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Degradation Kinetics of the Antioxidant Activity in Date Palm (*Phoenix dactylifera* L.) Fruit as Affected by Maturity Stages

حركيات الإنحدار في النشاط المضاد للأكسدة لرطب النخيل و تأثرها بمراحل النضج

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ABSTRACT: Fruits of three date palm (*Phoenix dactylifera* L.) cultivars, namely *Berhi*, *Khalas* and *Khawaja* were evaluated for their total antioxidant activity, total phenolics and ascorbic acid at four ripening stages; full-color, just-ripe, half-ripe and full-ripe. The total antioxidant activity was estimated by the ferric reducing ability of plasma (FRAP). FRAP values, ascorbic acid and total phenolics were all higher at full-color unripe state. *Khawaja* possessed the highest FRAP values (expressed as mmol/100 g dwb): (18.9±0.95), followed by *Khalas* (12.0±0.82) and *Berhi* (3.4±0.49) cultivars. Similar ranking was observed for total phenolics (expressed as mg GAE/100 g dwb): 434.3 ±20.7, 397.2 ±14.3 and 283.3 ±5.4, respectively. As the ripening proceeded, FRAP values, total phenolics and ascorbic acid progressively declined. The kinetic studies revealed that the decline of the FRAP values, total phenolics and ascorbic acid essentially followed a pseudo-first order reaction. The rate constants and half-life of these parameters are calculated and the probable role of total phenolics and ascorbic acid is further discussed.

Keywords: *Antioxidant activity, ascorbic acid, carotenoids, date fruit, date palm, degradation, FRAP values, kinetics, total phenolics*.

المستخلص: إستهدف البحث تقييم النشاط المضاد للأكسدة وتركيز المركبات الفينولية وحمض الأسكوربيك (فيتامين سي) لثلاث أصناف من الرطب البحريني (البرحي والخلاص والخواجة) خلال أربع مراحل نضج تشمل: البسر القاسي المكتمل اللون قبل الترطيب، وبدء الترطيب، وانتصافه، واكتماله. وقد أختيرت الأصناف المذكورة نظرا لتفاوت نشاطها المضاد للأكسدة في مرحلة البسر القاسي. وتم تقدير القدرة المضادة للأكسدة بطريقة الفراب (FRAP) وعبر عنها بقيمة الفراب بالمليمول/جرام من الوزن الجاف. وقد تبين أن أعلى قيم للفراب وللمركبات الفينولية ولحمض الأسكوربيك كانت في مرحلة البسر غير الناضج. ووجدت أعلى قيمة للفراب في بسر الخواجة (18.9±0.95) ويليه بسر الخلاص (12.0±0.82) ثم بسر البرحي (3.4±0.49)، كما لوحظ الترتيب نفسه فيما يتعلق بتركيز المركبات الفينولية (ملجرام/100 جرام من الوزن الجاف) وكانت 434.3±20.7 و 397.2±14.3 و 283.3±5.4، على التوالي. وبينت نتائج البحث بأن الإنحدار في القدرة المضادة للأكسدة وتركيز المركبات الفينولية وحمض الأسكوربيك يحصل تدريجيا ويرتبط بزيادة النضج. وقد كشفت التحاليل الحركية بأن الإنحدار في قيم المتغيرات الثلاثة المدروسة للأصناف الثلاثة خاضع

لما يشبه تفاعل من الرتبة الأولى. وقد تم احتساب معامل التغير وقيمة نصف الحياة لهذه المتغيرات. كما ناقش البحث الدور المحتمل لكل من المركبات الفينولية وحمض الأسكوربيك.

