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Comparison among Five Varieties of Date Fruit and Their Nutritional Value at Different Ripening Stages

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ABSTRACT

Date palm (*Phoenix dactylifera* L.) is known for its social, environmental , and economic importance by many people in tropical and subtropical regions. Dates are an essential agricultural product in Iran and sometimes a staple food because of their high sugar content, vitamins, minerals, phenolic compounds, and antioxidants. This research aimed to explore the changes that occur in chemical compounds at different stages of fruit ripening. Five palm cultivars were comparable with each other in this regard. The fruits were harvested at various ripening stages (Hobabok, Kimri, Khalal, Rutab, and Tamar) from five date varieties, i.e., 'Khenizi,' 'Mazafati,' 'Kaloteh,' 'Shahani,' and 'Mordasang.' We measured phenolic compounds, anthocyanin, tannin, moisture, and total soluble solids (TSS) in the fruits at their different ripening stages. Average comparisons showed that the TSS content, anthocyanin, and phenol compounds increased during ripening. In contrast, antioxidant capacity, tannins, flavonoids, and moisture content decreased. Chemical compounds in the cultivars were different from one another at ripening. Thus, harvesting should take place according to the harvest purpose in each cultivar.

Introduction

Date palm (*Phoenix dactilifera*; Araceae) is a monocotyledonous plant, having male and female flowers on separate trees. Regarding fruit production, the economic life of date palms is about 40 years (Mostaan et al., 2017).

Dates are essential horticultural crops that play an important role in food security, preservation, and sustainability of the environment and the national economy. Iran has a rich source of germplasm, with more than 400 varieties of dates, of which about 50 types have commercial and export value (Pezhman, 2002).

Dates have high nutritional value and come in different varieties with various colors, tastes, sizes, etc. In addition, the characteristics of date fruit in various stages of its growth and

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development are different. Therefore, biochemical changes of cultivars at different stages of their growth and development appear diverse. Biochemical changes in fruits of varying date varieties remain a mystery, and this research is the first report on this subject.

The role of antioxidants in minimizing or preventing the risk of many human diseases is well recognized (Benzie, 2003). Such a role is currently attracting attention from various disciplines throughout the world. Databases and recommended daily allowance for antioxidants have been promoted by such interest (Wu et al., 2004).

The growth stages of date fruit include several steps, including Hababok (unripe and inedible), Kimri (unripe, green color and inedible), Khalal (complete-size, and edible), Rutab (soft, brown to a black color and edible), and Tamer (fully ripe, reduced moisture and edible). Tamer is defined as the final stage of date fruit ripeness once their color converts to brown or black, and their composition changes toward relatively lower moisture (about 20%) content and higher sugar content (Hussain et al., 2020).

The chemical composition of dates can vary depending on the variety, soil conditions, agricultural practices, and the ripening stage (Al-Kharusi et al., 2009). While ripening, the fruit loses its moisture, and its sugars convert into glucose and fructose. Small amounts of mannose and maltose also appear at this stage (Shinwari, 1993).

Dates are rich in carbohydrates and other nutrients such as minerals, proteins, fats, and vitamins. As a result, dates have long been an essential part of most Middle Eastern diets (Siddiq et al., 2013).

The most critical quality attributes when grading dates are color, flavor (sugar level), moisture (26–30%), and absence of defects such as insects, damage, cracks, and surface damage. Date fruit is a good source of high nutritional value food. Indeed, it is rich in carbohydrates, dietary fibers, proteins, minerals, and vitamin B complex, such as thiamine (B1), riboflavin (B2), niacin (B3), pantothenic (B5), pyridoxine (B6), and folate (B9) (Siddiq et al., 2013; Eoin, 2016).

Dates contain various types of phytochemicals such as carotenoids (beta-carotene, lycopene, lutein, zeaxanthin, neoxanthin, etc.), phenolics, mainly cinnamic acids and their derivatives (ferulic, sinapic, syringic, vanilla, gallic, caffeine, protocol) (Bigleri et al., 2008).

