández-Bolaños, J. Agr.
533 Food Chem. **60**, 1175 (2012).
534 52 A. Coutouly, A. Riaublanc, M. Axelos, and I. Gaucher, Dairy Sci. Technol. **94**, 125 (2014).
535 53 S. Lee and H. Klostermeyer, LWT-Food Sci. Technol. **34**, 288 (2001).
536 54 E. J. McMahon, K. L. Campbell, and J. D. Bauer, Appetite **83**, 236 (2014).
537 55 F. Guido, S. E. Behija, I. Manel, Z. Nesrine, F. Ali, H. Mohamed, H. A. Noureddine, and A. Lotfi,
538 Food chem. **127**, 1744 (2011).
539
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Figure Captions

Fig. 1: Diagram of date paste preparation from date fruits (A) and photographs of date fruits and pastes (B).

DPG, Reference date paste prepared from *Ghars* cultivar (DFG); DPT, date paste prepared from *Tamjouhert* cultivar (DFT); DPZ, date paste prepared from *Tazarzeit* cultivar (DFZ).

Fig. 2: Hedonic profile of date pastes.

The hedonic profile of the three date pastes (DPG, DPT, and DPZ) was studied using a 9- point scale for the each descriptor of the following sensory attributes : texture, taste, color and smell. DPG, Reference date paste prepared from *Ghars* cultivar; DPT, date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit* cultivar, For each attribute, different letters indicate statistical significant difference (ANOVA-Dunnett test, $p<0.05$, b< a).

Fig. 3: Principal Component Analysis between sensory profile and physico-chemical composition of date paste.

Table 1. Physico-chemical composition of date fruits and pastes

	Date fruits		Date pastes		
	DFT	**DFZ**	**DPT**	**DPZ**	**DPG**
pH	5.77 ± 0.04^{b}	5.74 ± 0.10^{b}	6.02 ± 0.02^{a}	$5.98 \pm 0.02^{a(-)}$	6.03 ± 0.02
MC (%)	$11.75 \pm 0.35^{b(*)}$	10.63 ± 0.03^{b}	$15.52 \pm 0.29^{a(-)}$	$13.77 \pm 0.25^{a(-)}$	17.17 ± 0.48
SC (%)	79.82 ± 2.14^{a}	82.53 ± 1.58^{a}	$72.17 \pm 1.52^{b(+)}$	$74.14 \pm 2.94^{b(+)}$	66.10 ± 0.88
PC (%)	1.87 ± 0.04^{a}	1.50 ± 0.32^{a}	$1.82 \pm 0.08^{a(-)}$	1.44 ± 0.04^{a}	1.25 ± 0.14
FC (%)	1.31 ± 0.07^{b}	1.33 ± 0.07^{b}	$1.90 \pm 0.04^{a(-)}$	1.97 ± 0.10^{a}	2.11 ± 0.04
AC (%)	2.54 ± 0.25^{a}	2.45 ± 0.10^{a}	$2.48 \pm 0.02^{a(-)}$	$2.37 \pm 0.02^{a(+)}$	2.30 ± 0.03
HMF (%)	nd	nd	3.01 ± 0.21	$4.58 \pm 0.12^{(+)}$	2.71 ± 0.32
Furfural (%)	nd	nd	$0.05 \pm 0.01^{(-)}$	$0.08 \pm 0.01^{(-)}$	0.13 ± 0.02

Each value in the table is the mean ± standard deviation (n=3); Result of date fruit with asterisk $^{(*)}$ is statistically higher than that of the other one (Student-t test); Results of the same cultivar (fruit/paste) with different letters are statistically different (Student-t test, $p>0.05$, a>b); Results of date pastes (DPT or DPZ) and control (DPG) were compared with Dunnett test (-/+ significantly lower/higher at $p<0.05$); MC, moisture content; SC, sugar content; PC, protein content; FC, fat content; AC, ash content; DFT, date fruit of *Tamjouhert* cultivar; DFZ, date fruit of *Tazarzeit* cultivar; DPG, control date paste prepared from *Ghars* cultivar; DPT, date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit* cultivar; nd, net detected.

