Characteristics changes of date fruits during ripening period on-palm

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Abstract: The degree of ripeness is a key factor for consumption, marketing, and minimal processing of fruits. This study was conducted to describe the physicochemical changes (geometrical and gravimetrical properties) and the relationships between different ripeness indexes i.e. pH, total soluble solid (TSS), titratable acidity (TA), firmness, dry weight content (DW) and color of date fruit during four ripening periods on-palm including kimri, khalal, rutab and tamr stages. These four stages were selected by visual fruit color and days after anthesis (DAA). Duncan's multiple tests was performed to separate means at a 5% level of significance. A correlation analysis by Pearson correlation matrix method was also made between the colorimetric ripeness parameters and pH, TSS, TA, firmness and DW from kimri to tamr stage. Significant (p<0.05) decrease in geometrical properties (except width) and gravimetrical properties (fruit mass, true volume of fruit) was observed during ripening. Parameters as L^*, b^*, C^*, linearly decrease during ripening; conversely, h° decreased as a result of color change from green to black. The results showed that fruit firmness decreased from about 20.5 N at the start of the ripening period (kimri stage) to about 2.5 N at its end (tamr stage). Additionally, pH, TSS and TA values increased when ripening was developed. So, the highest pH value and TSS of date juice were 4.76 and 19.45 %, respectively at tamr stage. The results of Pearson correlation between ripeness indexes allowed to establish model equations for destructive tests values such as TSS and firmness with nondestructive test such as CIEL$^*a^*b^*$ and CIEL$^*C^*h$ scales. The results show that studied models are a feasible alternative to be used as a practical detection system in the ripening, avoiding eventual human errors.

Keywords: color, date fruits, firmness, index, ripening, TSS.

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1 Introduction

Date fruit (*Pheonix dactylifera* L.) is one of the most productive fruits in the Middle Eastern countries. Based on FAO statistics, Iran with production of about 1016610 Mt of date fruits was in the second rank of the world in 2017 (FAO, 2017). More than 400 varieties of date fruit are cultivated in different regions of Iran, especially in southern regions (Anonymous, 2011). Due to its high nutritional value, favorite taste, excellent flavour and low calories, it has very high demand in the world and fetches a good price in the world market (Biglari et al., 2008). It is consumed both as fresh fruit as well as in processed form such as juice, jams, etc. In most of the date fruit producing countries, the bulk of date fruit is consumed as fresh fruit. So, because of this market demand it has become increasingly important to characterize its different varieties and clones to obtain a high quality product with economic interests.

The economical yield of date fruits depends on many factors. One of them is harvesting in optimum stage (Lobo

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et al., 2014; Sassi et al., 2020). Generally, date fruits have four distinct stages of ripeness to satisfy different consumption requirements (e.g., fresh and processed). They are known throughout the world by their Arabic names which are kimri, khalal, rutab and tamr in order of ripeness (Lobo et al., 2014; Hussain et al., 2020). Decreasing moisture content and increasing sugar content happens gradually while the date ripeness approaches to tamr stage. From kimri to khalal stage, the size and acidity decrease when the color of Mazafati variety (the most popular date in Iran) changes from green to red. The change in acidity continues from rutab to tamr stage while color transforms from brown to black. At the final stage of ripeness, Mazafati variety is soft and has a good storability (Lobo et al., 2014; Marondedze et al., 2014; Sassi et al., 2020).

These changes in composition, color, texture or other sensory attributes of date fruits during ripening stages have been identified due to accumulation of phytochemicals such as carotenoids, the phenolics, flavonoid glycosides, flavones, flavonols, flavoxanthin in the fruit (Shahidi and Naczk, 2004; Al-Farsi et al., 2005; Biglari et al., 2008). The concentration of these phytochemicals decreases with advancing stage of fruit ripeness. The astringent taste of date fruit during the early stages of ripeness is closely associated with the level of tannins content (Barreveld, 1993; Al-farsi et al., 2005) that decreases with the ripening of date fruit and almost disappears at tamr stage (Myhara et al., 1999). Considering current situation of date fruit harvesting which is nonselective and single-pass method (Mireei et al., 2010), the development of nondestructive techniques that can identify internal tannin changes for evaluating ripening stages of date fruits could be necessary. Despite extensive researches which have been carried out on date fruit so far, a limited research has been conducted on the ripeness indexes and physicochemical changes of date fruit during ripening on-palm. In this regard some physical properties of date fruit (Mazafati variety) as a function of ripening have been reported by Keramat Jahromi et al. (2008). Mireei et al. (2010) have investigated physicochemical and quality attributes of Mazafati date fruit by NIR spectroscopy for postharvest handling and processing in Iran.