كلمات مدخلية : *النشاط المضاد للأكسدة، حمض الأسكوربيك، الكاروتينات، رطب النخيل، إنحدار، قيمة الفراب، حركيات، المركبات الفينولية.*

INTRODUCTION

The fruit of date palm tree (*Phoenix dactylifera* L.) is commonly consumed in the Arabian Peninsula, Middle East and North Africa where it is widely cultivated. Date palm is also cultivated in other hot climate regions of the world such as in California (USA) and Australia. The average annual consumption of dates in the Gulf Corporation Council Countries is relatively high with an average of about 25 kg in Bahrain (Bahrain Government Statistics, 2005) and up to 60 kg in Oman (Al-Farsi, *et al*. 2005).

Nutritionally, date fruits are rich in sugars, fibers and some minerals such as potassium, but poor in protein and lipids (Barreveld, 1993). Dates are also rich in some phytochemicals particularly phenolic compounds. Phenolic constituents (free and bound) of date fruits have been studied by many workers (Regnalut-Roger, *et al*. 1987; Vayalil, 2002; Al-Farsi, *et al*. 2005; Mansouri, *et al*. 2005; Mohamed and Al-Okbi, 2005; Vinson, *et al*. 2005; Hong, *et al*. 2006; Al Farsi, *et al*. 2007; Biglari, *et al*. 2008; Allaith, 2008). The relationship between the phenolics and antioxidant activity of date fruits have been also been demonstrated. The major free phenolic acids in dates include: ferulic, syringic and vanillic. Caffeic, *p*- and *o*-coumaric, gallic and protocatechuic acids are found as bound acids. Anthocyanins, which also possess antioxidant activity, were largely found in fresh red date, but lacking in sun-dried dates (Al-Farsi, *et al*. 2005).

Previously, it has been shown that the antioxidant activity of date fruits depends on the cultivar and the maturity stage (Allaith, 2008). The highest antioxidant activity was found in mature unripe *(biser)* and the lowest was observed in the dried dates (*tamer)*. The same research has also shown that the total phenolics content varies with maturity stage being higher at biser stage.

Date fruits are non-climacteric drupes and dates of different cultivars exhibit different lengths of development ranging from 5 to 9 months, and a full harvesting season that lasts from mid June to early November (Barreveld, 1993). During developmental stages, date fruits undergo substantial chemical and physical changes. Maximum and minimum fruit weight and size, moisture, crude fiber, crude protein, crude fat, ash, tannins, vitamins A and C correspond to the end of greenish and full-ripe (dried date or *tamer*) stages, respectively (Sawaya, 1986). Total and reducing sugars increase progressively.

Dates are usually consumed at several ripening stages, depending on many factors including the astringency. Astringency depends on the tannins content, the higher the tannins content, the more stringent the fruit and less palatable (Myhara, *et al*. 2000). Maximum level of tannins has been reported at the late greenish stage, known as *khalal*, then declines and reaches its lowest level in fully ripened fruit, where it is stored as condensed tannins. This study aimed at evaluating the antioxidant activity at four ripening stages, and attempt to explain the degradative kinetics of the antioxidant activity in date fruits in relation to total phenolics and ascorbic acid.

MATERIALS AND METHODS

Chemicals

L-Ascorbic acid was from BDH laboratory (England); *2, 4, 6*-tripyridyl-s-triazine (TPTZ), gallic acid and 2,6-dichlorophenolindophenol (2,6-DCIP) were from Fluka Chemic AG (Deisenhofen, Switzerland); Folin-Ciocalteu (FC) reagent was from Sigma (St. Louis, MO, USA). All other chemicals were of analytical grade.