Table 2. Total phenolic and flavonoid contents and antioxidant activities of date fruits and pastes

Parameter	Date fruits		Date pastes		
	DFT	**DFZ**	**DPT**	**DPZ**	**DPG**
Phenolic content (mg/100g DW)					
TPC (mg GAE/ 100g DW)	268.04 ± 6.50^{b}	264.87 ± 6.12^{b}	$288.37 \pm 0.99^{a(+)}$	$298.11 \pm 7.44^{a(+)}$	281.47 ± 1.54
TFC (mg QE/ 100g DW)	16.11 ± 0.19^{a}	17.36 ± 1.38^{a}	$17.17 \pm 0.95^{a(-)}$	$18.15 \pm 1.92^{a(-)}$	28.27 ± 0.89
Antioxidant activity					
FRP (mg GAE /100g DW)	766.97 ± 9.16^{b}	$927.55 \pm 0.39^{b*}$	809.29 ± 9.73^{a}	$1005.16 \pm 2.60^{a(+)}$	806.16 ± 2.60
DPPH (%)	$69.89 \pm 1.98^{a*}$	55.77 ± 0.53^{a}	$70.39 \pm 1.38^{a(-)}$	$58.52 \pm 3.42^{a(-)}$	75.46 ± 0.60
FIC (%)	$71.20 \pm 0.03^{b*}$	70.39 ± 0.18^{b}	$78.49 \pm 3.51^{a(+)}$	$75.60 \pm 1.87^{a(+)}$	69.17 ± 1.45

Each value in the table is the mean ± standard deviation (n=3); Result of date fruit with asterisk $^{(*)}$ is statistically higher than that of the other one (Student-t test); Results of the same cultivar (fruit/paste) with different letters are statistically different (Student-t test, $p>0.05$, a>b); Results of date pastes (DPT or DPZ) and control (DPG) were compared with Dunnett test (-/+ significantly lower/higher at $p<0.05$); TPC, total phenolic content; TFC, total flavonoids content; FRP, Ferric reducing power; DPPH, free radical scavenging activity; FIC, Ferrous ion chelating capacity; DFT, date fruit of *Tamjouhert* cultivar; DFZ, date fruit of *Tazarzeit* cultivar; DPG, control date paste prepared from *Ghars* cultivar; DPT, date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit* cultivar; GAE, gallic acid equivalent; QE, Quercetin equivalent; DW, dried weight.

