Nutritional Quality and Physico-Chemical Characteristics of Selected Date Fruit Varieties of the United Arab Emirates

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Keywords: biomaterials, amino acids, phytoconstituents, date sugar, physico-chemical characteristics, proximate analysis, date fruits

Abstract:

Production of highly soluble date sugar powder from the nutritive date fruits will be a suitable and superior alternative to commercial refined sugar, providing sustainability in date palm cultivation. A good understanding of the nutritional and phytochemical composition of date fruits is imperative for this purpose. In this work, 11 different date fruit species commonly cultivated in the United Arab Emirates were studied for their chemical composition, physical properties, amino acids, minerals, and anti-nutritional contents. The results revealed that the date fruits contain moisture, protein, lipid, and ash content in the ranges of 14.8%?20.5%, 2.19%?3.12%, 0.25%?0.51%, and 1.37%?1.97%, respectively. Potassium was identified as the major microelement in all the date varieties. Amino acid assay depicted that the date fruits mainly contained glutamine and aspartic acids, along with other essential acids. Monosaccharides (glucose and fructose) were more prevalent in the date fruits than polysaccharides (sucrose), exhibiting the potential of date fruit for non-diabetic sugar production. Phytoconstituents present in date samples, such as flavonoids, oxalates, tannins, saponins, alkaloids, and cyanides, were also evaluated and reported. Results showed that although all date fruit varieties were nutritious, they contain significant variation in their nutritional, physical, elemental, and phytochemical properties.

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Nutritional Quality and Physico-Chemical Characteristics of Selected Date Fruit Varieties of the United Arab Emirates

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Abstract: Production of highly soluble date sugar powder from the nutritive date fruits will be a suitable and superior alternative to commercial refined sugar, providing sustainability in date palm cultivation. A good understanding of the nutritional and phytochemical composition of date fruits is imperative for this purpose. In this work, 11 different date fruit species commonly cultivated in the United Arab Emirates were studied for their chemical composition, physical properties, amino acids, minerals, and anti-nutritional contents. The results revealed that the date fruits contain moisture, protein, lipid, and ash content in the ranges of 14.8%–20.5%, 2.19%–3.12%, 0.25%–0.51%, and 1.37%–1.97%, respectively. Potassium was identified as the major microelement in all the date varieties. Amino acid assay depicted that the date fruits mainly contained glutamine and aspartic acids, along with other essential acids. Monosaccharides (glucose and fructose) were more prevalent in the date fruits than polysaccharides (sucrose), exhibiting the potential of date fruit for non-diabetic sugar production. Phytoconstituents present in date samples, such as flavonoids, oxalates, tannins, saponins, alkaloids, and cyanides, were also evaluated and reported. Results showed that although all date fruit varieties were nutritious, they contain significant variation in their nutritional, physical, elemental, and phytochemical properties.

Keywords: date fruits; proximate analysis; physico-chemical characteristics; date sugar; phytoconstituents; amino acids; biomaterials

1. Introduction

The date palm (*Phoenix dactylifera*) fruit is the major staple food and the primary source of agricultural wealth in the United Arab Emirates (UAE) [1]. Although the exact origin of the fruit is still unknown, it is believed that date palm cultivation originated in the southern parts of modern Iraq about 6000 years ago [2]. The good adaptability, storage durability, and high food value of the date fruit has led to the spread of date palm cultivation in other parts of the world, especially in arid and semi-arid conditions. Today, the tree is cultivated as one of the major crops in south central Asia, northern parts of Africa, parts of Europe, and in California and Arizona states in the United States of

America [3]. The total production of date fruit around the world was more than 7.5 million tons in 2017 [4], with an equivalent utilization rate. Egypt (1.08 million tons), Iran (0.95 million tons), Saudi Arabia (1.08 million tons), Iraq (1.08 million tons), and the United Arab Emirates (1.08 million tons) are the five major growing countries in the world, which contribute 54% of the total production of date fruit globally [5]. Date palm cultivation in the UAE has experienced tremendous growth in last two decades, with over 250 varieties of crop being farmed in various part of the nation, especially in Al Ain and Abu Dhabi emirates. The total growth rate of date fruit is paralleled by a high consumption rate in the UAE, with a per capita daily intake of 10 to 200 g in Abu Dhabi emirate alone [6].

Research on date fruit has shown that the fruit has a wide range of uses and applications. Primarily, the fruit is seen as a rich source of energy, minerals, and vitamins for human health [7]. Additionally, the fruit is also administrated as a medicinal cure for cancer and various other infectious diseases [8]. The high anti-oxidant and antimutagenic contents present in date fruit makes it an ideal source for the production of a wide range of confectionary, medicinal, and cosmetic products [9]. In recent times, date fruits have been critically analyzed for the production of fruit sugar, which is seen as a very healthy and nutritious substitute for commercial refined sugar [10]. The date seeds obtained from the date fruit have also been widely studied for the production of a variety of potential useful products, such as activated carbon, bio-oil production, cellulose separation, biohydrogen synthesis, and water treatment [11–15].

Although several works have been carried out on date fruit, research studies concerned with the nutritional and physico-chemical characteristics of the fruit are very limited. Especially, key information on various minerals, amino acids, and the anti-nutritional content present in date fruits is not available for various date varieties found in the UAE. This presents a considerable research gap, especially regarding the cultivars, industries, and consumers of the dates, in understanding the complete potential of the fruit. Additionally, a comparative study of the nutritional assay of date varieties for sugar, mineral, and amino acid contents, along with their physical properties, would provide pivotal information for production of soluble fruit sugar and other related food products for the industry. Thus, this paper attempts to report the nutritional and physico-chemical properties of the 11 abundantly grown date fruit varieties in the UAE. Various critical characterizations, such as proximate analysis, total sugar estimation, mineral composition, amino acid quantification, and anti-nutritional assessment, were performed on the fruits. The physical properties of the date varieties, including the fruit weight, were also studied.