Sample Collection

Three date palm trees were selected in advance from private properties, each

representing one of the three chosen cultivars identified by their Arabic names: *Berhi*, *Khalas* and *Khawaja*. Arabic names and terminology were previously detailed (Allaith, 2008). The trees were of about 12-15 year old. No attempt was made to study or control agronomical, cultivation and environmental variables. The study was conducted during the summer season of 2004. The average minimum and maximum temperatures during this season usually range between 27°C and 38°C with an average relative humidity of 72%. The selection of these cultivars was based upon the following criteria: (1) The color of the fruits of the three cultivars is yellow at full-color stage, in order to minimize the effect of pigmentation on antioxidant activity since red cultivars possess higher antioxidant properties (Allaith, 2008); (2) astringency; *Berhi* is the least astringent and could be eaten at biser stage, *Khalas* was a modest, however, it is not very palatable at biser stage as *Berhi* and *Khawaja* is the most astringent among the three, thus it is the least palatable, and is only eaten when ripe; (3) the three cultivars belong to mid season (July/ Aug) hence they share a similar ripening period, thus minimizing the effect of variation due to temperature and humidity; and (4) each cultivar was represented by a single palm tree, from which all samples were withdrawn at specified ripening state to minimize other abiotic variations.

Ripening stage of fruits was superficially characterized and classified by color, firmness and taste into four stages as follows: (1) unripe (physiological maturity stage without any sign of softness and discoloration and will be referred to as full-color; (2) just-ripe with incipient signs of ripening, (3) half-ripe when the fruit is about 50% ripe and (4) full-ripe, when yellow color was completely changed into golden brown. These stages of maturation correspond to approximately 17, 18, 19, and 20 weeks from the day of pollination.

Sample Preperation

At harvest, 15-20 fruits of uniform maturity state of each cultivar were selected and picked at weekly interval, transferred to the lab, rinsed with water, plotted dry and analyzed in the same or next day. During this period, date fruits were kept refrigerated at 4°C. Two composite samples were prepared from pitted fruits by maceration using a cold Warring homogenizer and extracted as mentioned below. Analysis was conducted in triplicate for each parameter, except for moisture, which was made in duplicates. Reported data are the mean ± SD of six determinations.

Chemical Analysis

Determination of antioxidant activity

One gram of the composite sample prepared as described above was extracted with 9 ml acetate buffer (300 mM, pH 3.6) using a cold Warring homogenizer, at full speed for 2 min. The homogenate was centrifuged at 8000 g for 5 min at 4°C using High Speed Centrifuge equipped with rotor J2-21 (Beckman, USA). The clear extract was used to determine the antioxidant activity by the ferric reducing ability of plasma (FRAP) assay as described by Benzie and Strain (1996). Briefly, 100 μl of appropriately diluted sample extract was mixed with 2.9 ml of ferric-TPTZ reagent (prepared by mixing acetate buffer (300 mM, pH 3.6), 10 mM 2,4,6-TPTZ in 40 mM HCl, and 20 mM $FeCl_{3.}6H_20$ in a ratio of 10:1:1; v/v/v). The absorbance at 593 nm was measured after 6 min. Antioxidant activity is expressed as FRAP value; mmol/100 g dwb (dry weight basis). L-ascorbic acid was used as a reference.

Determination of total phenolics

One gram of the macerated composite sample mentioned above was extracted with 9 ml of 70% methanol using Warring homogenizer as described above. A clear methanolic extract was obtained by centrifugation at 2100 g for 5 min at room temperature using CS-6 Bench-type (Beckman, USA). The amount of total phenolics of the methanolic extract of date fruits was measured at 720 nm by the Folin-Ciocalteu (FC) reagent as described by Singleton, *et al*. (1999). Briefly, 0.5 ml of the extract was added to 2.5 ml of 1:10 FC reagent and 2 ml of 0.75% Na_2CO_3. The mixture was incubated for 30 min at 40°C. Absorbance was measured at 750 nm. Gallic acid was used to generate the standard curve and the results are expressed as mg gallic acid equivalent (GAE/100 g dwb).

Determination of ascorbic acid

Ascorbic acid was estimated by the official AOAC titrimetric procedure using 2,6-DCIP (AOAC, 1992). 3-5 grams of the macerated sample were extracted twice with 1% phosphoric acid and 0.2% acetic acid. The combined extraction solution was made to a final volume of 100 ml. A 10 ml aliquot was titrated with standardized DCIP solution. The amount of ascorbic acid was calculated as mg/100 g on dwb.