Carotenoids and phenolic compounds (flavonoids and anthocyanins) can contribute to varying degrees of antioxidant and antimutagenic activity. The contribution of total phenol to the antioxidant activity of dates is higher than that of ascorbic acid (Shivashankara et al., 2004).

Phenols are components in dates that significantly affect color, taste, and antioxidant properties. They comprise about 3% of the dry fruit weight and include four main groups of tannins, flavones, flavans, and flavonols (Rastegar and Rahemi, 2015).

Mansouri et al. (2005) identified the primary phenolic acids, including p-coumaric acid, ferulic acid, and sinapic acid. Moreover, three different isomers of 5-o-caffeoyl shikimic acid appeared additionally, i.e., xanthoxylin acid, hydrocaffeic acid, and coumaroylquinic acid.

These compounds reduce the damage of reactive oxygen species (ROS). Damage mediated by ROS can disrupt membrane fluidity, protein denaturation, lipid peroxidation, oxidative DNA, and alteration of platelet functions (Hussah Al-Shwyeh, 2019), which can cause many chronic health problems such as cancers, inflammation, aging, and atherosclerosis. Antioxidants destroy free radicals and reactive oxygen. However, due to a defect in the production of antioxidants in the body or due to environmental factors or pathophysiological situations in which they occur, sometimes in the wrong place and time, dietary antioxidants can help to prevent oxidative damage (Chaudiere and Ferrari-Iliou, 1999). Regarding the available statements, this research aims to evaluate the nutritional value of several date palm cultivars during the stages of fruit ripening.

Materials and Methods

Plant material

This experiment was conducted in a commercial orchard (Jiroft) that hosted 15-year-old trees. All trees were maintained in similar conditions and comprised five date palm varieties named "Khenizi," "Mordasang," "Shahani," "Mazafati," and "Kaloteh." Fruit samples were collected at different ripening stages, i.e., Hobabok, Kimri, Khalal, Rutab, and Tamar.

Fruits were randomly selected from 4 clusters in 4 directions of the tree and 15 fruits from each date cluster. After harvesting the fruits at different growth stages, the chemical properties were analyzed, including phenols, flavonoids, anthocyanin, tannin, moisture content, and total soluble sugar. The experiment was a completely randomized block design with two factors, i.e., harvest stage and variety.

Total phenolic content

Total phenolic content was assessed with a colorimeter by applying Folin-Ciocalteu reagent,

as explained by Al-Farsi et al. (2005), with minor changes. The extracts (200 µL) were merged with 1.5 mL of Folin-Ciocalteu reagent (diluted 10-fold with distilled water previously) and remained at 22 °C for 5 min. The mixture was mixed with 1.5 mL sodium bicarbonate solution (60 g L^{-1}) and then incubated for 90 min. The concentrations are reported as milligrams of gallic acid equivalents (GAE) per gram of dry weight (DW).

Anthocyanin

Total anthocyanin content was measured using a modified pH differential method (Halliwell et al., 1998). Two grams of plant tissue was homogenized with 5 mL of acidic methanol (99.5 ethyl alcohol and 99.1 hydrochloric acid). Absorbance values of the methanolic extract of anthocyanins were measured at 510 and 700 nm in different pH buffers (pH 1.0 and 4.5, respectively).

Moisture content and total soluble solids

Ten samples were selected from each treatment group. Seeds were removed, the samples were weighed, and then oven-dried at 105 °C until reaching a constant weight. Total soluble solids (TSS) were measured using a hand-held refractometer (American Optical Co., Keene, N.H.)

Total tannins

Total condensed tannins were determined according to Heimler et al. (2006). Accordingly, 400 mL of the date fruit extract was mixed with 3 mL of vanillin methanolic solution (4%) and 1.5 mL of concentrated hydrochloric acid. The mixture was incubated at room temperature for 15 min and the absorbance was determined at 500 nm.