2. Materials and Methods

2.1. Sample Collection and Preparation

Eleven date palm fruit varieties, namely Barhe, Bumaan, Dabbas, Fard, Jabri, Khalas, Lulu, Maktoomi, Raziz, Shiakt, and Shishi, were directly procured from the cultivation sites of Abu Dhabi and Al Ain farmlands of the UAE. All the samples were at the "Tamr stage", which is the final phase of the fruit growth. The as-received samples were thoroughly rinsed with distilled water, followed by air drying at ambient temperature. The dried palm fruits were then pitted, segmented, crushed into paste, and stored in air-tight containers for subsequent analysis.

2.2. Physico-Chemical and Proximate Analysis

Physical characteristics, such as mass, volume, density, and fruit content, of the date palm samples were analyzed by randomly selecting fifteen fruits from each variety. The mass (g) of the individual samples was analyzed using digital mass balance, the volume (mL) of each sample was determined by water displacement method, and density (g/mL) was calculated as mass by volume ratio. For fruit

content analysis, the mass of thirty date fruits (with and without seeds) from each variety were measured. The fruit content (%) was measured by the following Equation (1).

$$Wt.\,of\ Fruit\ content\ (\%) = \frac{Wt.\,of\ date\ fruit\ with\ seeds - Wt.\,of\ date\ fruit\ with\ seeds)}{Wt.\,of\ date\ fruit\ with\ seeds} \quad (1)$$

Proximate analysis (moisture content, protein, lipid, and ash contents) of date fruits were carried out in accordance to the standard analytical procedure for food analysis, as reported by Shaba et al. [16]. Generally, for moisture content analysis, a pre-weighed crucible was filled with 2 grams of the sample and kept in an oven at 105 °C overnight. The dried samples were weighed again and the difference in sample weight was expressed as percentage moisture content. However, for ash content analysis, the same procedure was repeated by keeping the moisture-free samples in a muffle furnace at 600 °C for 3 h. Additionally, the lipid content of date fruits was determined by extracting the samples in petroleum ether at 60–80 °C for 5 h using a soxhlet extractor. The Kjeldahl method was implied to determine the total protein content in date palm samples. For this purpose, 0.5 g of the sample was digested in a concentrated H_2SO_4 solution, followed by distillation and titration with 40% NaOH and 0.01 M HCl solutions, respectively.

2.3. Total Sugar Content

The total and reducing sugar content in different varieties of date fruits were analyzed according to the standard procedure reported by Ismail et al. [7]. Generally, 20 g of the fruit sample was homogenized in boiling water for 90 s. The resultant suspension was then diluted by deionized water followed by filtration. The sample was then examined and compared with the calibration curves of the two standard solutions (fructose and glucose) by utilizing a Waters High Performance Liquid Chromatography (HPLC) system (Waters 717 Plus Autosampler, Milford, NH, USA). The same method was repeated for all the date varieties examined in this research work.

2.4. Determination of Mineral Contents

The mineral contents, namely potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), sodium (Na), and iron (Fe), in the date samples were determined as reported by Heckman et al. [17]. A known amount of date fruit sample was heated in a furnace at 550 °C for 4 h. The cooled sample was then boiled with 3N HCl solution for 10 min, followed by cooling and filtration. The mineral contents in the resultant solution were then tested by using inductively coupled plasma mass spectrometry (ICP-MS 7900, Agilent Technologies, Waldbron, Germany).

2.5. Amino Acid Analysis

The relative distribution of essential amino acids present in the date fruits was measured by oxidation followed by hydrolysis using hydrogen peroxide/formic acid/phenol and 6 M hydrogen peroxide solution, respectively, as described by Al-Barnawi [18]. The amino acids were then separated and analyzed by ion-exchange chromatography and photometric detection (440 and 570 nm) using ninhydrin reagent, respectively [18].

2.6. Quantitative Determination of Phytoconstituents

To ascertain the composition of anti-nutritional constituents, an aqueous solution containing 20 wt % date fruit sample was boiled at 95 °C for 30 min. After filtering the resultant suspension, the solution was treated with different solvents, such as isoamyl-alcohol, H_2SO_4, $FeCl_3$, HCl + NaOH, and hydrogen cyanic acid, to measure the various phytoconstituents, namely flavonoids, oxalates, tannins, saponins, and cyanides, respectively. After titration (color development), the resultant solutions were tested by spectrophotometer at 490 nm wavelength. Moreover, the alkaline precipitation gravimetric method was employed to quantitatively analyze the alkaloid content in the date fruits.

Shaba et al. [16] and Selmani et al. [19] have presented the detailed analytical procedure for determining the phytoconstituents in the *Phoenix dactylifera L.* pollen and fruits, respectively.

2.7. Statistical Analysis

Experimental results were statistically analyzed through Tukey's multiple test and analysis of variance (ANOVA) modes using Minitab software (Minitab Inc., State College, PA, USA). The significance level was set to $p < 0.05$ for the analysis.

3. Results

3.1. Physico-Chemical and Proximate Analysis of Date Fruits

The physical properties, such as mass (g), volume (mL), density (g/mL), and fruit content (%), of the date fruits are significant factors in describing their diet suitability and storage. Figure 1A depicts the physical properties of various date fruit varieties cultivated in the UAE. Jabri (10.49 g) and Buman (9.78 g) recorded the highest and lowest masses for the studied date selections in the "Tamr" stage. Maximum and minimum fruit volumes were measured as 11.43 mL and 4.35 mL for Maktoomi and Dabbas breeds, respectively. The results also revealed that the density of date fruits varied in the range of 0.8 g/mL (Lulu) to 1.43 g/mL (Raziz). Moreover, the percentage of fruit content was also analyzed for the studied *Phoenix Dactylifera* species. Their variation is illustrated in Figure 1B. It can be observed that the percentages of fruit content differed between 88.51% (Raziz) and 92.13% (Fard). The differences in physical properties for various date species depend on the geographical and cultivation conditions, seed nature, chemical fertilization, and pre- and post-harvesting treatment techniques.