585 **Table 3.** Phenolic profile of date fruits and pastes

Content (mg/kg DM)	Date fruits		Date pastes		
	DFT	**DFZ**	**DPT**	**DPZ**	**DPG**
Gallic acid	2.49±0.11^{b}	2.44±0.38	29.36±0.20$^{a(+)}$	24.09±1.32^{a}	25.02±0.18
O-Coumaric acid	2.44±0.02^{b}	Traces	12.18±0.13$^{a(+)}$	4.88±0.07$^{(-)}$	8.25±1.00
Protocatechuic acid	9.34±0.42^{a}	6.69±3.16^{b}	12.62±2.02^{a}	16.9±0.07$^{a(+)}$	12.68±1.29
Tyrosol	8.17±0.2^{b}	9.63±0.42^{b*}	16.37±0.23^{a}	16.12±0.29^{a}	16.54±0.08
PHBA	5.22±0.27^{b}	3.79±4.85^{b}	14.70±0.19^{a}	18.89±0.05$^{a(+)}$	14.86±0.93
Vanillic acid	2.55 ± 0.28^{b*}	1.45 ± 0.22^{b}	5.55 ± 0.14^{a}	5.31 ± 1.56^{a}	5.35 ± 0.09
Syringic acid	4.89 ± 0.46^{a*}	3.7 ± 0.2^{a}	4.16 ± 2.11^{a}	4.81 ± 1.84^{a}	5.56 ± 0.11
Caffeic acid	5.12 ± 1.16^{a}	4.71 ± 0.29^{b}	6.53 ± 0.05$^{a(+)}$	7.56 ± 0.38$^{a(+)}$	5.94 ± 0.24
P-Coumaric acid	1.41 ± 0.07^{b}	0.8 ± 0.46^{b}	3.01 ± 0.09^{a}	4.48 ± 0.06$^{a(+)}$	3.16 ± 0.06
Sinapic acid	6.7 ± 0.22^{a*}	4.3 ± 0.70^{b}	6.61 ± 0.14$^{a(-)}$	7.24 ± 0.01^{a}	7.45 ± 0.22
Ferulic acid	4.5 ± 0.34^{b*}	2.27 ± 1.33^{b}	7.77 ± 1.93^{a}	7.53 ± 0.41$^{a(+)}$	6.05 ± 0.04
Cinnamic acid	12.59 ± 0.28^{b}	11.79 ± 0.48^{b}	18.68 ± 0.16$^{a(+)}$	17.79 ± 1.69$^{a(+)}$	14.35 ± 0.54
Catechin	12.93 ± 0.07^{b*}	7.56 ± 0.06^{b}	21.56 ± 0.36$^{a(-)}$	15.86 ± 0.43$^{a(-)}$	22.91 ± 0.50
Vanillin	3.01 ± 0.37^{b}	3.47 ± 0.54^{b}	15.62 ± 0.05$^{a(+)}$	13.45 ± 0.16$^{a(+)}$	12.12 ± 0.02
Rutin	14.25 ± 2.04^{a}	19.35 ± 3.40^{a}	12.25 ± 0.19^{a}	13.93 ± 1.73^{a}	10.18 ± 3.26
Luteolin	16.27 ± 1.04^{a}	16.23 ± 0.43^{a}	14.27 ± 0.16$^{b(+)}$	9.02 ± 0.48^{b}	10.4 ± 1.27
Quercetin	1.21 ± 0.05^{b}	1.27 ± 0.16^{b}	6.25 ± 0.02$^{a(-)}$	4.81 ± 0.01$^{a(-)}$	7.10 ± 0.02