Total flavonoids

Total flavonoid content (TFC) in the date extracts was measured according to a colorimetric assay described by Kim et al. (2003). Accordingly, 0.5 g of fruit tissue was mixed with 3 mL of 80% methanol, followed by homogenization and centrifuging for 10 min. Then, 1 mL of the methanolic extract was added to 300 µL sodium nitrite solution (5%), followed by 300 µL aluminum chloride (10%). Test tubes were incubated at room temperature for 5 min, and then 2 mL of sodium hydroxide was added. Immediately, the volume of the reaction mixture was increased with distilled water to reach 10 mL, and the mixture was thoroughly vortexed. The absorbance value was determined at 510 nm.

Antioxidant capacity

DPPH analysis was carried out following a method described by Brand-Williams et al. (1995). A stock solution (24 mg DPPH/100 mL methanol) was diluted with methanol to obtain an absorbance of 1.1 at 515 nm using a spectrophotometer. Total antioxidant activity in the diluted extracts was determined according to the following formula.

$$\%DPPHsc = [\frac{(Acont - Asamp)}{Acont}] \times 100$$

Statistical analysis

This research comprised an experiment as a completely randomized block design with two factors, i.e., harvest stage and variety. Data were analyzed by analysis of variance (ANOVA), and mean values were compared ($P \leq 0.05$) by Duncan's Multiple Range Test (DMRT). All analyses were performed using a version of SAS software (SAS Institute, Cary, NC, USA).

Results

According to analysis of variance, there was a significant difference in the chemical compounds of different cultivars ($P \leq 0.05$) at the ripening stage (Table 1).

Table 1. Analysis of variance related to some chemical compounds in different date varieties during fruit ripening.

Variation Sources	Degree Free	TSS	DPPH	Moisture	Tannins	flavonoids	anthocyanin	phenol
Treatment	4	4.01**	2.21**	9.39**	1.01**	0.08**	3.41**	9.17**
Block		11.04**	15.01**	0.9**	3.45**	1.28**	12.01**	20.07**
Error	10	10.11	1.15	1.33	18.01	2.08	0.87	18.7
cv		4.09	11.01	8.16	7.17	9.14	5.08	9.14

A comparison of average total soluble solids (TSS) in different date varieties showed that the amount of TSS increased during the ripening stage of date fruits. Accordingly, in all of the cultivars, a 70% increase in TSS was observed at the final stages compared to the early stages of fruit ripening (Table 2).

Table 2. Changes in total soluble solids (TSS) in different date varieties at various fruit ripening stages.

TSS (%)	Ripening stages				
Varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	1.54^{hij}	3.11^{gh}	45.01^{f}	69.23^{c}	70.21^{bc}
Shahani	1.11^{j}	2.87^{hig}	51^{d}	70.21^{b}	72.13^{a}
Mazafati	1.41^{hij}	2.95^{g}	48.12^{e}	71.03^{ab}	71.89^{a}
Kaloteh	1.29^{ij}	3.01^{g}	49.28^{d}	71.11^{b}	72.01^{a}
Khenizi	1.32^{ij}	2.89^{g}	50.27^{d}	69.38^{b}	70.02^{a}

Means followed by the same letter are not significantly different (P<0.05) according to Duncan's multiple range test.

Antioxidant capacities in the date fruits of different varieties showed that the Hobabok and Kimri stages had the highest antioxidant capacity (54%) compared to the other stages (40-50%). As the fruit ripened, the antioxidant capacity decreased. The highest antioxidant capacity was found in 'Mordasang,' 'Shahani,' 'Mazafati,' 'Kaloteh,' and 'Khenizi' varieties at the Hobabok stage, respectively (Table 3).

Table 3. Changes in DPPH of the different date varieties at various fruit ripening stages.

DPPH	Ripening stages				
Varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	54.01^{a}	52.11^{b}	48.51^{gh}	45.23^{n}	42.32^{m}
Shahani	52.14^{a}	51.23^{bc}	49.12^{ef}	47.21^{ij}	42.32^{m}
Mazafati	53.01^{a}	52.59^{a}	51.022^{bc}	46.39^{ij}	44.05^{i}
Kaloteh	51.11^{cd}	50.23^{bcd}	49.32^{de}	46.35^{ij}	43.08^{i}
Khenizi	50.29^{bcd}	49.38^{d}	48.11^{fg}	48.02^{fg}	47.01^{hi}

Means followed by the same letter are not significantly different (P<0.05) according to Duncan's multiple range test.