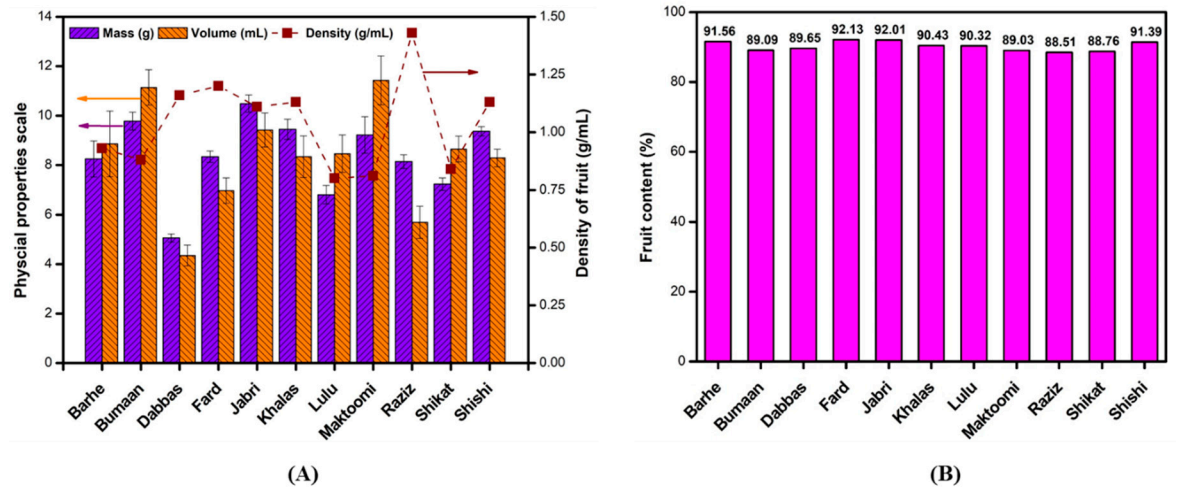

Figure 1. Physical properties of date fruit varieties of the UAE: (**A**) mass, volume, and density of the fruit; (**B**) fruit content of the dates.

The results for proximate analysis of the 11 different varieties of date fruits cultivated in the UAE are presented in Table 1. The results revealed that among various date fruit samples, Maktoomi and Khalas exhibited the lowest (13.6%) and highest (20.5%) moisture content, respectively. Moreover, the protein and lipid contents for the fruit varieties ranged from 2.19% (Jabri) to 3.12% (Khalas) and from 0.25% (Raziz) to 0.51% (Shiakt), respectively. Shishi and Fard reported the minimum (1.37%) and maximum (1.97%) ash content, respectively. No noticeable variation was observed in ash or lipid contents for Barhe, Bumaan, Fard, Khalas, Maktoomi, and Raziz dates. In summary, for all the studied date varieties, slight deviations in the protein, lipid, and ash contents were observed compared to moisture content. The variation in the proximate analysis of various date fruit samples might be because of differences in geographic locations and agro-climatic and environmental conditions.

Table 1. Proximate analysis for the date fruit varieties of the UAE.

Date Variety	Moisture *	Protein *	Lipid *	Ash *
Barhe	16.4 ± 0.1 ^{a}	2.73 ± 0.04 ^{a}	0.29 ± 0.005 ^{a}	1.96 ± 0.02 ^{a}
Bumaan	17.7 ± 0.2 ^{b}	2.36 ± 0.02 ^{b}	0.38 ± 0.002 ^{b}	1.77 ± 0.01 ^{b}
Dabbas	19.5±0.3 ^{c}	2.54±0.01 ^{c,d}	0.41±0.004 ^{c}	1.64 ± 0.02 ^{c}
Fard	18.1 ± 0.2 ^{b}	2.89 ± 0.03 ^{e}	0.33 ± 0.001 ^{d}	1.97 ± 0.03 ^{a}
Jabri	15.4 ± 0.4 ^{d}	2.19 ± 0.02 ^{f}	0.48 ± 0.002 ^{e}	1.53 ± 0.02 ^{d}
Khalas	20.5 ± 0.3 ^{e}	3.12 ± 0.05 ^{g}	0.31 ± 0.003 ^{f}	1.72 ± 0.01 ^{b,e}
Lulu	16.9 ± 0.1 ^{a}	2.63 ± 0.02 ^{h,i}	0.44 ± 0.005 ^{g}	1.68 ± 0.05 ^{c,e}
Maktoomi	13.6 ± 0.2 ^{f}	2.58 ± 0.03 ^{c,i}	0.37 ± 0.003 ^{h}	1.85 ± 0.03 ^{f}
Raziz	15.3 ± 0.2 ^{d}	2.67 ± 0.02 ^{a,h}	0.25 ± 0.001 ^{i}	1.87 ± 0.04 ^{f}
Shikat	13.8 ± 0.1 ^{f}	2.46 ± 0.01^{d}	0.51 ± 0.000 ^{j}	1.64 ± 0.01 ^{c}
Shishi	14.8 ± 0.3 ^{d}	2.53 ± 0.04 ^{c,d}	0.35 ± 0.002 ^{k}	1.37 ± 0.02 ^{g}

* Results are presented as g/100 g of fruit flesh's weight; mean values superscripted with different alphabets within the same column are significantly different ($p < 0.05$), as established by Tukey's test.

3.2. Sugar Content in Date Fruits

Sugar is the main component of date fruits and is present mainly in the form of monosaccharides (glucose and fructose) and polysaccharides (sucrose). Figure 2 illustrates the amount of total and reducing sugars analyzed in 11 different date varieties of the UAE. It can be inferred that a maximum of 90.5% total sugar content was present in Maktoomi dates, while Fard dates contained the minimum sugar content of 71.8%, as compared to other varieties. The compositions of sucrose, glucose, and fructose, along with the glucose to fructose ratio (G/F), are summarized in Table 2. It can be observed that the major components of date sugar were glucose and fructose, whereas a relatively small amount of sucrose was also found in all of the examined dates. Interestingly, Barhe had the lowest sucrose content and higher fructose content than glucose, as evident from its low G/F ratio of 0.88. In contrast, some dates, such as Dabbas, Khalas, Lulu, and Maktoomi, showed a higher concentration of glucose than fructose, with G/F values > 1. Overall, the G/F ratios of all analyzed date types varied in the range of 0.88 (Barhe) to 1.33 (Maktoomi).

