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# Evaluation of nutritional quality and antioxidant activity of Tunisian date juices (*Phoenix dactylifera* L.)

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**Abstract -** Renewed interest in the role of vegetable consumption in maintaining and enhancing human health has highlighted the importance of considering the chemical composition of vegetables available to consumers. Juices from sixteen coastal cultivars of Tunisian date palm (*Phoenix dactylifera* L.) were analysed for their main chemical composition. This study is a contribution to valorise marginalized date palm cultivars by their transformation into juices.
Results show that the yield of juices extraction exceeds 80% for studied cultivars. These juices are rich in reduced sugars (glucose and fructose); moderately acid; and their acidity ranged from 0.084 g $L^{-1}$ for Ammari juice to 0.198 g $L^{-1}$ for Bekrari juice. The studied juices are exceptionally rich in potassium (K) having a highest value of 1426.7 mg $kg^{-1}$ of dry weight (DW) in the juice of the cultivar Mermella. The Na/K ratio was very low for all juices, which gives a nutritional and therapeutic importance for this product. Other minerals were also present with significant concentrations in all juices. Concerning the inhibition percentage of free radicals DPPH, it ranges from 51.11% in Smitti2 juice to 84% in Nefzawi juice.

**Keywords:** date juice, Physico-chemical characteristics, mineral composition, Antioxidant capacity.

## 1. Introduction

The date palm (*Phoenix dactylifera* L.) is one of the oldest plants cultivated in the World. Its cultivation had taken place 6000 years ago (Ben Salah and Hellali 1995). It grows in warm arid and half-arid areas of the globe. The date palm is, most often, the main production of oasis in the desert areas. In Tunisia, the production of dates increases reaching 198 miles 850 tons for the season 2013-2014; from which the production of "Deglet Nour" was 141 miles 200 tons in the same season against 57 miles 650 tons for others varieties (GIFruit, htpp://*gifruits.com*). The variety 'Deglet Nour' present about 60% of national date production.
Other varieties of date are of less commercial importance and known as secondary or common varieties (Rhouma 1995). Date palm fruits have been used for nutritional and medicinal purpose (Alkaabi et al. 2011). Dates are a high energy food because of their exceptional richness in sugar, vitamins and minerals (Ahmed et al. 1995). These fruits were also rich in antioxidants which are useful for human health. The protection offered by date palm fruits against oxidative stress in several diseases has been attributed to various antioxidant activities (Bauza et al. 2002; Gerber, et al. 2002). Recent research has focused on antioxidant compounds derived from plants. Due to the nutritional value of the fruit; researchers have focused on characterization of the physico-chemical analysis of date palm cultivars (Al-Shahib and Marshall 2003).
Biotechnological transformation of date palm fruits into juice can prologues the period of its exploitation out their season and give them a presentation, a structure and functionality (Estanove 1990). The Tunisian coastal dates are until now marginalized on the exception of their traditional transformation into paste for just local consumption. Therefore, it would be necessary to reduce the loss of these vegetal resources and contribute to the industrial and agricultural development.

Its valorisation can be performed by introducing biotechnology of transformation to obtain by-products of dates as juice. In fact, biotechnological extraction of juice differs from the traditional method by introducing new techniques for clarification and conservation.
The characterisation of the physical-chemical parameters, the mineral composition and the antioxidant capacity give an idea about the nutritional and therapeutic value of such product (Ben Salah and Hellali 1995). So, the aim of our work is to produce and to characterize date juices as a manner of the valorisation of coastal dates. This product can be consumed directly or used as raw material for the production of others by-products of interest according to the characteristics of each juice.

## 2. Materiel and methods

### 2.1 Chemical Reagents

The analytical reagent grade acetonitrile was obtained from Lab-Scan (Lab scan Ltd., Ireland). Sucrose standard is purchased from Fluka (Sigma Aldrich, Switzerland). Glucose and fructose were purchased from Carlo Erba (Carlo Erba Reactifs, France). Absolute ethanol from Riedel-de-Haën (Sigma Aldrich, Germany). The water used in high-performance liquid chromatography (HPLC) and sampling was prepared with a Millipore Simplicity (Millipore S.A.S, France).

### 2.2 Plant material

Date palm fruits can be eaten before the final stage of ripening, which is called Rotab (50% soft brown colour and 50% hard yellow or red colours), or consumed after complete ripening and offered as Tamar (100% soft with brown colour). The fruits of sixteen coastal date palm cultivars were collect at their stage "Tamar" from coastal oases of Gabes and the island of Djerba from Tunisia (table1). The fruits were kept in cool until analysis.

**Table 1.** Origin of palm date cultivars used for juices preparation

| Cultivar | Origin of collecte | Juice Code | Latitude | Longitude |
|---|---|---|---|---|
| **Ammari** | Djerba | J1 | 33° 49' N | 10° 54'E |
| **Baht** | Zarat | J2 | 33° 39' N | 10° 21'E |
| **Bekrari** | Elhamma | J3 | 33° 53' N | 09° 47'E |
| **Bou Hattem** | Chenenni | J4 | 33° 51' N | 10° 04'E |
| **Eguiwa** | Dkhilt Toujène | J5 | 33° 27' N | 10° 09'E |
| **Garn Gzel** | Elhamma | J6 | 33° 53' N | 09° 47'E |
| **Halway** | Zarat | J7 | 33° 39' N | 10° 21'E |
| **Kenta** | Elhamma | J8 | 33° 53' N | 09° 47'E |
| **Korkobi 1** | Djerba | J9 | 33° 49' N | 10° 54'E |
| **Korkobi 2** | Zarat | J10 | 33° 39' N | 10° 21'E |
| **Lemsi** | Djerba | J11 | 33° 49' N | 10° 54'E |
| **Mermella** | Elhamma | J12 | 33° 53' N | 09° 47'E |
| **Nefzawi** | Zarat | J13 | 33° 39' N | 10° 21'E |
| **Smitti 1** | Elhamma | J14 | 33° 53' N | 09° 47'E |
| **Smitti 2** | Zarat | J15 | 33° 39' N | 10° 21'E |
| **Rotbi** | Chenenni | J16 | 33° 51' N | 10° 04'E |

### 2.3 Preparation of date palm juices

Date palm juices were obtained by the cooking method to remove colloids (Oudot 1999). The fruits were washed with water, and the seeds were removed, drained and cut into small pieces, then a quantity of deionised water was added in the proportions 1:3 (dates : water). The mixture was incubated in a water bath at 80°C for about 90 minutes. Then, the extract was filtered to separate the juice, forming the aqueous fraction, from the solid fraction. The filtrate was centrifuged at 8000 rotations minute$^{-1}$ (rpm) for 20 min at 4 °C and the obtained supernatant was considered as the clarified juice (figure 1). Juices are codified from 1 (J1) to 16 (J16) (table 1).