Estimation of total carotenoids

One gram of the macerated date sample was extracted with 5 ml hexane until the residue became colorless. The volume was brought to 50 ml and the absorbance was measured at 470 nm. The following equation was used to calculate total carotenoids using the extinction coefficient of 2,500, $E_{1\%}$ (wt/v) (Britton, 1995):

$$\text{Total carotenoids } (mg/100g) = \frac{(A_{470nm} \times V \times 10^6)}{(2500 \times 100g)}$$

where V is the total volume.

Moisture content

Moisture content was estimated by heating thin slices of the fresh fruit samples in an oven at 65ºC until a constant weight was obtained (48-72 h) and the difference in weight is expressed as percent.

Kinetics

Calculation of the reaction rate constants for the degradation of FRAP values, total phenolics and ascorbic acid was assumed to follow pseudo-first order kinetics, as in the case of many other biological and chemical transformation processes. Rate constant (k) was calculated using the formula

$$k = (\frac{2.3}{t}) \times \log(\frac{C_0}{C_t})$$

where t is the number of days from start, C_0 is the initial concentration (or value) at day one, and C_t is the concentration at the corresponding time: 7, 14, and 21 days. The average half-life was calculated as $t_{0.5} = 0.693/k$. All calculations were based on dwb.

Statistical Analysis

SPSS statistical package (version 12.1, SPSS, Chicago, IL, USA) and Microsoft Excel (Microsoft Corporation, Redmond) were used for statistical analysis. Data were subjected to analysis of variance (ANOVA) and regression analyses. Separation of the means of FRAP values, total phenolics, and ascorbic acid content at various stages were carried out using Duncan multiple range test. Significant difference was defined as $p \leq 0.05$.

RESULTS AND DISCUSSION

Moisture Content

The progressive development of date fruits from full color to full-ripe stage was accompanied by significant loss of water in the three cultivars (Table 1). Overall, the three cultivars lost between 33-35% water.

Total Carotenoids

The level of total carotenoids was investigated only at full-color and full-ripe stages (Table 1). At full-color stage, *Khalas* possessed the highest total carotenoids (6.49 ± 1.88 mg/100 g dwb), followed by *Khawaja* (5.11 ±1.55) and *Berhi* (3.70 ±0.11). At full-ripe stage, the level in *Khalas* and *Khawaja* (0.91-0.93 mg/100 g) was twice as that of *Berhi* (0.47 mg/100 g). Values reported here for total carotenoids are similar to those reported by others (Sawaya, 1986; Al-Farsi, *et al*. 2005).

FRAP Values

The antioxidant activity (FRAP values), total phenolics and ascorbic acid during the four ripening stages of the three cultivars were calculated on a dry-weight-basis (dwb), and are shown in Figures (1A) to (1C)**.** Levels of each of these variables at the four ripening stages were significantly different ($p < 0.05$). The exception was that the FRAP values of *Berhi* at half- and full- ripe in which they were not significantly different. The highest antioxidant activity, measured as FRAP mmol/100 g dwb, was at full-color and the lowest was at full-ripe in the three cultivars. It ranged from 3.38 to 18.88 mmol/100 g for full-color and 1.51 to 1.62 mmol/100 g for

full-ripe stage. *Khawaja* possessed the greatest antioxidant activity at full-color, followed by *Khalas* and *Berhi*. A gradual decrease in FRAP value was observed during the transition from full-color to full-ripe stage in all cultivars. The three cultivars differed significantly with respect to their FRAP values at full-color stage, amounting to 6-fold difference between the highest and the lowest. At full-ripe stage, the difference in FRAP value became negligible.