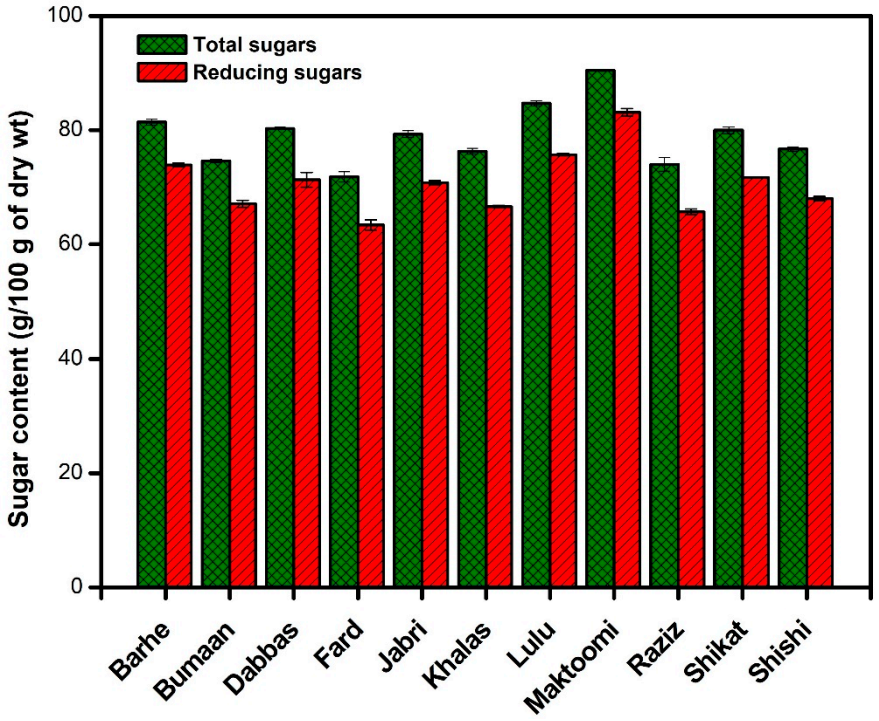

Figure 2. Sugar content of date fruit varieties of the United Arab Emirates (UAE).

Table 2. Sucrose, glucose, and fructose contents for the date fruit varieties of the UAE.

Date Variety	Sucrose *	Glucose(G) *	Fructose (F) *	G/F Ratio
Barhe	4.2 ± 0.1 ^{a}	34.6 ± 0.1 ^{a,b}	39.3 ± 0.2 ^{a}	0.88
Bumaan	4.4 ± 0.3 ^{a}	32.3 ± 0.1 ^{c}	34.8 ± 0.1 ^{b,c}	0.93
Dabbas	6.4 ± 0.7 ^{b,c,d}	36.3 ± 0.5 ^{d}	35 ± 0.2 ^{b,d}	1.04
Fard	5.2 ± 0.2 ^{a,e,f,g}	31.3 ± 0.2 ^{c}	32.1 ± 0.2 ^{e}	0.98
Jabri	5.8 ± 0.1 ^{c,d,e,f}	35.2 ± 0.2 ^{a}	35.6 ± 0.3 ^{f}	0.99
Khalas	6.1 ± 0.5 ^{b,c,d,e}	33.4 ± 0.3 ^{e}	33.2 ± 0.1 ^{g}	1.01
Lulu	6.7 ± 0.3 ^{b,c}	40.2 ± 0.5 ^{f}	35.5 ± 0.1 ^{d,f}	1.13
Maktoomi	6.9 ± 0.1 ^{b}	47.4 ± 0.4 ^{f}	35.7 ± 0.2 ^{f}	1.33
Raziz	4.5 ± 0.1 ^{a,g}	31.8 ± 0.7 ^{c}	33.9 ± 0.1 ^{h}	0.94
Shikat	4.9 ± 0.2 ^{a,f,g}	35.1 ± 0.4 ^{a}	36.6 ± 0.3 ^{i}	0.96
Shishi	5.5 ± 0.6 ^{d,e,f,g}	33.7 ± 0.2b ^{e}	34.3 ± 0.2 ^{c}	0.98

* Results are presented as g/100 g of fruit flesh weight; mean values superscripted with different alphabets within the same column are significantly different ($p < 0.05$), as established by Tukey's test.

It is worth mentioning the fact that the diverse variety of dates or the same variety cultivated in different regions of the world may have different G/F ratios based on their geographical and environmental aspects in addition to cultivation conditions. Convincingly, Barhe dates of UAE contained significantly higher levels of total sugar (81.4%) with maximum fructose (39.3%) and minimum G/F ratio of among other stated varieties. Hence, this date variety is one of the ideal date fruit breed for solid date sugar production.

3.3. Mineral Composition of Date Flesh

Commonly, date fruits possess substantial amount of essential micronutrients necessary for human health. Concentration of various essential micronutrients such as K, P, Mg, Ca, Na and Fe in the examined date variants are displayed in Table 3. Results showed that potassium was the major mineral element present in all date varieties. The date selections contained potassium, phosphorus, magnesium, calcium and sodium in the range of 281.74 (Bumaan)–478.29 (Lulu), 48.36 (Dabbas)–77.94 (Raziz), 42.17 (Dabbas)–70.38 (Barhe), 15.46 (Bumaan)–42.39 (Barhe) and 6.25 (Bumaan)–17.52 (Maktoomi) mg/100 g of fruit flesh (FF), respectively. Iron, an essential trace element, was present in good levels in all date breeds with a maximum (1.51 mg/100 g of FF) in Raziz and minimum (0.78 mg/100 g of FF) in Dabbas. Interestingly, Barhe dates comprised noticeably virtuous amount of all the vital minerals such as K (444.69 mg/100 g of DF), P (65.84 mg/100 g of DF), Mg (70.38 mg/100 g of DF) and Ca (42.39 mg/100 g of DF) compared to other date species. In general, potassium and phosphorous elements impart strength for human cells regeneration, while magnesium and calcium are vital for healthy bones development [8,20]. Iron is very critical for blood production and tissue respiration [6]. Hence, due to the presence of these essential elements, date fruits are considered to be healthy diet containing a rich source of minerals and play a pivotal role in development of the immune system for humans.