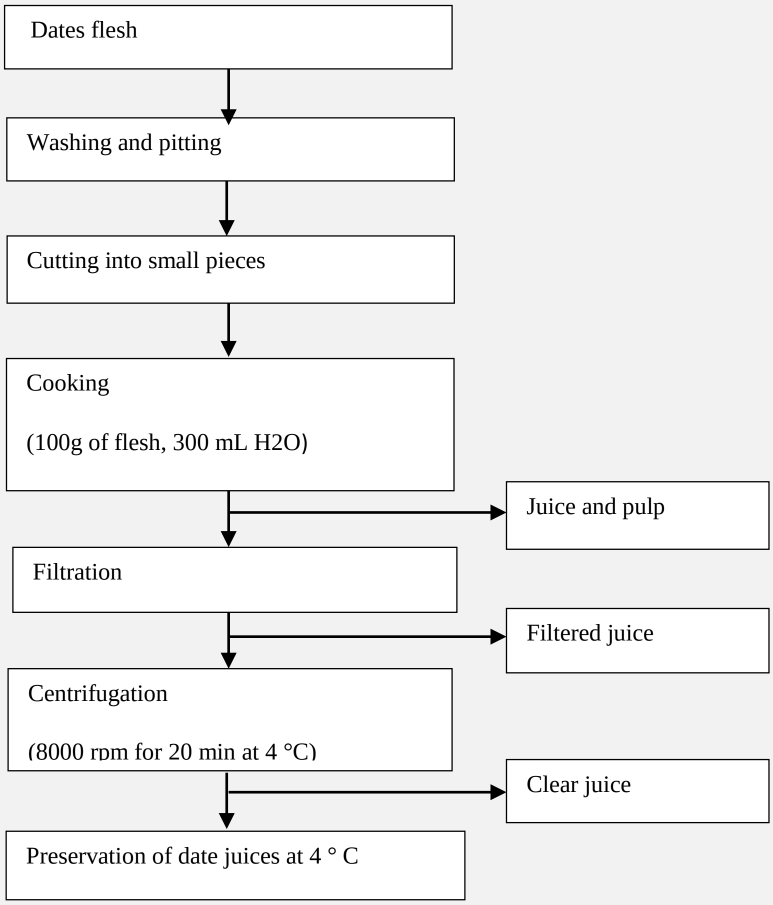


**Figure 1.** Diagram of date juice preparation process

### 2.4 Determination of yield (Yd)

The determination of juice yield was obtained by simple weighting of the juice mass after and before the filtration. Yield (Yd) is expressed as the ratio between the mass of juice after filtration and the total mass of juice (after cooking).

### 2.5 Titrable acidity, pH, and °Brix

Titrable acidity was calculated as percentage of citric acid by titrating 10 mL of date palm juice with a solution of KOH (0.1N) till pH 8.1. The pH was measured by a pH meter (InoLab, Germany). The level of sugars was measured as °Brix (°B) by a digital refractometer, (Models 10430, 0- 30 ° Brix, Cambridge Instruments Inc, USA).

### 2.6 Sugar contents

The analysis of sugar from date palm juice was performed by the high-pressure liquid chromatography (HPLC) (Knauer Wellchrom model, Germany). Clear juice is filtrated by a 0.45µm membrane filter. Separation was carried out at room temperature on Eurospher NH2 column, 100 Å pore size, 7µm particles size, 250 mm 4.6mm i.d. (Knauer, Germany). The mobile phase was acetonitrille and ultrapure water (80/20, v/v). The liquid chromatography was connected to RI detector K-2301 from Knauer (Germany). The integrator was calibrated with external standards consisting of glucose (2 g L$^{-1}$), fructose (2 g L$^{-1}$) and sucrose (1 g L$^{-1}$) solutions. Each sample was carried out from integrated pick are as of the sample against the corresponding standard graph. Total reducing sugars were obtained as the sum of glucose and fructose values. The fructose concentration (Cfr), glucose concentration (Cgl) and concentration of reducing sugar (CSred) were expressed as g $L^{-1}$ of juice.

## 2.7 Antioxidant Capacity

The antioxidant activities of date palms juices were measured in vitro using DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging assay as previously described (Elfalleh et al. 2009). Herein, stock solution of each sample was prepared to contain 100 µL of each juice, 900 µL of distilled water and 3.9 mL of DPPH 25 mg $L^{-1}$ in methanol. After the reaction was allowed to take place in the dark for 30 min, the absorbance at 515 nm was recorded to determine the concentration of remaining DPPH using a Secom am 1000 spectrophotometer in a 10 mm quartz cuvette. The disappearance of DPPH was recorded and the percent of inhibition of the DPPH radical of samples and the positive control was calculated through the equation 1:

$$\% \text{ Inhibition of DPPH} = [(Ab - As)/Ab] \times 100 \qquad \text{Eq1}$$

with Ab is the absorbance of blank (has the highest value) and As is the absorbance of sample.

## 2.8 Mineral contents

Mineral contents were prepared as described by Al-Shwiman (1990). Samples were dried in an oven set at 70°C and incinerated in a muffle furnace at a temperature of 550°C for 4 hours. The ash was then dissolved in 5 mL of hydrochloric acid (20%) The mineral constituents: phosphorus, calcium, sodium, potassium, magnesium, copper, zinc, iron and manganese (P, Ca, Na, K, Mg, Cu, Zn, Fe and Mn respectively) present in the juice ashes were analysed separately as previously described (Elfalleh, et al., 2011), using an atomic absorption photometer (Shimadzu A 6800, Kyoto, Japan). Phosphorus content was determined by ultraviolet (UV) spectrophotometer (Secom am 1000, Ales, France). The results were expressed as mg $kg^{-1}$ dry weight basis (DW).

## 2.9 Statistical Analysis

All analyses were carried out in triplicate and the results were presented as means ± Standard Deviation (SD). Differences between mean values were assessed using a one-way analysis of variance (ANOVA) followed by the Duncan's multiple range test. The level of significance was set at $P < 0.05$. All analyses were performed using XLSTAT Software.

# 3. Results and discussions

## 3.1 Physical-chemical quality of juices

The analysis of variance (ANOVA) showed a significant difference ($P < 0.05$) among all juices, according to the studied parameters (Table 3). The juice yield ranged from 80.44% in the juice of Korkobi2 to 86.22% in the juice of Nefzawi. These yields are higher than that of the juice prepared from Deglet Nour that does not exceed 80.3% under the same conditions of extraction. In fact, these high yields of extraction represent a technological advantage for the production of date juice. The value of Brix is an important parameter for the analysis of juice. It gives an idea about the composition of these products on total soluble solids.