In Iran harvesting time of dates is between the end days of June and September, but there are no standard ripeness indices or postharvest quality attributes to assist in the harvesting and management of postharvest fruit quality. On the other hand, as regards several date fruit cultivars have been successfully grown and utilized in Iran, no published data were found on their physicochemical properties related to ripeness. Such data will assist in the selection of cultivars for commercial production to meet market demand. Therefore, the current study was conducted to develop knowledge on physicochemical changes during ripeness in date fruit which commonly cultivated in Iran. To achieve this objective, a various collection of date fruit differing in fruit internal color (from green to deep black) and taste (from sour to sweet) was examined on four distinct stages of ripeness (kimri, khalal, rutab and tamr). The properties including physical and chemical properties were determined at the four stages of ripeness. Knowledge of the changes in fruit ripeness attributes during the time course of fruit growth and development would be useful in efforts to develop objective ripeness indices for harvest and postharvest management.

2 Materials and methods

2.1 Plant material

Mazafati variety of date fruit was used for this study. During the harvest seasons of 2016 (July-August), the samples from each four stages of ripening namely kimri, khalal, rutab and tamr were collected from two different orchards in Jiroft area, Kerman Province, Iran (latitude 28.6751° N, longitude 57.7372° E, and altitude 690 m above sea level). This region has an annual average temperature of 23.5°C, relative humidity higher than 18%, annual rainfall of 82 mm. A number of 100 date samples were collected in this study, and transported individually to the Postharvest Laboratory of Biosystems Department in the Ferdowsi University of Mashhad. Then, the samples were kept at 5°C in a refrigerator for 7 days to distribute the moisture uniformly throughout the sample. Before measurement, the required quantities of date fruits in each ripeness stage was taken out of the frig and allowed to warm with room temperature for approximately 2 h (Khodabakhshian and Emadi, 2016). The external features of the four stages are exemplified in Figure 1.

Figure 1 Example images of Mazafati variety of Date fruit samples at different ripeness stages.

2.2 Physical properties measurement

2.2.1 Geometrical properties

To determine the size and shape of the samples, three linear dimensions namely as length (*L*), width (*W*) and thickness (*T*) were measurement by using a digital caliper with an accuracy of ±0.01 mm. Geometric mean diameter, D_g (mm); sphericity, ϕ; and surface areas, S (mm^2); were determined by using the following formulas, respectively (Mohsenin, 1986; Khodabakhshian et al., 2010a; Lorestani and Ghari, 2012; Lobo et al., 2014; Marondedze et al., 2014):

$$D_g = (LWT)^{1/3} \quad (1)$$

$$\phi = D_g / L \quad (2)$$

$$S = \pi D_g^2 \quad (3)$$

where *L* is length of date fruit (mm), *W* is width of date fruit (mm); *T* is thickness of date fruit (mm).

To determine the volume, three volume values were measured or calculated. First, actual volume (V_m) was measured, and then the fruit date shape was assumed as a regular geometric shape, that is, oblate spheroid (V_{obl}) (mm^3) and prolate spheroid (V_{pro}) (mm^3). Therefore the volume was estimated as follows as reported by Mohsenin (1986), Seyedabadi et al. (2011) and Shahbazi and Rahmati (2013):

$$V_{obl} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)^2 \quad (4)$$

$$V_{pro} = \frac{4\pi}{3}\left(\frac{L}{2}\right)\left(\frac{W}{2}\right)\left(\frac{T}{2}\right) \quad (5)$$

2.2.2 Gravimetrical properties

The gravimetrical properties of studied date fruit as a function of ripeness were measured as follow (Mohsenin, 1986; Khodabakhshian et al., 2010b; Mireei et al., 2010; Seyedabadi et al., 2011):

Fruit mass was determined using a precision electronic balance with an accuracy of 0.001 g (TC-620, Phantom Scales LLC). Fruit volumes were measured by the water displacement method. Fruits were weighed in air and allowed to float in water. Fruits were lowered with a needle into a beaker containing water and the volume of water displaced by fruit was recorded. Finally, fruit densities (g cm^{-3}) were calculated by using the following equation (Mohsenin, 1986):

$$\rho_f = \frac{M_a}{M_a - M_w}\rho_w \quad (6)$$

where ρ_f and ρ_w are the fruit and water density (g cm^{-3}); M_a (g) and M_w (g) are the mass of fruit in air and water, respectively.