3.4. Amino Acid Composition of Date Flesh

Date fruit comprises various amino acids essential for human metabolism, especially for cell growth and regeneration [16]. In the present study, the date varieties of UAE were assessed for the composition of essential amino acids (glutamine, aspartic acid, glycine, proline, histidine, and valine) present in them. Figure 3 presents the results of the amino acids assessment for different varieties of UAE dates on a relative percentage scale for comparative quantification. The results revealed that glutamine was the major amino acid found in all date varieties, except for Bumaan and Shikat. Additionally, it was observed that all date selections contained high levels of glutamine and aspartic acid (>50% composition) as compared to other essential amino acids. Histidine was present at the lowest concentration in all date varieties. These essential amino acids present in the date fruits are vital

in muscle building and generation of red and white blood cells in humans [21]. The consumption of date fruits overcomes the problems caused by malnutrition, and serves as a building block for protein and energy regulation in humans [22,23].

Table 3. Composition of various mineral content in the date fruits of UAE.

Date Variety	Ca *	P *	Na *	K *	Mg *	Fe *
Barhe	42.39 ± 0.84 ^{a}	65.84 ± 0.14 ^{a}	14.73 ± 0.09 ^{a}	444.69 ± 3.63 ^{a}	70.38 ± 0.59 ^{a}	1.37 ± 0.05 ^{a}
Bumaan	15.46 ± 0.57 ^{b}	59.21 ± 0.65 ^{b}	6.25 ± 0.14 ^{b}	281.74 ± 2.18 ^{b}	55.92 ± 0.31 ^{b}	1.05 ± 0.03 ^{b}
Dabbas	35.71 ± 1.27 ^{c}	48.36 ± 0.65 ^{c}	14.38 ± 0.32 ^{a,c}	419.05 ± 6.11 ^{c}	42.17 ± 1.44 ^{c}	0.78 ± 0.02 ^{c}
Fard	34.23 ± 0.79 ^{c,d}	55.04 ± 1.27 ^{d}	11.56 ± 0.17 ^{d}	466.28 ± 4.50 ^{d,e}	61.56 ± 0.62 ^{d}	0.84 ± 0.01 ^{c,d}
Jabri	29.48 ± 1.44 ^{e}	71.45 ± 0.38 ^{e}	12.12 ± 0.58 ^{d}	398.51 ± 7.29 ^{f}	50.97 ± 0.47 ^{e}	0.93 ± 0.03 ^{d,e,f}
Khalas	40.25 ± 0.39 ^{a}	52.19 ± 0.47 ^{f}	8.41 ± 0.07 ^{e}	431.17 ± 1.63 ^{c}	46.28 ± 0.83 ^{f}	1.42 ± 0.04 ^{a,g}
Lulu	36.19 ± 0.65 ^{c}	66.82 ± 0.77 ^{a}	13.78 ± 0.26 ^{c}	478.29 ± 5.34 ^{d}	50.56 ± 0.36 ^{e}	1.26 ± 0.02 ^{h}
Maktoomi	30.14 ± 1.08 ^{e}	74.17 ± 1.36 ^{g}	17.52 ± 0.43 ^{f}	424.81 ± 4.93 ^{c}	67.53 ± 0.19 ^{g}	0.89 ± 0.01 ^{d,f}
Raziz	53.82 ± 0.36 ^{f}	77.94 ± 0.82 ^{h}	9.26 ± 0.11 ^{g}	462.42 ± 2.72 ^{e,g}	42.35 ± 0.85 ^{c}	1.51 ± 0.06 ^{g}
Shikat	32.67 ± 0.51 ^{d}	65.56 ± 0.96 ^{a}	11.41 ± 0.05 ^{d}	450.96 ± 3.26 ^{a,g}	62.41 ± 0.09 ^{d,h}	1.00 ± 0.04 ^{b,e}
Shishi	30.11 ± 0.86 ^{e}	67.28 ± 0.30 ^{a}	14.87 ± 0.37 ^{a}	375.33 ± 0.98 ^{h}	64.01 ± 0.24 ^{h}	0.97 ± 0.03 ^{b,e,f}

* Results are presented as mg/100 g of fruit flesh's weight; Mean values superscripted with different alphabets within the same column are significantly different ($p < 0.05$) as established by Tukey's test.

3.5. Anti-Oxidant and Anti-Nutritional Assessment of Date Fruits

The nutritional aspects of date fruits could also be expressed in terms of phytoconstituents [24]. Measurement of flavonoids indicates the anti-oxidant capacity, while concentrations of oxalates, tannins, saponins, alkaloids, and cyanides highlight the anti-nutritional nature of the fruit. The results for the anti-oxidant and anti-nutritional contents of various varieties of *Phoenix dactylifera* fruits cultivated in UAE are presented in Table 4. The oxalate content in the date samples ranged from 0.26% to 1.18% for Maktoomi and Raziz, respectively. Among the different fruit varieties examined, Barhe, Fard, Lulu, Shikat, and Shishi had imperceptible oxalate content, while the remaining samples had negligible oxalate content, indicating that even the excessive utilization of these date samples has no deleterious impact on the human body. The flavonoid and alkaloid contents in the dates ranged between 24.33% (Shikat) and 54.26% (Barhe), and between 0.09% (Dabbas) and 1.28% (Lulu), respectively. The high levels of flavonoids in Barhe variety exhibited their better anti-oxidant capacity as compared to other date varieties. The cyanide, saponin, and tannin contents in the date samples were in the ranges of 0.0%1–0.04%, 0.02%–1.06%, and 0.19%–0.92%, respectively. Overall, the composition of the anti-nutrients was very low in all fruit types, ensuring their safety and health benefits for consumption. Remarkably, the Barhe fruit possessed high levels of flavonoids and extremely low levels of anti-nutrients, which makes it the best date sample amongst all other studied varieties.

Table 4. Anti-nutritional assessment of date fruit varieties of the UAE.