Brix values of juices ranged from 12° Brix for juice of Mermella and Rotbi to 18 ° Brix in juice of Halway. The last juice showed Brix value higher than juice of Tunisian Deglet Nour which doesn't exceed 17.56 (Cheikh-rouhou et al. 2006). These Brix values are higher than those given by Al-Hakkak et al. (1988) for Iraqi cultivars that do not exceed 10.2. According to these authors, the content of total soluble solids is related to the extraction technique, especially the effect of mode of clarification on juice °Brix.

The pH values ranged from 4.99 in Nefzawi juice to 6.16 in Ammari juice. These juices are slightly acidic. The values of the acidity of the juices ranged from 0.084 g $L^{-1}$ in the juice of Ammari to 0.198 g $L^{-1}$ in the juice of Bekrari. This acidity is insufficient to conserve the juice. Such acidity promotes microbial growth. So, the addition of the conservatives is necessary to ensure a long period of conservation.

### 3.2 Antioxidant capacity

The percentage inhibition of DPPH free radicals ranged from 51.11% (Smitti juice) to 84% (Nefzawi juice) (Table 1). These results are in agreement with those obtained by Wu et al. (2004) and Mansouri et al. (2005). According to these authors a strong correlation was shown between the phenolics composition and antioxidant activity of dates extracts. It has been reported that another factors may influence this activity, such as development of fruit at high temperature (Aguilo-Aguayo et al. 2009).
Because of their ability to damage almost all types of molecules in the body, derived reactive oxygen species (ROS) were involved in a very large number of diseases, both acute and chronic Van Duyn and Pivonka (2000). It is possible to limit oxidative tissue damage and hence prevent disease progression by antioxidant defence supplements which have a role as "protector".
The protection offered by fruits and vegetables against oxidative stress in several diseases has been attributed to various antioxidants and vitamins. It has been demonstrated that there is a relation between consumption of vegetables and fruit and reduction of risk of inflammatory diseases (Alkaabi et al. 2011), cardiovascular diseases (Lindquist et al. 2000) and cancer (Bauza et al., 2002). Hirvonen et al. (2006) indicated that consumption of fruit juices is correlated with decrease of breast cancer risk. The beneficial effect of fruit extracts have been demonstrated (Rudnicki et al. 2007). The fruit extracts are tonic, sedative, and they intervene in the treatment of hypertension and injury (Rudnicki et al. 2007). These effects are associated with richness of these extracts in phenols (Pereira et al. 2004; Reginatt et al. 2001). Several studies of the active compounds of plants have demonstrated the possibility of their exploitation in many preparations (Qiang et al. 2006; Mullenet al. 2007).
Thus, due to their richness in antioxidants elements, consumption of juices prepared from coastal cultivars of dates is useful for human health. They can be incorporated in the resolution and prevention from several diseases. Therefore, theses palm cultivars would be valorized based on their juices characteristics.

**Table 2.** Physico-chemical characterisation and antioxidant activity of coastal Tunisian date palm juices

| Cultivars | Yield (%) | pH | Acidity (g/l) | DPPH(% Inhibition) |
|---|---|---|---|---|
| **Ammari** | 85.69 ± 0.11$^{a}$ | 6.16 ± 0.92 $^{a}$ | 0.08 ± 0.02 $^{a}$ | 66.28 ± 0.12 $^{ef}$ |
| **Baht** | 85.93 ± 0.21$^{b}$ | 5.95 ± 0.34 $^{ab}$ | 0.10 ± 0.002 $^{a}$ | 66.07 ± 0.20 $^{ef}$ |
| **Bekrari** | 81.07 ± 0.62 $^{e}$ | 5.01 ± 0.5 $^{e}$ | 0.19 ± 0.017 $^{d}$ | 76.92 ± 0.17 $^{c}$ |
| **Bou Hattem** | 83.52 ± 0.30 $^{d}$ | 5.56 ± 0.40 $^{cd}$ | 0.15 ± 0.005 $^{d}$ | 82.02 ± 0.25 $^{b}$ |
| **Eguiwa** | 84.08 ± 0.11 $^{cd}$ | 5.44 ± 0.10 $^{cd}$ | 0.17 ± 0.004b $^{cd}$ | 63.32 ± 0.11 $^{g}$ |
| **Garn Gzel** | 80.54 ± 0.10 $^{e}$ | 5.64 ± 0.80 $^{c}$ | 0.14 ± 0.004 $^{b}$ | 75.19 ± 0.23 $^{c}$ |
| **Halway** | 85.98 ± 0.10 $^{a}$ | 5.52 ± 0.98 $^{cd}$ | 0.16 ± 0.036b $^{cd}$ | 80.08 ± 0.51 $^{ab}$ |
| **Kenta** | 83.65 ± 0.86 $^{d}$ | 5.32 ± 0.12 $^{d}$ | 0.19 ± 0.057 $^{d}$ | 64.34 ± 0.18 $^{fg}$ |
| **Korkobi1** | 85.65 ± 0.10 $^{a}$ | 5.32 ± 0.18 $^{d}$ | 0.16 ± 0.057 $^{bcd}$ | 83.55 ± 0.31 $^{ab}$ |
| **Korkobi2** | 80.44 ± 0.10 $^{e}$ | 5.58 ± 0.04 $^{cd}$ | 0.15 ± 0.002 $^{b}$ | 54.56 ± 0.66 $^{h}$ |
| **Lemsi** | 84.50 ± 0.11 $^{c}$ | 5.58 ± 0.04 $^{cd}$ | 0.16 ± 0.006 $^{bc}$ | 67.26 ± 0.29 $^{e}$ |
| **Mermella** | 84.08 ± 0.14 $^{c}$ | 5.92 ± 0.03 $^{ab}$ | 0.10 ± 0.011 $^{a}$ | 71.12 ± 0.31 $^{d}$ |
| **Nefzawi** | 86.22 ± 0.12 $^{a}$ | 4.99 ± 0.04 $^{e}$ | 0.19 ± 0.036 $^{d}$ | 84.92 ± 0.61 $^{a}$ |
| **Smitti1** | 84.84 ± 0.19 $^{b}$ | 5.78 ± 0.04 $^{bc}$ | 0.12 ± 0.011 $^{a}$ | 74.89 ± 0.19 $^{c}$ |
| **Smitti2** | 86.17 ± 0.25 $^{a}$ | 5.30 ± 0.17 $^{d}$ | 0.19 ± 0.017 $^{cd}$ | 51.11 ± 0.12 $^{i}$ |
| **Rotbi** | 86.03 ± 0.12 $^{a}$ | 6.08 ± 0.04 $^{a}$ | 0.09 ± 0.060 $^{a}$ | 67.80 ± 0.13 $^{e}$ |

(1) Each population value is the mean of five analysis performed on different juice samples

(2) Superscript letters with different letters in the same column of cultivar respectively indicate significant difference (P <0.05) analyzed by Duncan's multiple range test.