The results showed that the moisture content decreased (30%) as the fruit ripening stages progressed. However, at the Kimri stage, the highest-to-lowest moisture content (80-87%) was observed in the fruits of 'Khenizi,' 'Kaloteh,' 'Mazafati,' 'Shahani,' and 'Mordasang' varieties, respectively (Table 4).

Table 4. Changes in moisture content (%) in the different date varieties at various fruit ripening stages.

Moisture (%)	Ripening stages				
varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	71.02^{fg}	78.41^{d}	69.23^{fg}	45.12^{m}	31.21^{r}
Shahani	69.21^{gh}	81.02^{bc}	67.32^{i}	42.13^{no}	41.23^{o}
Mazafati	63.21^{j}	80.12^{c}	61.02^{k}	48.12^{i}	45.28^{m}
Kaloteh	71.02^{ef}	82.15^{b}	70^{h}	42.85^{n}	35.12^{p}
Khenizi	72.12^{e}	85.32^{a}	71.02^{ef}	47.12^{i}	33.98^{q}

Means followed by the same letter are not significantly different (P<0.05) according to Duncan's multiple range test.

Tannin content decreased (20%) through fruit ripening. The lowest tannin content was observed in all varieties at the Tamar stage. The highest tannin content (400-600mg 100g-1) was observed at the Kimri and Khalal stages in 'Khenizi,' 'Mazafati,' 'Shahani,' 'Kaloteh' and 'Mordasang' varieties, respectively (Table 5).

Table 5. Changes in tannin content in the different date varieties at various fruit ripening stages.

Tannin (mg $100g^{-1}$)	Ripening stages				
Varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	35.02^{gh}	485.21^{e}	423.08^{f}	30.21^{gh}	25.12^{gh}
Shahani	38.23^{gh}	569.212^{b}	560.35^{bc}	35.21^{gh}	23.14^{gh}
Mazafati	41.08^{gh}	632.28^{b}	626.12^{a}	39.21^{gh}	22.18^{gh}
Kaloteh	40.21^{g}	542.29^{c}	500.98^{d}	36.21^{gh}	21.25^{gh}
Khenizi	43.26^{g}	628.12^{a}	621.03^{a}	39.12^{gh}	25.36^{gh}

Means followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

The results showed that total flavonoids in the different date varieties decreased during fruit ripening. The lowest-to-highest amount of flavonoids at the Tamar stage was observed in 'Mordasang,' 'Shahani,' 'Kaloteh,' 'Khenizi,' and 'Mazafati' varieties, respectively. The highest amount of flavonoids was observed in the Hobabok and Kimri stages in all cultivars (Table 6).

Table 6. Changes in the amount of flavonoids in the different date varieties at various fruit ripening stages.

Flavonoid (mg g^{-1})	Ripening stages				
varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	1.32^{gh}	1.21^{gh}	1.1^{j}	0.63^{k}	0.41^{l}
Shahani	1.45^{de}	1.42^{cde}	1.21^{gh}	1.04^{j}	0.91^{j}
Mazafati	1.98^{a}	1.98^{a}	1.69^{ab}	1.41^{ef}	1.23^{gh}
Kaloteh	1.56^{bc}	1.54^{bcd}	1.32^{ef}	1.16^{hi}	1.09^{ij}
Khenizi	1.63^{ab}	1.6^{bc}	1.41^{ef}	1.16^{gh}	0.98^{ij}

Means followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

The amount of anthocyanin in different date varieties increased during the stages of fruit ripening (Table 7). The lowest amount of anthocyanin at the Kimri stage was observed in Shahani and Mazafati. However, the highest amount of anthocyanin was observed at the Rutab stage in the Mordasang and at the Tamar stage in Kaloteh and Khenizi varieties.