Date Variety	Flavanoid *	Oxalate *	Tannin *	Saponin *	Alkaloid *	Cyanide *
Barhe	54.26 ± 2.17 ^{a}	-	-	0.05 ± 0.00 ^{a,b}	0.93 ± 0.03 ^{a}	-
Bumaan	36.37 ± 1.63 ^{b}	1.09 ± 0.03 ^{a,b}	-	0.22 ± 0.04 ^{a,c}	0.64 ± 0.05 ^{b}	0.02 ± 0.00 ^{a,b}
Dabbas	46.35 ± 0.99 ^{c}	0.87 ± 0.19 ^{b,c}	0.52 ± 0.03 ^{a}	-	0.09 ± 0.01 ^{c}	-
Fard	29.56 ± 0.87 ^{d,e}	-	0.78 ± 0.12 ^{b,c}	0.39 ± 0.06 ^{c,d}	0.57 ± 0.04 ^{b}	-
Jabri	37.21 ± 0.32 ^{b,f}	0.43 ± 0.06 ^{d,e}	0.19 ± 0.02 ^{d}	1.06 ± 0.14 ^{e}	-	0.04 ± 0.01 ^{c}
Khalas	45.18 ± 0.72 ^{c}	0.59 ± 0.05 ^{c,d}	-	0.16 ± 0.01 ^{a,b}	-	0.04 ± 0.01 ^{c}
Lulu	32.49 ± 0.55 ^{d,g}	-	0.64 ± 0.05 ^{a,c}	-	1.28 ± 0.14 ^{d}	0.01 ± 0.00 ^{b}
Maktoomi	29.14 ± 0.61 ^{e}	0.26 ± 0.02 ^{e}	0.92 ± 0.04 ^{b,c}	0.02 ± 0.00 ^{b}	0.72 ± 0.09 ^{b}	-
Raziz	39.72 ± 0.82 ^{f}	1.18 ± 0.14 ^{a}	0.23 ± 0.02 ^{d}	-	0.11 ± 0.02 ^{c}	0.01 ± 0.00 ^{b}
Shikat	24.33 ± 0.63 ^{h}	-	0.63 ± 0.01 ^{a,c}	0.41 ± 0.05 ^{d}	-	0.03 ± 0.01 ^{a,c}
Shishi	34.28 ± 1.01 ^{b}	-	-	0.77 ± 0.09 ^{f}	0.26 ± 0.04 ^{c}	-

* Results are presented as % concentration; mean values superscripted with different alphabets within the same column are significantly different ($p < 0.05$), as established by Tukey's test.

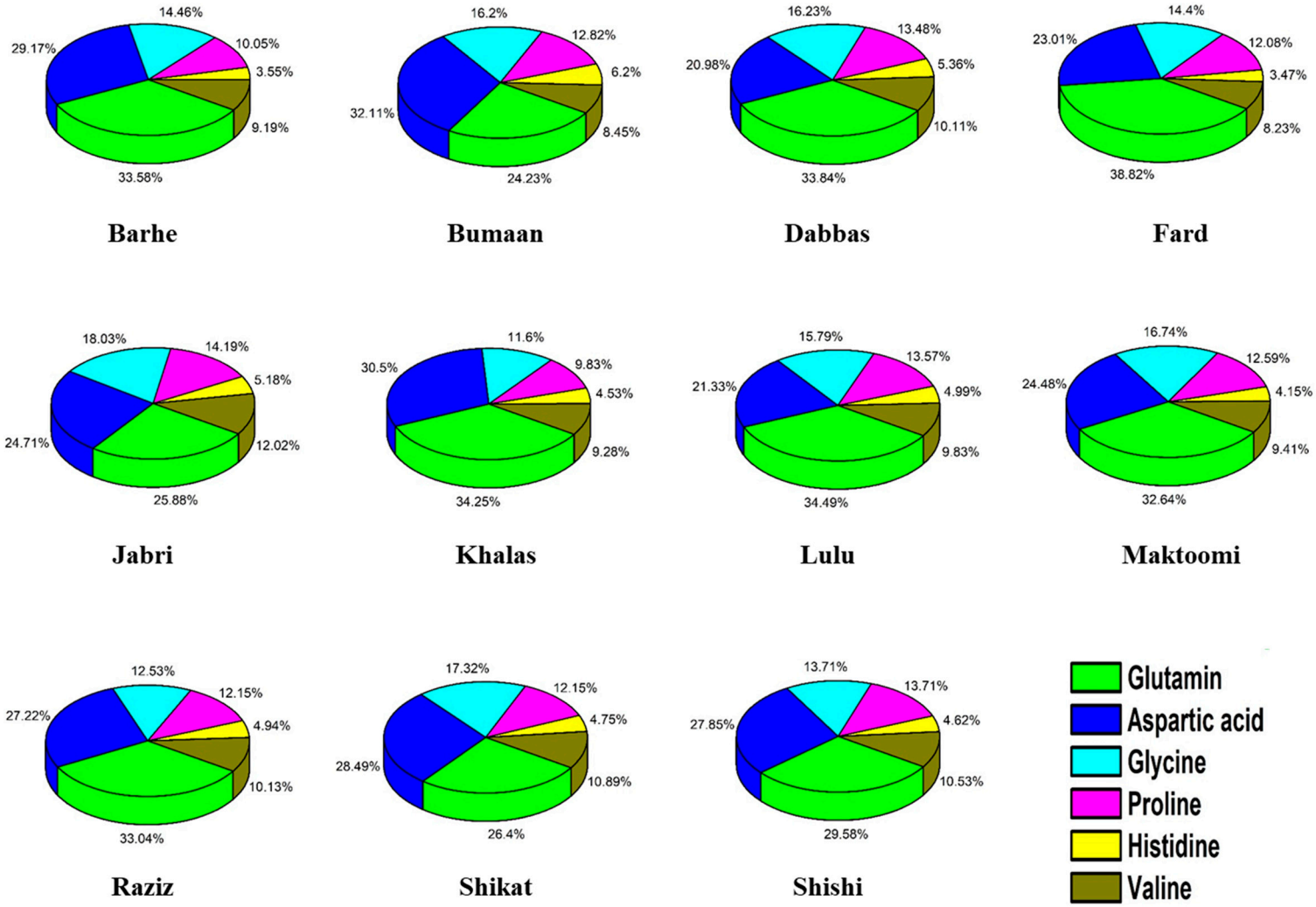

Figure 3. Relative distribution of essential amino acids present in the date fruit varities of the UAE.