### 3.3 Sugar Content

The juice of Mermella showed the lowest levels of glucose (37.8 g $L^{-1}$), fructose (40.9 g $L^{-1}$) and reducing sugar (78.7 g $L^{-1}$) concentrations. The highest values of theses concentrations were observed in Halway juice, respectively, Cgl= 92.1 g $L^{-1}$, Cfr= 97.3 and CSred= 187.3 g $L^{-1}$. The fructose/glucose ratio (Rs) ranged from 0.92 for Lemsi juice to 1.23 for Korbi1 juice.
Concerning sugar composition, juices are without sucrose, they form equivocal solutions of reducing sugar (glucose and fructose) (Table 3). In fact, Sucrose is reversed into fructose and glucose with a slight dominance of fructose. The absence of sucrose may be due to the richness of coastal cultivars

dates in reduced sugars, they contain a very low quantity of sucrose (Besbes et al. 2009). Moreover, the method of the preparation of juice at high temperature (80°C) and at acid pH (around 5) causes the activation of invertase, the enzyme responsible for hydrolysis of sucrose into reducing sugars (Aguilo-Aguayo et al. 2009). Our results are different from those obtained for juices prepared from Tunisian Deglet-Nour whose major sugar is sucrose with a concentration of 185.8 g $L^{-1}$. The concentration of reduced sugar does not exceed 26.5 and to 39.5 g $L^{-1}$ for glucose and fructose, respectively (Chaira et al. 2007).

**Table 3.** Total content of soluble solids and main sugars from Tunisian date palm juices

| Cultivars | °Brix | Glucose (g $L^{-1}$) | Fructose (g $L^{-1}$) | reducing Sugar (g $L^{-1}$) | Rs (fr/gl) |
|---|---|---|---|---|---|
| **Ammari** | 14.50 ± 0.34 $^{c}$ | 68.0 ± 0.31$^{fg}$ | 71.7 ± 1.02 $^{gh}$ | 142.7 ± 0.55 $^{g}$ | 1.09 ± 0.011 $^{bc}$ |
| **Baht** | 15.00 ± 0.46 $^{c}$ | 72.6 ± 0.15 $^{h}$ | 77.3 ± 0.36 $^{hi}$ | 150.0 ± 0.51 $^{g}$ | 1.06 ± 0.027 $^{abc}$ |
| **Bekrari** | 13.00 ± 0.28 $^{e}$ | 51.8 ± 0.16 $^{cde}$ | 54.2 ± 0.21 $^{bcd}$ | 109.0 ± 0.31 $^{def}$ | 1.10 ± 0.021 $^{abc}$ |
| **Bou-Hattem** | 14.20 ± 0.17 $^{d}$ | 56.8 ± 0.10 $^{e}$ | 64.1 ± 0.17 $^{ef}$ | 121.0 ± 0.28 $^{ef}$ | 1.12 ± 0.012 $^{bc}$ |
| **Eguiwa** | 15.20 ± 0.11 $^{c}$ | 70.7 ± 0.12 $^{gh}$ | 75.3 ± 0.16 $^{gh}$ | 146.0 ± 0.18 $^{g}$ | 1.08 ± 0.007 $^{abc}$ |
| **Garn Gzel** | 14.20 ± 0.17 $^{d}$ | 65.0 ± 0.07 $^{f}$ | 72.5 ± 0.19 $^{gh}$ | 137.5 ± 0.26 $^{f}$ | 1.11 ± 0.018 $^{bc}$ |
| **Halway** | 18.00 ± 0.23 $^{a}$ | 92.1 ± 0.12 $^{j}$ | 97.3 ± 0.27 $^{ji}$ | 189.5 ± 0.40 $^{i}$ | 1.05 ± 0.067 $^{bc}$ |
| **Kenta** | 16.30 ± 0.17 $^{b}$ | 77.8 ± 0.22 $^{j}$ | 82.7 ± 0.15 $^{i}$ | 160.5 ± 0.37 $^{h}$ | 1.06 ± 0.011 $^{abc}$ |
| **Korkobi1** | 13.60 ± 0.17 $^{de}$ | 54.8 ± 0.21 $^{de}$ | 67.8 ± 0.22 $^{g}$ | 122.6 ± 0.44 $^{f}$ | 1.23 ± 0.008 $^{d}$ |
| **Korkobi2** | 12.20 ± 0.11 $^{g}$ | 45.1 ± 0.09 $^{b}$ | 51.7 ± 0.21 $^{bcd}$ | 99.6 ± 0.31 $^{c}$ | 1.14 ± 0.024 $^{c}$ |
| **Lemsi** | 15.20 ± 0.11 $^{c}$ | 69.3 ± 0.08 $^{fgh}$ | 68.7 ± 0.18 $^{g}$ | 138.1 ± 0.26 $^{h}$ | 0.92 ± 0.010 $^{a}$ |
| **Mermella** | 12.00 ± 0.28 $^{g}$ | 37.8 ± 0.16 $^{a}$ | 40.9 ± 0.19 $^{a}$ | 78.7 ± 0.35 $^{a}$ | 1.08 ± 0.006 $^{bc}$ |
| **Nefzawi** | 14.20 ± 0.17 $^{cd}$ | 52.9 ± 0.16 $^{de}$ | 57.5 ± 0.28 $^{df}$ | 110.4 ± 0.45 $^{de}$ | 1.01 ± 0.032 $^{abc}$ |
| **Smitti1** | 13.40 ± 0.23 $^{e}$ | 50.8 ± 0.07 $^{cd}$ | 56.0 ± 0.26 $^{cd}$ | 106.8 ± 0.32 $^{cd}$ | 1.10 ± 0.035 $^{bc}$ |
| **Smitti2** | 12.90 ± 0.23 $^{e}$ | 43.6 ± 0.17 $^{b}$ | 48.2 ± 0.34 $^{a}$ | 91.8 ± 0.51 $^{b}$ | 1.10 ± 0.035 $^{bc}$ |
| **Rotbi** | 12.00 ± 0.23 $^{g}$ | 47.2 ± 0.15 $^{b}$ | 49.4 ± 0.25 $^{bc}$ | 96.8 ± 0.40 $^{bc}$ | 1.04 ± 0.021 $^{ab}$ |