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587 Each value in the table is the mean ± standard deviation (n=3); Result of date fruit with asterisk (*) is statistically higher than that of the
588 other one (Student-t test); Results of the same cultivar (fruit/paste) with different letters are statistically different (Student-t test, $p>0.05$,
589 a>b); Results of date pastes (DPT or DPZ) and control (DPG) were compared with Dunnett test (-/+ significantly lower/higher at $p<0.05$).
590 DFT, date fruit of *Tamjouhert* cultivar; DFZ, date fruit of *Tazarzeit* cultivar; DPG, control date paste prepared from *Ghars* cultivar; DPT,
591 date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit* cultivar; PHBA, phosphor-hydroxybenzoic acid.
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Table 4. Ranks attributed to the three date pastes

Samples	**DPG**			**DPT**			**DPZ**		
Aspects	Consistency	Sweetness	Aroma	Consistency	Sweetness	Aroma	Consistency	Sweetness	Aroma
Ranks sum	48	43	44	37	34	32	23	33	31
Rank	3	3	3	2	2	2	1	1	1

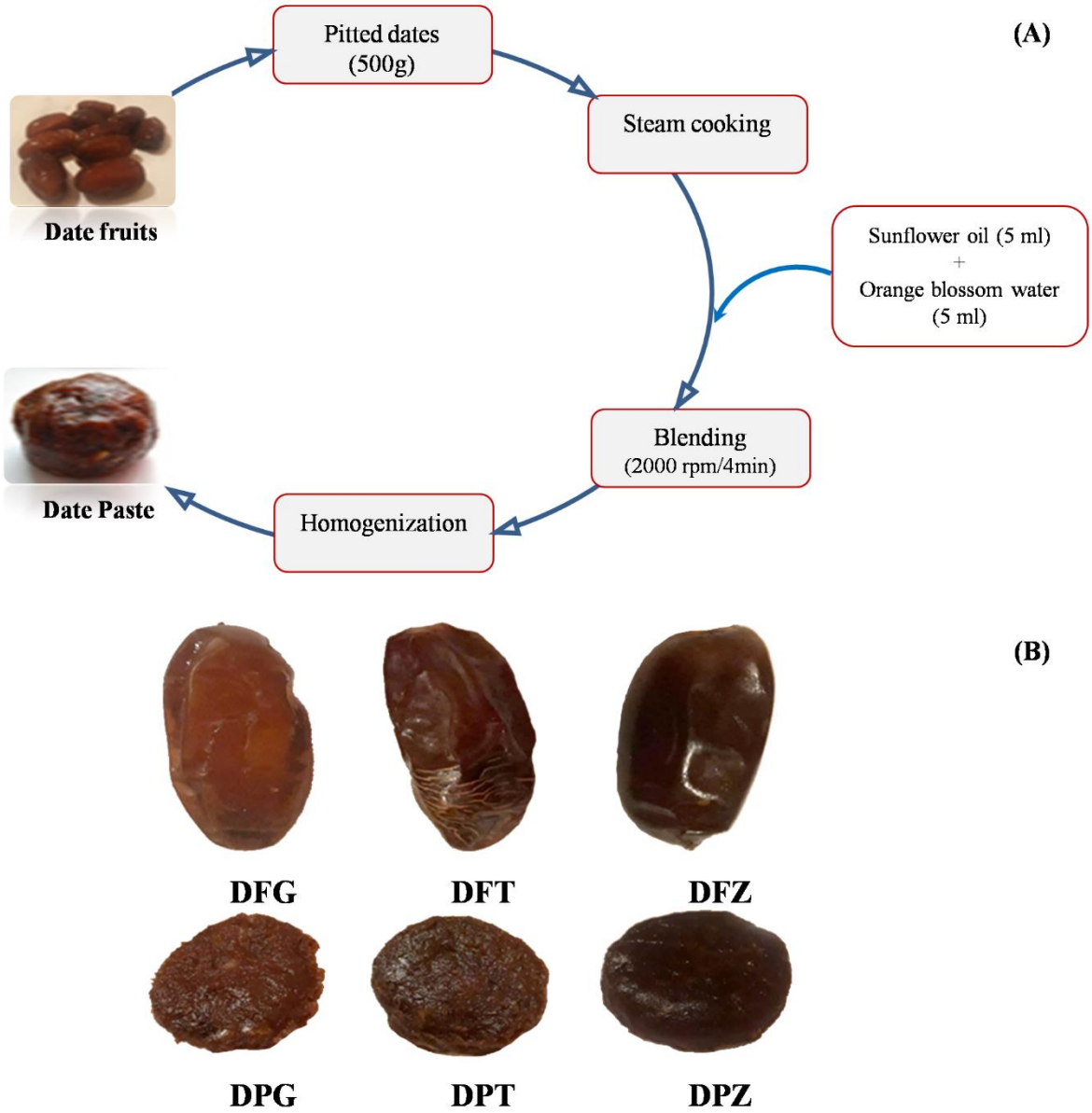
DPG, Reference date paste prepared from *Ghars* cultivar; DPT, date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit* cultivar.

Table 5. Differences between rank total pairs of pastes

Pairs	**DPG – DPT**	**DPG - DPZ**	**DPT – DPZ**
Consistency	11*	25**	14*
Sweetness	09*	10*	01*
Aroma	12*	13*	01*

DPG, Reference date paste prepared from *Ghars* cultivar; DPT, date paste prepared from *Tamjouhert* cultivar; DPZ, date paste prepared from *Tazarzeit*cultivar; * insignificant; ** significant (p>0.05)

Figure 1


(A)
Pitted dates
(500g)
Steam cooking
Sunflower oil (5 ml)
+
Orange blossom water
(5 ml)
Blending
(2000 rpm/4min)
Homogenization
Date Paste
Date fruits
(B)
DFG
DFT
DFZ
DPG
DPT
DPZ