4. Discussions

Date fruits have been predominately utilized as an integral component of the UAE food system to provide a wide range of nutrients and supplements for human health. Very recently, the scope of the date fruit has been extensively researched in UAE for production of numerous products that are expected to have versatile applications. These applications includes medicinal products, cosmetics, functional foods and beverages, specialty chemicals, biofuels, bioplastics, water treatment, animal fodder, and as mechanical sealants. Thus, a complete understanding of the nutritional and physico-chemical properties of the popular date palm fruits in the UAE is very essential for the intensified growth of the UAE industries producing date-fruit-related products. The presented study, which caters exactly to the above-specified requirement, provides vital information to these industries to help them effectively process the date fruits to achieve these products in an efficient manner. The reported physical properties for the date samples would serve both agricultural and industrial sectors in choosing the appropriate date type for cultivation and end-product application for a given purpose.

Details on the proximate analysis of the local date fruit variants provides the key information for processing, preservation, storage, and grading of the fruits [10]. The sugar assay for the specified varieties of UAE date fruits would aid the pharmaceutical and food and beverages industries for effective synthesis of commercial functional foods and medicinal items. The quantitative determination of the sugar components in date fruits is highly crucial for production of novel, soluble, solid date fruit sugar (fructose and glucose), which is foreseen to be a suitable and superior alternative to commercial refined sugar (sucrose). Additionally, the sugar analysis in conjunction with the phytochemical analysis of the date fruits provides the preliminary and pivotal data for synthesis of new types of healthy and non-alcoholic beverages through fermentation and thermo-chemical methods.

The abundant amount of minerals and salts present in the UAE date fruits at their respective computed levels are reported in this work. These nutrients would serve the pharmaceutical and cosmetics industries in identifying the right candidate for the production of versatile products, specifically in anti-cancer and anti-hyperlipidemic drugs, supplement capsules, skin creams, and lotions [18]. As date fruits are generally prescribed as natural supplements for minerals, the presented statistics would help the consumers in the UAE to opt for the suitable fruit breed for a particular mineral deficiency. The presented work is also an initial attempt to assess the amino acids in the eleven date palm fruit types cultivated in the UAE. High levels of amino acids, especially glutamine and aspartic acid, are detected in UAE-grown date fruits as compared to other topographical date fruit types. The amino acid assay for the UAE date breeds reported through this work could plausibly open a new field of bioengineering research. Studies on the selective extraction of amino acids from the date fruits using an efficient methodology is a promising research field with good commercialization potential. Additionally, novel efforts to bioengineer the native date palm to enhance the levels of existing amino acids (as well as to introduce new types of amino acids) in the fruit could be attempted. Additionally, since the local date fruit variants are rich in glutamine, an extended study on the influence of the ratio of glutamic acid (the precursor of glutamine) to glutamine on different stages of the date fruit growth and the shelf life of the final fruit could also be carried out [25]. The amino acids data would also help the pharmaceutical and food industries to pick the right candidates for synthesized drugs and potions rich in protein, especially for human blood, immune, and reproductive systems.

The anti-oxidant and anti-nutritional evaluation indicated the presence of significant levels of flavonoids in the abundantly cultivated local date fruit breeds, while the anti-nutritional components were almost negligible and non-detectable in most cases. This highlights the rich phytochemical nature of the fruit, which paves the way for research towards isolation, identification, and characterization of the various classes of flavonoids present in the fruits, with an emphasis on their functionality. Additionally, the preliminary results regarding the phytochemical nature of the fruit assures promising research potential in the development of active packaging biopolymer films and anti-oxidant bioplastic

sealants from the date fruit waste, which is abundant in the UAE. Additionally, the overall data presented in the work would benefit the industries, consumers, and regulatory bodies of the UAE and related agencies towards effective and efficient utilization of the UAE date fruit variants for new functionalities.

Although the presented work covers a range of characteristic features of the locally grown UAE date fruits types, there are still certain properties of the fruits (mostly secondary in nature) that are yet to be analyzed. For instance, the mechanical properties and the thermal responses of the fruits are important to understand the complete nature of these fruits for their intensified industrial processing. Additionally, the results presented for anti-oxidants and anti-nutritional assessment are elementary, and a detailed analysis for the same properties could be carried out as a possible extension of this work.

5. Conclusions

In summary, a detailed and comprehensive analysis of 11 popular varieties of *Phoenix dactylifera* in the UAE was presented to assess their nutritional and anti-nutritional aspects. The amounts of nutrients present in the fruits showed considerable variation based on the type of date fruit grown, either in the same region or elsewhere. Proximate analysis showed that the date fruits possessed good levels of proteins. Glucose and fructose were identified as major sugar constituents in all of the date types. All of the samples contained a reasonably significant amount of micronutrients (K, Mg, Ca, and P). Amino acid quantification and anti-nutritional assessment for the UAE date fruit varieties were reported for the first time. Studies showed that all date types predominately contained glutamine and aspartic amino acids. Other essential amino acids, such as glycine, proline, and valine, were also present to significant levels, with histidine showing the lowest concentration in all examined date breeds. Anti-nutritional assay of the date fruits confirmed their food safety and health benefits. Hence, these fruits could be effectively used as a nutritional source in food industries and as a precursor to the synthesis of a wide range of functional products. A close analysis of the results showed that among the examined date types, the Barhe variety possessed better nutritional and physio-chemical characteristics, such as high fructose level, substantial amounts of microelements, better anti-oxidants potential, and very low anti-nutrient contents. These features make the Barhe type an ideal candidate for soluble solid date sugar production through suitable processing technology.

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References

1. Oladipupo Kareem, M.; Edathil, A.A.; Rambabu, K.; Bharath, G.; Banat, F.; Nirmala, G.S.; Sathiyanarayanan, K. Extraction, characterization and optimization of high quality bio-oil derived from waste date seeds. *Chem. Eng. Commun.* **2019**, 1–11. [CrossRef]
2. Chao, C.T.; Krueger, R.R. The date palm (Phoenix dactylifera L.): Overview of biology, uses, and cultivation. *HortScience* **2007**, *42*, 1077–1082. [CrossRef]
3. Ortiz-Uribe, N.; Salomón-Torres, R.; Krueger, R. Date Palm Status and Perspective in Mexico. *Agriculture* **2019**, *9*, 46. [CrossRef]
4. Mohd Jaih, A.A.; Rahman, R.A.; Razis, A.F.; Ariffin, A.A.; Al-Awaadh, A.A.; Suleiman, N. Fatty acid, triacylglycerol composition and antioxidant properties of date seed oil. *Int. Food Res. J.* **2019**, *26*, 5120527.