(1) Each population value is the mean of five analysis performed on different juice samples

(2) Superscript letters with different letters in the same column of cultivar respectively indicate significant difference (P <0.05) analyzed by Duncan's multiple range test. Rs: fructose/glucose ratio

## 3.4 Mineral composition of juices

Mineral elements were classified into two major groups: the macro-elements and the micro-elements (Table 5). Results showed that date juices prepared from coastal cultivars are rich in potassium with the highest level in the juice of Mermella (1426.7 mg $kg^{-1}$ DW), followed by the Korkobi1 juice (1383 mg $kg^{-1}$ DW). The concentration of this element in the juice of Nefzawi is about 1265.3 mg $kg^{-1}$ DW. These cultivars are richer in potassium than continental ones which potassium level does not exceed 870 mg $kg^{-1}$ DW (Reynes et al. 1993).

The potassium levels of other juices ranged from 632 (Halway juice) to 954.4 mg $kg^{-1}$ DW (Bekrari juice). Indeed their richness in potassium, theses coastal date palm juices would be considered as natural sources of potassium. This element is very important in the reactions involved in the assimilation of chlorophyll and in the carbohydrates synthesis at different stages of fruit ripening. It is absorbed with big quantities by the date palm and is deposited on its organs, particularly on fruits (Demolon 1968). Potassium helps in maintaining regular fluid balance and proper functionality of nerves and muscles (Butt and Sultan 2011).

The date juices are considered moderately rich in sodium with levels ranging from 126 (Korkobi1 juice) to 332 mg $kg^{-1}$ DW (Rotbi juice).

The Na/K ratio is very low for all juices; it does not exceed 0.042 for the juice of Korkobi2. Several researches have been shown that any food richer in potassium and low in sodium is beneficial for maintaining the acid balance of human body, and plays a role in the inhibition and in the treatment of hypertension (He 1998). This may explain the use of dates by oasis dwellers for the hypertension treatment.

Calcium exists in significant quantities in most studied juices. The levels ranged from 115.7 mg $kg^{-1}$ DW for the juice of Korkobi2 to 922.3 mg $kg^{-1}$ DW for the juice of Halway. These results are similar

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to those obtained by Reynes, Bouabidi, Boimbo and Risteruccium (1993).for other cultivars of Tunisian dates (from 200 to 1010 mg $kg^{-1}$ DW). Calcium is one of the important minerals for human health because of its critical role in bone and teeth development. It intervenes in the composition of cell membranes and bones. It is involved in the electrochemical phenomena (Huheey et al. 1996).

Phosphorous acts synergistically with calcium in bone development. Moreover, it is important in human metabolism, and nerve and muscle function.

Studied juices are rich in magnesium with levels ranging from 338 mg $kg^{-1}$ DW for the juice of Korkobi2 to 887 mg $kg^{-1}$ DW for the juice of Nefzawi. These levels are higher than those obtained by Al-Houti et al. (2002).

Zinc exists in all juices in quantities reaching 22.8 mg $kg^{-1}$ DW in the juice of Mermella. This concentration is higher than those obtained by Al-Houti et al. (2002), which don't exceed 2.8 mg $kg^{-1}$ DW for the variety Safri. This micro-nutrient is beneficial for human health. It is integrated in the immune system.

The juices are moderately rich in other micro-elements: copper, iron and manganese that are all beneficial for human health (Willet 1994). Iron intake is important as it is an integral part of hemoglobin essential for oxygen transport. Zinc enhances the bioavailability of iron from the diet. It is important in improving the oxidative defence capacity of the body (Butt and Sultan 2011). Selenium, copper, manganese, and molybdenum are the other minerals present in vegetables. They are required in very small amounts but are components of various reactions within the body (Butt and Sultan 2011). Therefore, these juices constitute a source of copper and manganese which required in small amounts. Bioavailability of minerals from different vegetables is important; indeed assessing the mineral profile of date juice indicates their richness in minerals.

## 3.5 Juices classification

### 3.5.1 Principal Components Analysis (PCA)

The PCA was conducted on date palm juices based on physicochemical parameters and mineral contents (Table 6 and Figure 1a and 1b). Axis 1 and 2 explain 34.862 and 17.74% of total inertia, respectively. The axis 1 is positively correlated with °Brix, glucose , fructose and reduced sugar . It is negatively correlated with potassium, iron and copper contents. The axis 2 is positively correlated with yield, potassium, Calcium, and Magnesium contents. Therefore, the axis 1 is defined by sugar contents and the axis 2 by minerals contents.

The variable and juices plot in the plan defined by axes 1 and 2 is shown in the figure 1a and 1b, respectively. This dispersion showed that the juices of the cultivars Ammari, Eguiwa and Kenta, were characterized by high levels of reducing sugars. However, the cultivars Rotbi, Bekrari , Bou Hatem, Smitti1, Smitti2 and Korkobi were rich in sodium and Zinc contents.

PCA showed two clusters. The first cluster (CL1) comprised five juices J1, J2, J9, J12 and J13. The second cluster (CL2) comprised ten juices: J3, J4, J5, J6, J8, J10, J11, J14, J15 and J16. The juice J7 from Halway cultivar is distinguished from the two clusters by its highs sugar and minerals contents (Table 6).

### 3.5.2 Hierarchical classification (HC)

The juices classification was made using physical-chemical and mineral contents (Figure 3). The dendrogram showed five groups (Gp1 to Gp5) (Table 6, Figure 3):

- The group1 contains the juices of the cultivars Ammari and Baht which are characterized by their richness in reducing sugar, potassium (904.15 mg $kg^{-1}$) and other minerals. The concentration of reduced sugar and the degree Brix in this group has an average of 14.64 and 14.75, respectively. This group has 85.82 as yield percentage. So they can be used directly and intervene in the treatment of hypertension considering their exceptional richness in potassium;
- The group2 comprise the juices of cultivars Bekari, Bou Hatem, Lemsi and Rotbi. They are characterized by their high sugar quantity (116.3 g $L^{-1}$). Their potassium quantity is 883.5 mg $kg^{-1}$DW. These juices can be used directly or indirectly. They can intervene in the sweet industry or transformed into by-products (alcohol, liquor, and vinegar) considering their high content on reducing sugars;

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**Table 4.** Levels of mineral elements in Tunisian coastal date juices (mg/100g DW).