The FRAP values reported here at full-ripe stage are similar to previously reported values (Allaith, 2008). However, the FRAP values at full-color stage for *Khalas* and *Khawaja* are considerably higher than those reported previously. Such large differences may reflect the effect of the collection and sampling procedure. In the current study, more stringent approach was exercised during the selection of samples representing each maturation stage. The remaining antioxidant activity at full-ripe stage amounted to 45% in *Berhi,* 13.5% in *Khalas* and 8.5% in *Khawaja*. It should be noted that the higher the initial antioxidant activity at full-colored, the greater the loss inflected in the antioxidant power.

Total Phenolics

The highest level of total phenolics was also found at full-color in the three cultivars, and ranged from to 283 to 434 mg GAE/100 g in full-color stage and between 153 to 184 mg GAE/100 g dwb in full-ripe stage (Fig 1-B). *Khawaja* possessed the highest total phenolics, followed by *Khalas* and *Berhi*, in this order. A gradual decline in the total phenolics was noticed in the three cultivars. Previous studies indicate that the levels of free and total phenolics vary with stage of maturation of date fruit. Vinson, *et al*. (2005) reported that the increase in free phenolics ranged between 47 to 60% for fresh and dried date, respectively, whereas the remaining of total phenolics level was 77%. Al-Farsi, *et al*. (2005) reported a significant increase in total phenolics in sun-dried dates to that of fresh date fruits in the three Omani cultivars. When the figures given in the literature are corrected for the water loss accompanying the progressive maturation, the difference in free phenolics between fresh and dried dates remarkably diminishes.

An adaptive response to extreme temperature was suggested by Vinson, *et al*, (2005) as a reason for such high level of phenolics in date fruits. However, the author is in favor of the opinion that such high level of phenolics is rather associated with a long debated defense mechanism. Phenolic compounds have long been implicated in plant defense mechanism by protecting plant parts from infection prior to maturity (Knee, *et al*. 1991). At early stage of development, the date fruits are more prone to attacks by insects and herbivores. However, as date fruits mature, water activity decreases, tannins level declines substantially and the strong physical barrier of the date collapses, increasing the susceptibility to microbial attacks. Meanwhile, the total sugar content increases to 60-80% (Sawaya, 1986), making the fruit more resistant to microbial attacks. At such physical and chemical characteristics, the main potential spoilers of date fruits are the osmophilic fungi (Djerbi, 1983).

Almost all dates cultivars studied so far by different researchers showed higher tannins content at *khalal* (full-green color) stage. Tannins content of several date cultivars, collected from different geographical parts of Saudi Arabia, averaged 4.6 g/100 dwb at *khalal* stage compared to 1.4 g/100 g dwb at dried *tamer* stage (Sawaya, 1986). In date fruits, tannins are located immediately under the skin in large cells. When the fruit ripens, tannins precipitate and become water insoluble and condensed granules. Such transformation is associated with lower astringency and better palatability (Myhara, *et al*. 2000).

Ascorbic Acid

The highest level of ascorbic acid was found at full-color stage and the lowest at full-ripe stage in all cultivars (Figure 1-C). At full-color, the level of ascorbic acid in *Khalas* (16.0 ±1.27 mg/100 g) and *Khawaja* (18.1 ± 1.14 mg/100 g) was similar, but significantly different than *Berhi* (13.5 ± 1.21 mg/100 fw). Ascorbic acid concentration leveled out at half- and full-ripe stages. The content of ascorbic acid at fresh full-color and full-ripe stage is consistent with previously reported values (Sawaya, 1986; Allaith, 2008). Beside being an important natural antioxidant, ascorbic acid also

plays other physiological roles, of which some are involved in the formation of polyphenolics (Hirai, *et al*. 1995). In the majority of date cultivars, both total phenolics and ascorbic acid content reach their maximum level at early *khalal* (green) stage, and then begin to decline during ripening (Sawaya, 1986). The concomitant decline of the total phenolics and ascorbic acid content as the date fruit begins to ripe, most probably reflects massive structural and chemical changes leading to loss of integrity, release of degrading enzymes and to the decomposition of ascorbic acid.