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623 **Figure 2**

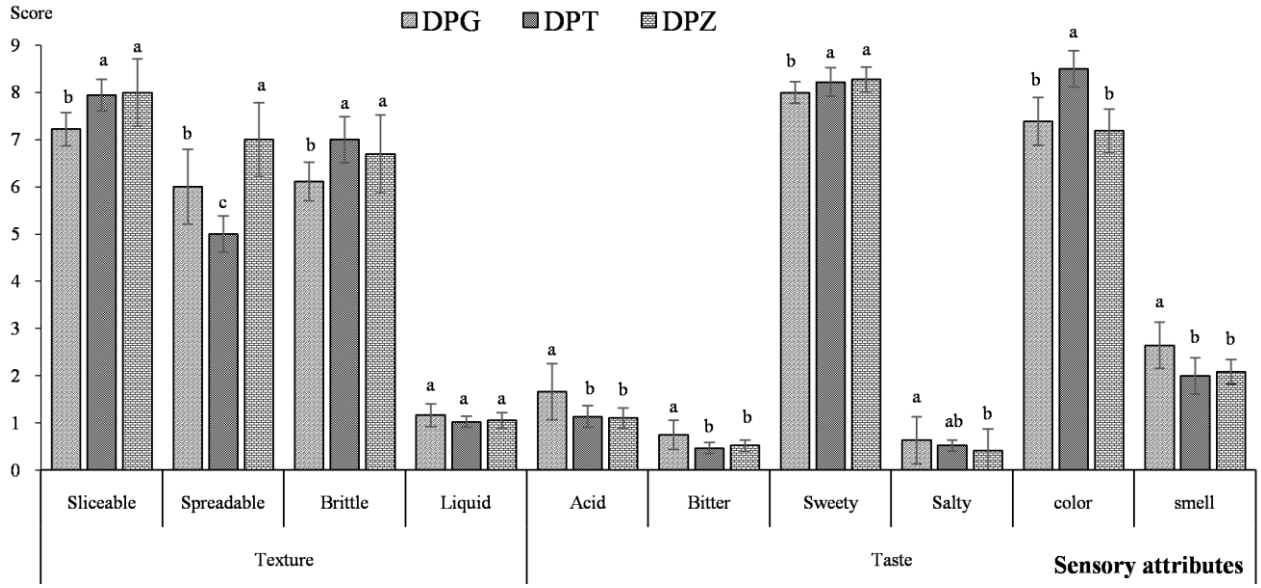

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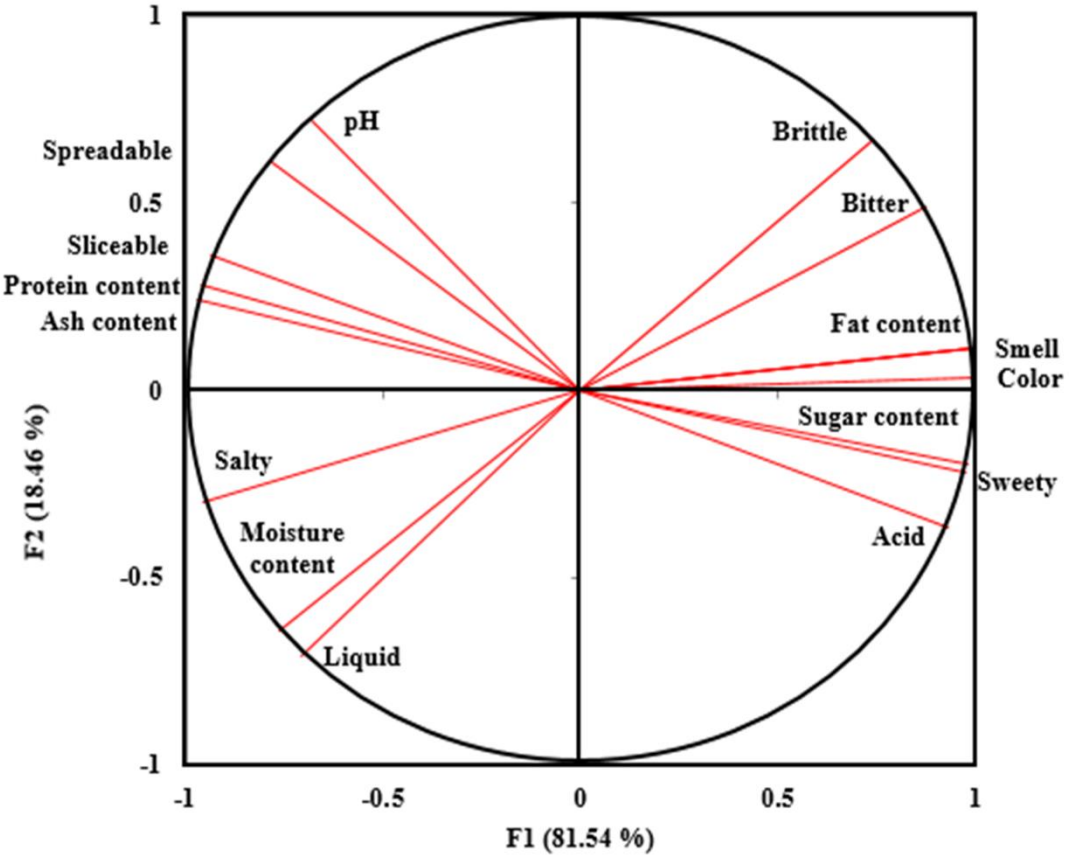
Figure 3


pH
Brittle
Spreadable
Bitter
Sliceable
Protein content
Ash content
Fat content
Smell
Color
Sugar content
Salty
Sweety
Moisture
content
Acid
Liquid
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
F2 (18.46 %)
F1 (81.54 %)