| | Macro-elements mg kg$^{-1}$ | | | | | | Micro- elements mg kg$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cultivars** | **P** | **Na** | **K** | **Ca** | **Mg** | **Rm (Na/K)** | **Cu** | **Zn** | **Fe** | **Mn** |
| **Ammari** | 135.0 ± 0.15 $^{i}$ | 157.0 ± 0.12 $^{h}$ | 881.7 ± 1.12 $^{g}$ | 318.0 ± 0.12 $^{d}$ | 644.5 ± 0.64 $^{e}$ | 0.17 ± 0.003 $^{ef}$ | 2.8 ± 0.012 $^{fg}$ | 8.0 ± 0.096 $^{j}$ | 5.8 ± 0.009 $^{ef}$ | 1.5 ± 0.012 $^{gh}$ |
| **Baht** | 259.0 ± 0.11 $^{d}$ | 264.0 ± 0.31 $^{d}$ | 926.6 ± 1.85 $^{e}$ | 401.5 ± 0.56 $^{c}$ | 753.0 ± 0.52 $^{d}$ | 0.28 ± 0.001 $^{cd}$ | 9.1 ± 0.031 $^{a}$ | 16.4 ± 0.012 $^{c}$ | 11.5 ± 0.013 $^{ab}$ | 1.3 ± 0.01 $^{h}$ |
| **Bekrari** | 155.0 ± 0.16 $^{h}$ | 232.0 ± 0.52 $^{e}$ | 954.4 ± 1.22 $^{d}$ | 222.0 ± 0.11 $^{h}$ | 520.0 ± 0.38 $^{g}$ | 0.24±0.005 $^{cde}$ | 7.1 ± 0.090 $^{c}$ | 12.6 ± 0.031 $^{ef}$ | 13.1 ± 0.01 $^{a}$ | 2.0 ± 0.011 $^{ef}$ |
| **Bou -Hattem** | 36.0 ± 0.10 $^{n}$ | 181.1 ± 0.16 $^{g}$ | 861.0 ± 1.31 $^{h}$ | 134.9 ± 0.12 $^{l}$ | 481.4 ± 0.41 $^{h}$ | 0.21 ± 0.003 $^{de}$ | 6.5 ± 0.053 $^{c}$ | 10.7 ± 0.069 $^{hi}$ | 7.8 ± 0.026 $^{cde}$ | 2.2 ± 0.023 $^{def}$ |
| **Eguiwa** | 93.0 ± 0.12 $^{k}$ | 217.0 ± 0.11 $^{f}$ | 654.0 ± 1.26 $^{m}$ | 156.0 ± 0.10 $^{j}$ | 372.0 ± 0.38 $^{l}$ | 0.33 ± 0.001 $^{bc}$ | 5.0 ± 0.033 $^{de}$ | 11.1 ± 0.01 $^{gh}$ | 7.6 ± 0.61 $^{cde}$ | 2.5 ± 0.031 $^{cd}$ |
| **Garn Gzel** | 72.0 ± 0.11 $^{l}$ | 146.0 ± 0.23 $^{i}$ | 632.0 ± 1.42 $^{o}$ | 130.0 ± 0.36 $^{l}$ | 378.0 ± 0.29 $^{l}$ | 0.23±0.003 $^{cde}$ | 4.3 ± 0.056 $^{e}$ | 13.1 ± 0.068 $^{de}$ | 6.8 ± 0.061 $^{de}$ | 2.0 ± 0.014 $^{ef}$ |
| **Halway** | 250. ± 0.35 $^{e}$ | 233.0 ± 0.45 $^{e}$ | 638.0 ± 1.34 $^{n}$ | 922.3 ± 0.52 $^{a}$ | 446.0 ± 0.38 $^{j}$ | 0.36 ± 0.009 $^{ab}$ | 2.1 ± 0.037 $^{g}$ | 5.5 ± 0.09 $^{k}$ | 3.3 ± 0.027 $^{f}$ | 1.9 ± 0.013 $^{fg}$ |
| **Kenta** | 129.0 ± 0.14 $^{j}$ | 146.0 ± 0.23 $^{i}$ | 653.4 ± 1.26 $^{m}$ | 160.0 ± 0.24 $^{ij}$ | 426.0 ± 0.21 $^{k}$ | 0.22±0.001 $^{cde}$ | 5.3 ± 0.022 $^{d}$ | 12.2 ± 0.013 $^{ef}$ | 4.9 ± 0.016 $^{ef}$ | 0.2 ± 0.004 $^{i}$ |
| **Korkobi1** | 463.0 ± 0.56 $^{a}$ | 126.0 ± 0.19 $^{j}$ | 1383.0 ± 1.98 $^{b}$ | 616.0 ± 0.36 $^{b}$ | 831.0 ± 0.69 $^{b}$ | 0.09 ± 0.002 $^{g}$ | 2.1 ± 0.010 $^{g}$ | 4.5 ± 0.032 $^{l}$ | 6.6 ± 0.036 $^{e}$ | 5.1 ± 0.053 $^{a}$ |
| **Korkobi2** | 451.0 ± 0.34 $^{b}$ | 297.0 ± 0.41 $^{b}$ | 697.0 ± 1.82 $^{l}$ | 115.7 ± 0.27 $^{m}$ | 338.0 ± 0.53 $^{m}$ | 0.42 ± 0.01 $^{a}$ | 3.0 ± 0.011 $^{f}$ | 3.9 ± 0.022 $^{d}$ | 6.0 ± 0.045 $^{ef}$ | 1.8 ± 0.036 $^{fg}$ |
| **Lemsi** | 162.0 ± 0.14 $^{g}$ | 150.7 ± 0.17 $^{i}$ | 832.0 ± 1.67 $^{i}$ | 163.0 ± 0.31 $^{i}$ | 427.0 ± 0.36 $^{k}$ | 0.18 ± 0.002 $^{ef}$ | 4.7 ± 0.021 $^{de}$ | 10.1 ± 0.008 $^{i}$ | 5.1 ± 0.039 $^{ef}$ | 2.4 ± 0.035 $^{cde}$ |
| **Mermella** | 64.0 ± 0.13 $^{m}$ | 156.4 ± 0.11 $^{h}$ | 1426.7 ± 1.99 $^{a}$ | 271.0 ± 0.29 $^{e}$ | 792.0 ± 0.59 $^{c}$ | 0.11 ± 0.003 $^{fg}$ | 8.3 ± 0.036 $^{b}$ | 22.8 ± 0.063 $^{a}$ | 10.0 ± 0.081 $^{bc}$ | 4.5 ± 0.016 $^{b}$ |
| **Nefzawi** | 220.0 ± 0.46 $^{f}$ | 271.0 ± 0.13 $^{c}$ | 1265.3 ± 1.87 $^{c}$ | 266.4 ± 0.23 $^{f}$ | 887.0 ± 0.61 $^{a}$ | 0.21 ± 0.004 $^{de}$ | 9.2 ± 0.091 $^{a}$ | 17.3 ± 0.080 $^{b}$ | 9.6 ± 0.064 $^{bcd}$ | 2.7 ± 0.015 $^{c}$ |
| **Smitti1** | 135.0 ± 0.21 $^{i}$ | 183.0 ± 0.30 $^{g}$ | 748.0 ± 1.86 $^{j}$ | 150.7 ± 0.18 $^{k}$ | 464.0 ± 0.34 $^{i}$ | 0.24±0.002 $^{cde}$ | 5.0 ± 0.029 $^{de}$ | 11.9 ± 0.058 $^{fg}$ | 5.7 ± 0.041 $^{ef}$ | 1.8 ± 0.01 $^{fg}$ |
| **Smitti2** | 315.0 ± 0.32 $^{c}$ | 184.0 ± 0.25 $^{g}$ | 733.0 ± 1.56 $^{k}$ | 158.0 ± 0.24 $^{ij}$ | 469.0 ± 0.16 $^{i}$ | 0.25±0.001 $^{cde}$ | 5.3 ± 0.031 $^{d}$ | 12.4 ± 0.037 $^{ef}$ | 5.0 ± 0.028 $^{ef}$ | n d |
| **Rotbi** | 320.0 ± 0.67 $^{c}$ | 332.0 ± 0.23 $^{a}$ | 906.0 ± 1.36 $^{f}$ | 228.0 ± 0.28 $^{g}$ | 591.0 ± 0.33 $^{f}$ | 0.36 ± 0.005 $^{ab}$ | 6.7 ± 0.046 $^{c}$ | 10.6 ± 0.021 $^{hi}$ | 5.1 ± 0.039 $^{ef}$ | 0.1 ± 0.006 $^{i}$ |