Table 7. Changes in the amount of anthocyanins in different date varieties at various fruit ripening stages.

anthocyanin(mg $100g^{-1}$)	Ripening stages				
varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	3.2^{bcdefg}	3.31^{abcdef}	$3.26^{abcdefg}$	3.56^{a}	3.39^{abcde}
Shahani	3.1^{efgh}	2.96^{gh}	3.17^{defgh}	3.03^{fgh}	3.17^{defgh}
Mazafati	3.08^{efgh}	2.93^{h}	3.04^{fgh}	3.22^{bcdefg}	3.46^{abcd}
Kaloteh	3.17^{defgh}	3.11^{efgh}	3.12^{efgh}	3.31^{abcdef}	3.5^{ab}
Khenizi	3.05^{fgh}	3.09^{efgh}	3.1^{efgh}	3.18^{cdefgh}	3.49^{abc}

Means followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

Comparison of mean values regarding phenols showed that the lowest amount of total phenolic compounds was observed in the Hobabok stage in all varieties (Table 8). The highest amount of phenol in different date varieties was observed at the Tamar stage. Although the amount of total phenolic contents increased during fruit ripening, the highest amount of total phenolic compounds in the different date varieties occurred at the Tamar stage. Generally, the amount of phenols increased throughout the fruit ripening process. Thus, the highest amount of total phenolic compounds in the different date varieties occurred at the Tamar stage in Shahani and Mazafati varieties.

Table 8. Changes in phenolic content in the different date varieties at various fruit ripening stages.

Phenolic content	Ripening stages				
Varieties	Hobabok	Kimri	Khalal	Rutab	Tamar
Mordasang	90.18^{p}	95.07^{n}	91.67^{o}	95.89^{mn}	100.73^{i}
Shahani	252.01^{f}	285.12^{d}	268.46^{e}	300.67^{c}	362.26^{a}
Mazafati	189.24^{j}	206.17^{h}	198.10^{i}	250.67^{g}	342.69^{b}
Kaloteh	95.45^{mn}	100.25^{l}	96.12^{mn}	101.42^{l}	106.16^{k}
Khenizi	84.17^{q}	89.62^{p}	85.21^{q}	90.25^{p}	96.54^{m}

Means followed by the same letter are not significantly different ($P<0.05$) according to Duncan's multiple range test.

Discussion

Date fruits are nutritious and highly rich in carbohydrates, minerals, dietary fibers, and amino acids (Al-Shahib and Marshall, 2003). The characteristics of date fruit, similar to other fruits, are influenced by cultivation conditions, environment, and, more importantly, the genetics of the plant (Al-Laith, 2009). The concentration and composition of these constituents vary widely depending on several parameters, including date variety, stage of fruit picking, storage, postharvest processing, the geographical origin of date palms, and soil conditions (Al-Laith, 2009). Several researchers reported that the chemical constituents and functional compositions in date fruits can vary dramatically during the date maturing period as reducing sugars increase in amount, while fiber, mineral, and vitamin levels decrease steadily (Al-Turki et al., 2010).

The results showed changes in chemical compounds during fruit ripening in the different date cultivars. The amount of TSS in date fruits of different cultivars increased at the various fruit ripening stages. They had the highest TSS at the final stages (Rutab and Tamer), approximating 70% of the fruit content.

Date palm fruits are an ideal addition to food and can provide essential nutrients with many potential health benefits (Erskine et al., 2004). According to various reports, date fruits are a rich source of carbohydrates (70-80%), mineral elements, and vitamins. Vinson and Freeman (1911) reported on total sugar content during ripening and noted the rapid accumulation of total sugars and the inversion of sucrose at the later stages of fruit development. The most essential sugars in date fruit are glucose, sucrose, and fructose. A rapid accumulation of glucose and fructose from the Khalal stage onward can be related to the enzyme invertase, which converts sucrose into monosaccharide sugars (Myhara et al., 1999).