2.3 Chemical analysis

Dry weight content (DW) of fruit was determined by a digital weighing scale (TC-620, Phantom Scales LLC), drying at 105ºC in a forced-air oven for 72 h and finally reweighing. Tissue samples were cut from each ripeness stage separately and then were macerated with a commercial juice extractor, filtered and centrifuged afterwards. The juice was then used to determine the total soluble solid content (TSS), Titratable acidity (TA) and pH. TSS was determined with a hand-held refractometer (TYM Model, China). The juice's soluble solid content was expressed in values of %. TA was determined by titration using a Metrohm862 compact titrosampler (Herisau, Switzerland), and the results were expressed as percentage citric acid. The pH value of samples was measured by a pH meter. These methods has also been employed by other researchers (Al-Maiman and Ahmad, 2002; Barragán-Iglesias et al., 2018; Sassi et al., 2020).

2.4 Mesocarp firmness analysis: puncture test

Mesocarp firmness was longitudinally measured by puncture method. The puncture test was done by a stainless-steel 5 mm cylindrical probe which was attached to moving platform of an Instron Universal Testing Machine (Figure 2). The apparatus was supplied with a load cell of 500 kgf. The system accuracy was ±0.001 N in force and 0.001 mm during deformation. The penetration speed was set on 10 mm min^{-1}. The samples were positioned on the fixed plate considering puncture position. The rupture test was initiated until rupture occurred as it is denoted by a rupture point in the force-deformation curve. As soon as the rupture point was detected, the test was stopped. Duplicate puncture tests were performed on opposite sides of equatorial region of each sample. Firmness was expressed in Newtons (N). All the experiments were studied for date fruits from each studied ripeness stages.

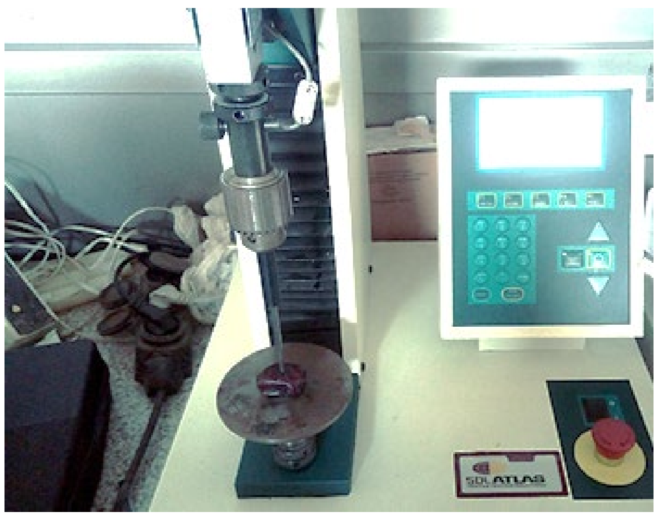

Figure 2 Location on the fruit where firmness were measured by penetration probe

2.5 Fruit color measurement

The fruit color properties of Mazafati variety at each four ripeness stages were analyzed using a Hunter colorimeter (Colorflex, VA, USA) on its date fruit juices. Hunter CIE $L*$ for lightness, $a*$ for redness, and $b*$ for yellowness were measured at any time. The color parameter chroma ($C*$) which describes the length of color vector in the plane formed by $a*$ and $b*$, and the hue angle (h^o) that determines the position of such vector was calculated according to the following formula (Yawadio and Morita, 2007; Ruslan and Roslan, 2016; Barragán-Iglesias et al., 2018):

$$C^* = (a^{*2} + b^{*2})^{1/2} \tag{7}$$

$$h^* = \arctan(\frac{b^*}{a*}) \tag{8}$$

2.6 Statistical analysis

The experiments were done at least in five replications for each stage of maturity, then the mean (±S.E.) values reported. Statistical analysis was applying the analysis of variance (ANOVA) using SPSS 16.0 software package for windows. Data obtained were analyzed by a multiple comparison test between each kimri and tamr and statistically significant differences between mean values were determined by Duncan's multiple ranges test ($p \leq 0.05$). The strength of the linear relationship between the colorimetric ripeness parameters, the chemical ripeness indices and fruit firmness was expressed through correlation coefficients ($p≤0.05$), these coefficients were determined by Pearson correlation matrix method. The analysis were compared with the highest R^2 coefficient of determination and closest to 1 for the best fitted line.