(1) Each population value is the mean of five analysis performed on different juice samples

(2) Superscript letters with different letters in the same column of cultivar respectively indicate significant difference ($P < 0.05$) analyzed by Duncan's multiple range test.

DW: dry weight; nd : not detected

- The group3 composed by the juices of six cultivars, Eguiwa, Garn Gzel, Kenta, Smitti1 and Smitti2. Their mean reducing sugar is 12.38 g/100 mL. These juices were rich in some minerals as phosphorus (19.9 mg $kg^{-1}$ DW) and Zin (12.4 mg $kg^{-1}$ DW).
- The group4 comprise the juice of only one cultivar Halway which is characterized by the high reducing sugar (189.5 g $L^{-1}$), phosphorus (25 mg $kg^{-1}$ DW), sodium (233 mg $kg^{-1}$ DW), Calcium (922.3 mg $kg^{-1}$ DW) and Manganese (1.9 mg $kg^{-1}$ DW) compared to others juices;
- The group5 comprises the juices of three cultivars Korbi1, Mermella and Nefzaoui. This juices group has the highest potassium (1358.3 mg $kg^{-1}$ DW), Magnesium (836.7 mg $kg^{-1}$ DW), copper (6.5 mg $kg^{-1}$ DW), Zinc (14.9 mg $kg^{-1}$ DW) and iron (8.7 mg $kg^{-1}$ DW) contents compared to other juices;
The group1 and group 5 (figure 1) constitute the cluster CL1 performed obtained through PCA (Figure 1b). The groups group 2 and group 3 constitute the cluster CL2 in PCA.
PCA and cluster analyses showed the separation of juice of Halway from all others juice (Table 6).

**Table 5.** PCA applied on sixteen Tunisian coastal date juices based on physico-chemical parameters and mineral contents

| | **F1** | **F2** |
|---|---|---|
| **Eigen value** | 5.58 | 2.84 |
| **Variability (%)** | 34.86 | 17.75 |
| **Actif variable** | **Correlations coefficient** | |
| **Yd** | 0.114 | 0.650 |
| **B** | 0.889 | 0.184 |
| **pH** | -0.035 | 0.114 |
| **Ac** | 0.189 | -0.278 |
| **Cgl** | 0.913 | 0.146 |
| **Cfr** | 0.923 | 0.198 |
| **Csred** | 0.923 | 0.165 |
| **P** | -0.040 | 0.241 |
| **Na** | -0.217 | -0.112 |
| **K** | -0.632 | 0.718 |
| **Ca** | 0.473 | 0.743 |
| **Mg** | -0.471 | 0.831 |
| **Cu** | -0.633 | 0.045 |
| **Zn** | -0.710 | -0.129 |
| **Fe** | -0.582 | 0.145 |
| **Mn** | -0.253 | 0.581 |
| **Supplementary variables** | **Correlations coefficient** | |
| **Rs** | -0.089 | 0.089 |
| **Na/K** | 0.254 | -0.463 |