The antioxidant activity of volatile compounds, phenolic components, and flavonoids resulted from their redox characteristics. These molecules are essential in scavenging free radicals, quenching oxygen, and decomposing peroxides. The results showed that the amount of antioxidant capacity, tannins, flavonoids, and moisture content (%) decreased during the ripening stage of the fruit. The highest antioxidant capacity occurred in Mordasang, Shahani, Mazafati, Kaloteh, and Khenizi varieties at the Hobabok stage. The highest amount of total flavonoid occurred at the Hobabok and Kimri stages in all date palm varieties studied herein. The highest-to-lowest tannin content occurred at the Kimri and Khalal stages in Khenizi, Mazafati, Shahani, Kaloteh, and Mordasang varieties.

The same trend of changes in antioxidant capacity and total phenolics strongly suggested the central role of phenolic compounds in fruit antioxidant capacity. Phenolic compounds occur widely in plants. They contribute to color and flavor and are responsible for astringent and bitter tastes in fruits and vegetables, not to mention their antioxidant properties (Ding et al., 2001). Phenolic compounds comprise simple phenols, benzoic and cinnamic acid, coumarins, tannins, lignins, lignans, and flavonoids (Khoddami et al., 2013).

The highest amount of anthocyanin occurred at the Rutab stage in the Mordasang and the Tamar stage in the Kaloteh and Khenizi varieties. The highest amount of phenols in the different date varieties appeared at the Tamar stage in the Shahani and Mazafati varieties.

Phenolic compounds and carotenoids (flavonoids and anthocyanins) can contribute to varying antioxidant and antimutagenic activities. For example, total phenolics contribute to antioxidant activity in dates more significantly than the contribution by ascorbic acid (Shivashankara et al., 2004).

Chlorophyll, carotene, and anthocyanin pigments were reportedly responsible for green, yellow, and red pigments in date fruits (Baliga et al., 2008).

Date fruits are a good source of phenolics, flavonoids, carotenoids, antioxidants, and antimutagenic, as they impart medicinal value (Al-Farsi et al., 2005).

Conclusion

Date fruits have a high nutritional diversity

throughout their ripening stages. The nutritional value is reflected differently depending on the cultivar and can benefit human health in numerous ways. The date varieties studied herein showed enhanced sugar content, phenolic compounds, and antioxidant activity at the final stages of fruit ripening.

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Conflict of Interest
The authors indicate no conflict of interest for this work.

References

Al-Kharusi LM, El-Mardi MO, Ali A, Al-Said AF, Kadhir M. 2009. Effect of minerals and organic fertilizers on the chemical characteristics and quality of date fruits. International Journal of Agriculture and Biology 11(3), 290–296.

Al-Farsi M, Alasalvar C, Morris A, Baron M, Shahidi F. 2005. Comparison of antioxidant activity, anthocyanins, carotenoids, and phenolics of three native fresh and sun-dried date (*Phoenix dactylifera* L.) varieties grown in Oman. Journal of Agricultural and Food Chemistry 53, 7592–7599.

Al-Laith AA. 2009. Degradation kinetics of the antioxidant activity in date palm (*Phoenix dactylifera* L.) fruit as affected by maturity stages. Arab Gulf Journal of Scientific Research 27, 16–25.

Al-Shahib W, Marshall, RJ. 2003. The fruit of the date palm: its possible use as the best food for the future? International Journal of Food Sciences and Nutrition 54, 247-259.

Al-Turki S, Shahba MA, Stushnoff CJ. 2010. Diversity of antioxidant properties and phenolic content of date palm (*Phoenix dactylifera* L.) fruits as affected by cultivar and location. Journal of Food, Agriculture and Environment 8, 253–260.

Blokhina O, Virolainen E, Fagerstedt KV. 2003. Antioxidants, oxidative damage and oxygen deprivation stress: a review. Annals of Botany 91, 179–194.

Benzie IFF. 2003. Evolution of Dietary Antioxidants. Comparative Biochemistry and Physiology 136, 113–126.