5. Food and Agricultural Organinzation of the United Nations. Available online: http://www.fao.org/faostat/en/#rankings/countries_by_commodity (accessed on 15 January 2020).
6. Habib, H.M.; Ibrahim, W.H. Nutritional quality of 18 date fruit varieties. *Int. J. Food Sci. Nutr.* **2011**, *62*, 544–551. [CrossRef]
7. Ismail, B.; Haffar, I.; Baalbaki, R.; Mechref, Y.; Henry, J. Physico-chemical characteristics and total quality of five date varieties grown in the United Arab Emirates. *Int. J. Food Sci. Technol.* **2006**, *41*, 919–926. [CrossRef]
8. Assirey, E.A.R. Nutritional composition of fruit of 10 date palm (Phoenix dactylifera L.) cultivars grown in Saudi Arabia. *J. Taibah Univ. Sci.* **2015**, *9*, 75–79. [CrossRef]
9. Miller, C.J.; Dunn, E.V.; Hashim, I.B. The glycaemic index of dates and date/yoghurt mixed meals. Are dates 'the candy that grows on trees'? *Eur. J. Clin. Nutr.* **2003**, *57*, 427–430. [CrossRef]
10. Ashraf, Z.; Hamidi-Esfahani, Z. Date and Date Processing: A Review. *Food Rev. Int.* **2011**, *27*, 101–133. [CrossRef]
11. Krishnamoorthy, R.; Govindan, B.; Banat, F.; Sagadevan, V.; Purushothaman, M.; Show, P.L. Date pits activated carbon for divalent lead ions removal. *J. Biosci. Bioeng.* **2019**, *128*, 88–97. [CrossRef]
12. Rambabu, K.; Banat, F.; Nirmala, G.S.; Velu, S.; Monash, P.; Arthanareeswaran, G. Activated carbon from date seeds for chromium removal in aqueous solution. *Desalin. Water Treat.* **2019**, *156*, 267–277. [CrossRef]
13. Swathy, R.; Rambabu, K.; Banat, F.; Ho, S.H.; Chu, D.T.; Show, P.L. Production and optimization of high grade cellulase from waste date seeds by Cellulomonas uda NCIM 2353 for biohydrogen production. *Int. J. Hydrogen Energy* **2019**. [CrossRef]
14. Rambabu, K.; Show, P.L.; Bharath, G.; Banat, F.; Naushad, M.; Chang, J.S. Enhanced biohydrogen production from date seeds by Clostridium thermocellum ATCC 27405. *Int. J. Hydrogen Energy* **2019**. [CrossRef]
15. Hai, A.; Bharath, G.; Babu, K.R.; Taher, H.; Naushad, M.; Banat, F. Date seeds biomass-derived activated carbon for efficient removal of NaCl from saline solution. *Process Saf. Environ. Prot.* **2019**, *129*, 103–111. [CrossRef]
16. Shaba, E.Y.; Ndamitso, M.M.; Mathew, J.T.; Etsunyakpa, M.B.; Tsado, A.N.; Muhammad, S.S. Nutritional and anti-nutritional composition of date palm (Phoenix dactylifera L.) fruits sold in major markets of Minna Niger State, Nigeria. *Afr. J. Pure Appl. Chem.* **2015**, *9*, 167–174.
17. Heckman, M. Collaborative study of a copper in feeds by atomic absorption spectrophotometry. *J. Assoc. Off. Anal. Chem.* **1971**, *54*, 666–668. [CrossRef]
18. Al-barnawi, H.M. Nutritional Composition of Protein Extract from Date Palm Fruit (Phoenix dactylifera L.) Cultivar Grown in Saudi Arabia. *SciFed J. Protein Sci.* **2018**, *1*, 1.
19. Selmani, C.; Chabane, D.; Bouguedoura, N. Ethnobotanical survey of phoenix dactylifera l. Pollen used for treatment of infertility problems in algerian oases. *Afr. J. Tradit. Complement. Altern. Med.* **2017**, *14*, 175–186. [CrossRef]
20. Gasim, A.A.A. Changes in sugar quality and mineral elements dur-ing fruit development in five date palm cultivars in Al-MadinahAl-Munawwarah. *J. King Abdul Aziz Univ.* **1994**, *6*, 29–36.
21. Xu, Y.T.; Ma, X.K.; Wang, C.L.; Yuan, M.F.; Piao, X.S. Effects of dietary valine:lysine ratio on the performance, amino acid composition of tissues and mRNA expression of genes involved in branched-chain amino acid metabolism of weaned piglets. *Asian-Australas. J. Anim. Sci.* **2018**, *31*, 106–115. [CrossRef]
22. Vayalil, P.K. Date Fruits (Phoenix dactylifera Linn): An Emerging Medicinal Food. *Crit. Rev. Food Sci. Nutr.* **2012**, *52*, 249–271. [CrossRef] [PubMed]
23. Zhang, C.R.; Aldosari, S.A.; Vidyasagar, P.S.P.V.; Shukla, P.; Nair, M.G. Health-benefits of date fruits produced in Saudi Arabia based on in vitro antioxidant, anti-inflammatory and human tumor cell proliferation inhibitory assays. *J. Saudi Soc. Agric. Sci.* **2017**, *16*, 287–293. [CrossRef]
24. Aletor, O.; Adebayo, A.O. Comparative Evaluation of the Nutritive and Physico-Chemical Characteristics of the Leaves and Leaf Protein Concentrates from Two Edible Vegetables. *J. Food Technol.* **2007**, *5*, 152–156.
25. Pratta, G.; Zorzoli, R.; Boggio, S.B.; Picardi, L.A.; Valle, E.M. Glutamine and glutamate levels and related metabolizing enzymes in tomato fruits with different shelf-life. *Sci. Hortic.* **2004**, *100*, 341–347. [CrossRef]

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