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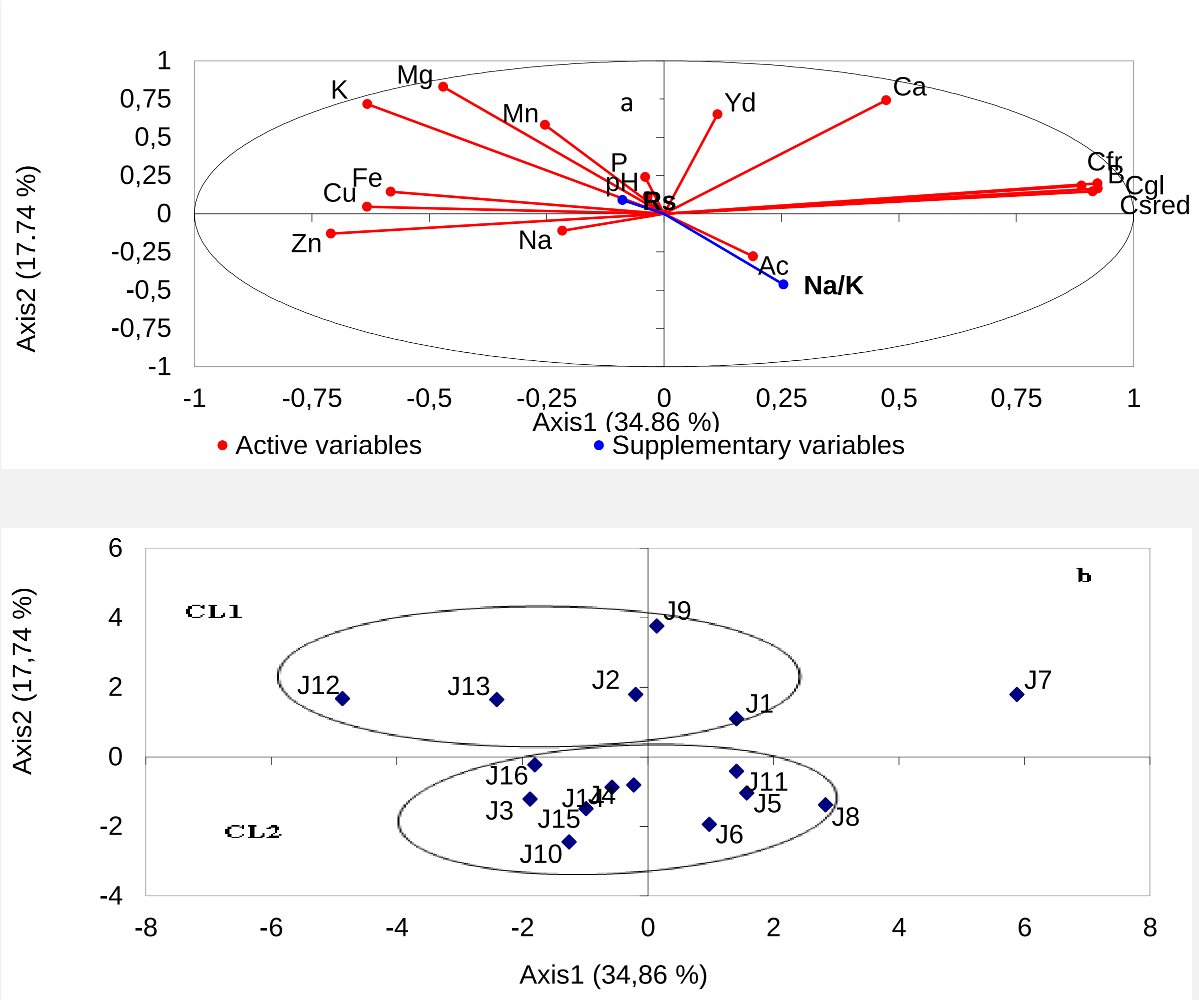


**Figure 2.** Principal Component Analysis applied on Tunisian coastal date juices based on physico-chemical parameters and mineral contents. a: plot of studied parameters; b: Plot of date palm juices

**Table 6.** Groups obtained through PCA and HC analyses of sixteen Tunisian coastal date juices based on physico-chemical parameters and mineral contents

| **Cluster PCA** | **Juice code** | **HC** | **Cultivars** |
|---|---|---|---|
| **CL1** | **J1** | Grp1 | Ammari |
| | **J2** | | Baht |
| | **J9** | Grp5 | Korkobi 1 |
| | **J12** | | Mermella |
| | **J13** | | Nefzaoui |
| **CL2** | **J5** | Grp3 | Eguiw |
| | **J6** | | Garn Gzel |
| | **J8** | | Kenta |
| | **J10** | | Korkobi 2 |
| | **J14** | | Smitti 1 |
| | **J15** | | Smitti 2 |
| | **J3** | Grp2 | Bekrari |
| | **J4** | | Bou Hattem |
| | **J11** | | Lemsi |
| | **J16** | | Rotbi |
| | **J7** | Grp4 | Halway |

PCA: principal components analysis, CH: hierarchical classification, CL: cluster, Gp: group

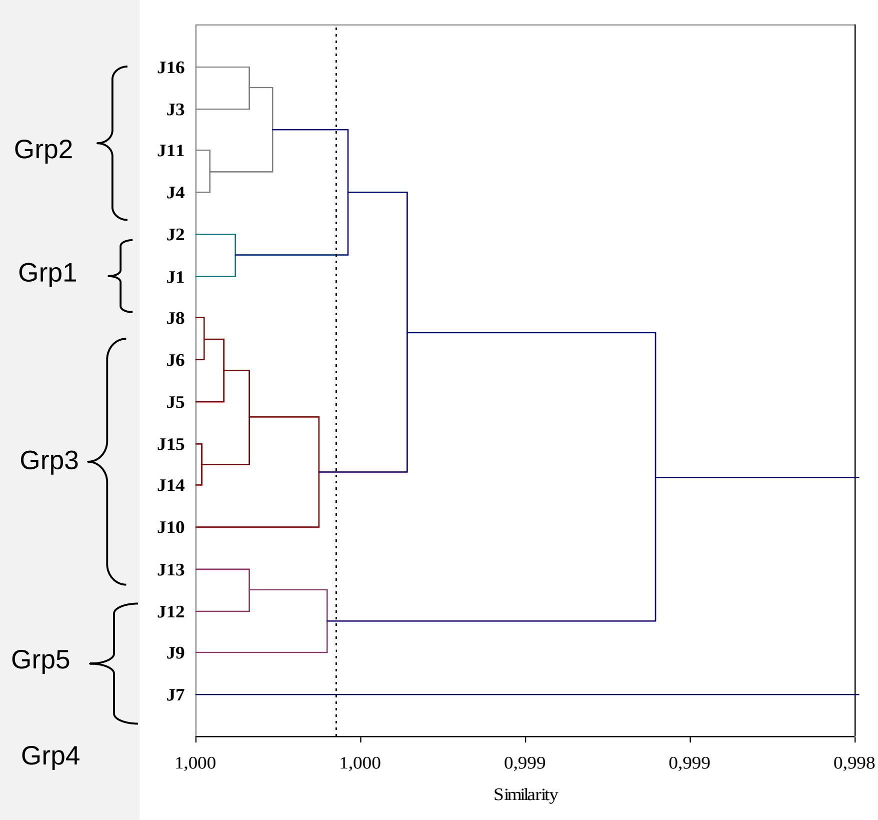


**Figure 3.** Dendrogram grouping coastal Tunisian date juices based on the physico-chemical and mineral contents

## 4. Conclusion

According to chemical analysis of date juices, Tunisian coastal dates, which are marginalized, would be good source of juices characterized by a good nutritional quality. The studied juices were interested nutritional antioxidants compounds because of their free radical scavenging activity showed by DPPH assay. The yield of juices extraction exceeds 81% from all cultivars which presents a technological advantage for operators. In addition, juices are rich in reduced sugar having energetic function. In other hand, the studied juices were rich in mineral elements, especially in potassium. The juices pH is around 5 for almost all juices. This acidy does not preserve juice for a long time, so the addition of a conserving element is necessary.

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