Biglari F, Abbas FM, Alkarkhi FM, Azahar ME. 2008. Antioxidant activity and phenolic content of various date palm (*Phoenix dactylifera*) fruits from Iran. Food Chemistry 107, 1636–1641.

Brand-Williams W, Cuvelier ME, Berset C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Science Technology 28, 25–30.

Chaudiere J, Ferrari-Iliou R. 1999. Intracellular antioxidants: from chemical to biochemical mechanisms. Food and Chemical Toxicology 37, 949-62.

Eoin LN. 2016. Systematics: blind dating. Nature Plants 2, 160-69.

Erskine W, Mostafa AT, Osman AE. 2004. Date palm in GCC countries of the Arabian Peninsula. International Center for Agriculture Research in Dry Areas (ICARADA) htpp://www.icarda.org/APRP/ Date palm/Introduction/intro-body.htm.

Hussain MI, Farooq M, Syed QA. 2020. Nutritional and biological characteristics of the date palm fruit (*Phoenix dactylifera* L.) – a review. Food Bioscience 34, 100509.

Halliwell B, Gutteridge JM. 1998. Iron Toxicity and Oxygen Radicals. In Free Radicals in Biology and Medicine, 2nd ed. Clarendon Press: Oxford.

Heimler D, Vignolini P, Dini MG, Vincieri FF, Romani A. 2006. Antiradical activity and polyphenol composition of local Brassicaceae edible varieties. Food Chemistry 99(3), 464–469.

Hussah Al-Shwyeh A. 2019. Date palm (*Phoenix dactylifera* L.) fruit is a potential antioxidant and antimicrobial agent. Journal of Pharmacy and Bioallied Sciences 11, 1-11.

Hasnaoui A, El Houmaizi MA, Asehraou A, Sindic M, Deroanne C, Hakkou A. 2010. Chemical composition and microbial quality of dates grown in Figuig oasis of Morocco. International Journal of Agriculture and Biology 12(2), 311–314.

Khoddami A, Wilkes MA, Roberts TH. 2013. Techniques for analysis of plant phenolic compounds. Molecules 18, 2328-2375.

Kim HB, Kim AJ, Kim SY. 2003. The study on the functional materials and effects of mulberry leaf. Food Science and Industry 36, 2–14.

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

Mostaan A, Latifian M, Torahi A. 2017. Technical guide for planting, protecting and harvesting dates. Agricultural Education Press.

Myhara HM, Karkala J, Taylor MS. 1999. The composition of maturing Omani dates. Journal of the Science of Food and Agriculture 47, 471–479.

Pezhman H. 2002. A view on date palm situation and its research program in Iran. Proceedings of Date Palm Global Network Establishment Meeting, UAE University 71-80.

Rastegar S, Rahemi M. 2015. Comparison of physicochemical characteristics of pollinated and unpollinated Piarom and Shahani date palms during fruit growth and development. Plant Production 38 (1), 65-74.

Shinwari MA. 1993. Date palm. In Encyclopedia of Food Science. Food Technology and Nutrition. Macrae, R,

Robinson, RK, and Sadler M. (eds). London, UK: Academic Press Limited, 1300–1305.

Siddiq M, Aleid SM, Kader AA. 2013. Dates Postharvest Science, Processing Technology and Health Benefits, 1st Ed. New Delhi: Wiley-Blackwell.

Singh V, Guizani N, Essa M, Hakkim F, Rahman M. 2012. Comparative analysis of total phenolics, flavonoid content and antioxidant profile of different date varieties (*Phoenix dactylifera* L.) from the Sultanate of Oman. International Food Research Journal 19, 1063–1070.

Shivashankara KS, Isobes S, Al-Haq MI, Takenaka M, Shinha T. 2004. Fruit antioxidant activity, ascorbic acid, total phenol, quercetin, and carotene of Irwin mango fruits stored at low temperature after high electric field pretreatment. Journal of Agricultural and Food Chemistry 52, 1281-1286.

Wu X, Beecher G, Holden J, Haytowitz D, Gebhardt S, Prior R. 2004. Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. Journal of Agricultural and Food Chemistry 52, 4026–4037.