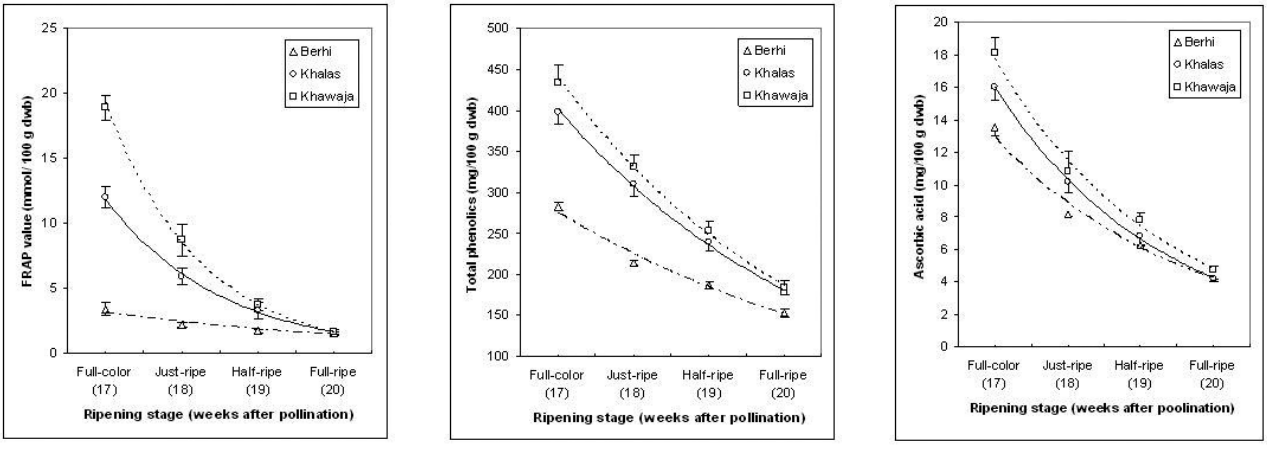
Kinetics Studies

The results of the antioxidant activity (FRAP value), total phenolics and ascorbic acid content were fitted to a first order decay model. Apparently, the decrease in the antioxidant activity (FRAP

Table 1. Moisture content, antioxidant activity (expressed as FRAP value), total phenolics, ascorbic acid and total carotenoids contents of the three dates cultivars during the various stages of maturation.

		Maturation stages			
		Full-color	**Just-ripe**	**Half-ripe**	**Full-ripe**
		17 [(1)]	**18**	**19**	**20**
Cultivar	**Constituent** [(2)]	**Mean (±SD)**	**Mean (±SD)**	**Mean (±SD)**	**Mean (±SD)**
Berhi	Moisture (%)	54.6 (2.97) [a (3)]	43.3 (1.71) [b]	39.6 (1.24) [c]	35.8 (2.4) [d]
	Total carotenoids (mg/100 g)	3.70 (0.11) [a]	-	-	0.47 (0.20) [b]
Khalas	Moisture (%)	52.1 (3.1) [a]	44.6 (3.14) [b]	40.1 (2.33) [b]	33.7 (2.9) [c]
	Total carotenoids (mg/100 g)	6.49 (1.88) [a]	-	-	0.91 (0.28) [b]
Khawaja	Moisture (%)	52.8 (2.38) [a]	44.7 (2.97) [b]	41.4 (2.55) [b]	35.4 (1.13) [c]
	Total carotenoids (mg/100 g)	5.11 (1.55) [a]	-	-	0.93 (0.39) [b]

[1] *Number of weeks from pollination.*
[2] *Except for moisture content, data represent the mean ±SD (n=6) calculated on dwb.*
[3] *Values within raw followed by the same letter are not significantly different ($p > 0.05$) according to Duncan's multiple range test.*



A **B** **C**

Fig. 1(A-C). FRAP values (mmol/100 g dwb) **(A)**, total phenolics (mg/100 g dwb) **(B)**, and ascorbic acid (mg/100 g dwb) **(C)** of the fruits of three date palm cultivars *Berhi*, *Khalas*, and *Khawaja* at four ripening stages represented by the number of weeks from pollination corresponding to full-color (17 weeks), just-ripe (18 weeks), half-ripe (19 weeks) and full-ripe (20 weeks).

value), total phenolics and ascorbic acid content, in the three investigated cultivars follows pseudo-first order kinetics when calculation is made on dwb as shown in Figure (**1**A-C)**,** respectively. The rate constants of the three parameters are given in Table (2). Rate constants calculated for the decrease in FRAP values of the three cultivars revealed significant differences. The rate constants for *Khawaja, Khalas* and *Berhi* were 0.115±0.032/day and 0.097±0.005/day and 0.050±0.125, respectively. Rate constants of *Khawaja* and *Khalas* were about two times grater than that of *Berhi*. No significant difference was found between the three cultivars with regard to rate constant of the total phenolics (Figure 1-B**)** with an average rate constant of 0.036 (±0.0042)/day. There was no significant difference between the rate constants of ascorbic acid degradation in the three cultivars (p= 0.388), with an average of 0.062/day. It is widely reported in the literature that degradation of ascorbic acid follows first order kinetics (Lee and Labuza, 1975; Uddin, *et al*. 2002). Findings of this study is in agreement with those reported by Lee and Labuza (1975), who reported a rate constant of decomposition of ascorbic acid between 0.06 and 0.07/day at 35°C. Generally, the decline of total phenolics proceeds via several pathways and the colorless polyphenolics presented at earlier stage of maturation are converted by enzymatic and non-enzymatic reactions into larger brownish polymers (Marshall, *et al*. 2000). In date fruits, textural changes immediately follow fruit attaining full-color (Sawaya, *et al*. 1983). Variations of phenolics level and composition between date cultivars and between different maturity stages of the same cultivar have been found as stated previously. When the texture of some Omani dates was examined as a function of astringency and tannins content (Myhara, *et al*. 2000), astringency was found to be closely related to tannin level, whereas texture closely followed the degree of pectin methylation.

Overall, FRAP values declined faster than total phenolics and ascorbic acid. The average half life of the FRAP value, total phenolics and ascorbic acid during the development of dates from full-color to full-ripe (calculated as $t_{0.5}$ = 0.693/k) were, 8, 19 and 11 days, respectively. In a previous study, using 16 different cultivars of date fruits, a relatively good correlation between FRAP and total phenolics at unripe (*biser)* stage was reported (r = 0.595), compared to a weaker correlation with ascorbic acid (r = 0.385) (Allaith, 2008). The correlation was even weaker at *Rutab* (ripe) stage. However, when the data of biser (unripe) and rutab (ripe) were pooled, a relatively stronger correlation was evident between FRAP and both total phenolics (r = 0.656) and ascorbic acid (r =0.658). In that study, the degree of ripening was not taken into consideration. Separation of ripening into four stages, as in the current study resulted in the establishment of a stronger relationship between total phenolics and FRAP values. Figure (2) shows the dependency of FRAP values on total phenolics. At full-color, just-ripe, and half-color stages the correlation coefficients were 0.965, 0.949, and 0.967, respectively. Although, the relationship was greatly reduced at full-ripe, (r = 0.203), the overall correlation coefficient was high (r= 0.922). It is obvious from Figure (2**)** that FRAP values were exponentially related to total phenolics when all data of the three date cultivars at the indicated stages were pooled. A linear relationship is obtained by plotting the natural logarithm (Ln) of the pooled FRAP values against pooled total phenolic.

Table 2. Rate constant (k) of the degradation of the antioxidant activity (FRAP values), total phenolics and ascorbic acid in the three date fruits cultivars, expressed on dry weight basis as mean (±SD).

	Rate constant (k) 1/day (±SD)		
Cultivars	**FRAP**	**Total phenolics**	**Ascorbic acid**
Berhi	0.050 (0.0121) [a]	0.033 (0.0061) [a]	0.060 (0.0084) [a]
Khalas	0.097 (0.0045) [b]	0.036 (0.0016) [a]	0.063 (0.0024) [a]
Khawaja	0.115 (0.0036) [c]	0.039 (0.0014) [a]	0.066 (0.0066) [a]
Average	0.087 (0.0296)	0.036 (0.0042)	0.062 (0.0064)

Rate constants followed by the same letter within a column are not significantly different ($p > 0.05$).

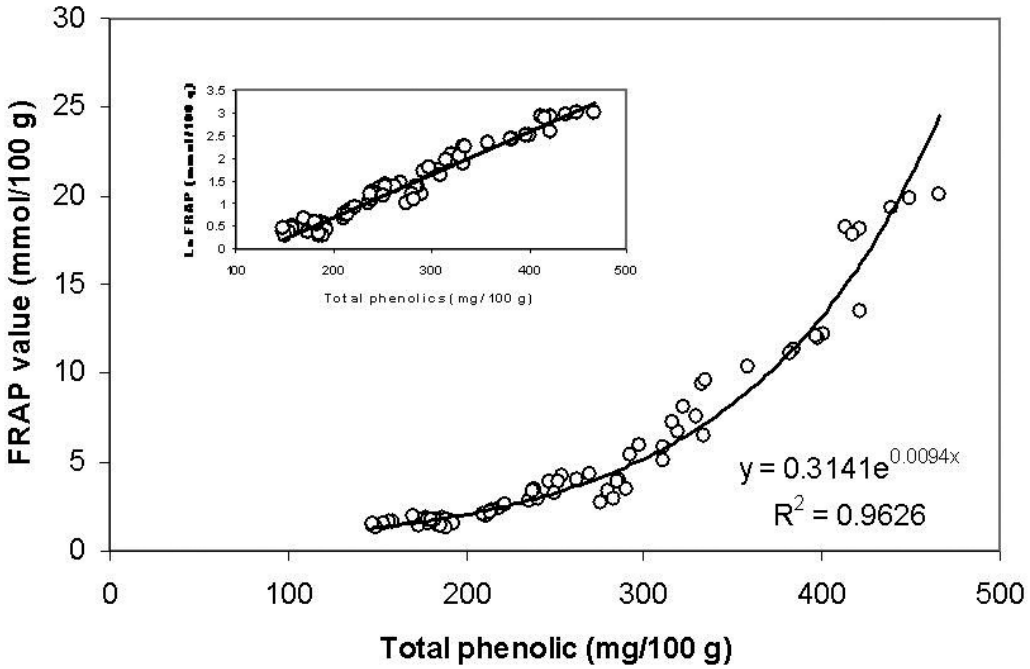


Fig. 2. Relationship between the combined FRAP values and total phenolics of date fruits of the three cultivars (*Berhi, Khalas, and Khawaja*) at various ripening stages. The inset shows the linearized form obtained by transforming the FRAP values into the natural logarithm.

CONCLUSION

The presented results in this work suggest that, as in the case of other fruits that are consumed as fresh and dried, a distinction should be made between the antioxidant activity of fresh and dried dates, particularly for nutritional and database purposes. Although, fresh dates possess high antioxidant activity, the activity is considerably reduced upon the completion of the ripening process and even before any further processing. Taking into consideration the current per capita consumption of dates among Arabian Gulf inhabitants, date fruits of all maturity stages are important sources of dietary antioxidants. Furthermore, the present work evidently shows that phenolics are among the major contributor towards antioxidant activity. Further research is needed to determine the contribution of each class of phenolics present in date fruits towards the antioxidant and antiradical activity.

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