3 Results and discussion

3.1 Changes in geometrical and gravimetrical properties

The average values of geometrical and gravimetrical properties during ripening for Mazafati date fruit were statistically significant at 5% probability level as shown in Table 1. However, in a research by Golshan Tafti and Fooladi (2006) on changes in physical and chemical properties of date fruit during ripening, they found that physical properties of date fruit (Shamsaei variety) of each stage showed no statistical differences ($p<0.05$) in geometrical and gravimetrical properties. It may be due to difference in studied varieties. From a marketing viewpoint, geometrical characteristics of fruit such as size and shape are one of the important attributes that influence consumer preference in fruits (Holland et al. 2009; Opara, 2000; Maguire et al., 2001; Marondedze et al., 2014; Sassi et al., 2020). Generally, fruit size (except width) decreased with advancing fruit ripeness. The main dimensions (length, width, thickness) of date fruit were 34.45, 17.52, and 16.80 mm, respectively at kimri stage and reached 31.05, 18.25 and 14.25 mm, respectively at tamr (full-ripe) stage. Similarly, surface area, volume and shape parameters of date such as, geometric mean diameter and sphericity decreased (shape index) with advancing date fruit ripeness (Table 1). As describe earlier, sphericity of fruit describes its shape relative to the shape of a sphere of the same volume. So, the decreasing of sphericity with advancing fruit ripeness means that date fruit at kimri stage was more spheroidal than the other three stages. In agreement with our study, according to Keramat Jahromi et al. (2008), date fruit conformed more closely to a sphere shape at the kimri stage. They investigated changes in some physical properties date fruit during three edible stages of ripening for the ‘Shahani’ cultivar grown in Jahrom, Iran. They reported that fruit length and diameter decreased while width increased. As it was shown in Table 2, gravimetrical properties of studied date fruit changes significantly with advancing fruit ripeness. Fruit mass decreased from 8.69 g at kimri stage to 7.36 g at tamr stage. Similarly, there were significant decrease in true volume of date fruit (5102.73-3468.05 mm^3), throughout the developmental stages investigated. However, in this ripeness stages the true density of fruit (1.71-2.12 g cm^{-3}) increased. The same result also was reported by Keramat Jahromi et al. (2008) for date fruit Shahani ' cultivar grown in Iran. Golshan Tafti and Fooladi (2006) reported that differences were obtained in fruit weight and fruit volume during ripening of date fruit (Shamsaei variety). These values increase from 10 till 24 weeks after pollination.

Table 1 Mean values of some physical properties of date fruit (Mazafati variety) during ripening (Standard deviations of the mean values are shown in parenthesis).

Characteristics	Different ripeness stages				Significant Level
	Kimri	Khalal	Rutab	Tamr	$p<0.05$
Moisture content (%)	84(1.5)	52(2.25)	43(2.5)	20(3.5)	$p<0.05$
Dimensions (mm)					
Length	34.45(2.25)	36.58 (2.12)	33.25(2.01)	31.05(1.15)	$p<0.05$
Width	17.52(1.02)	19.42 (1.25)	18.02 (1.08)	18.25(1.12)	$p<0.05$
Thickness	16.80(0.95)	18.45(1.05)	15.32 (0.92)	14.25(0.85)	$p<0.05$
Mass (g)	8.69(0.85)	9.86(0.56)	8.06(0.74)	7.36(0.85)	$p<0.05$
Volume (mm^3)					
V_m	5102.73(95.1)	6619.92(98.2)	4393.08(90.8)	3468.05(80.1)	$p<0.05$
V_{pro}	5804.36(80.6)	7467.27 (92.8)	50.37.98(91.3)	3944.58(96.5)	$p<0.05$
V_{obl}	6174.85(86.2)	7943.90(95.4)	5359.56(90.2)	4196.34(89.5)	$p<0.05$
Geometric mean diameter	21.36(1.11)	23.90(1.85)	20.82(1.52)	19.78(1.22)	$p<0.05$

(mm)					
Sphericity	0.65(0.02)	0.63(0.02)	0.60(0.01)	0.58(0.02)	$p<0.05$
Density (g cm^{-3})	1.71(0.07)	1.38(0.11)	1.83(0.04)	2.12(0.03)	$p<0.05$
Surface area (mm^2)	1433.35(95.1)	1794.51(120.3)	1297.17(85.1)	1108.03(80.5)	$p<0.05$

3.2 Mesocarp firmness changes during ripening

Figure 3 shows the experimental data on firmness of date fruit as affected by ripeness stage. As it can be found, the ripeness stage of the fruit significantly influenced the values of firmness ($p<0.05$). The results showed that fruit firmness decreased from about 20.5 N at the start of the ripening period (kimri stage) to about 2.5 N at its end (tamr stage). The investigators believed that these discrepancies could be due to the cell structure and the volume of outer fleshy part (epicarp, or skin; and mesocarp, or pulp) and single shell (pit or stone) of fruit, as ripeness advances (Mustafa et al., 1986; Myhara et al., 2000; Serrano et al., 2001). Their reports have indicated that at least three enzymes are involved in the degradation of different polyuronides from the cell wall in dates and consequently in their softening: polygalacturonase, β-galactosidase, and cellulase. In addition, inverse activities have been also implicated in date fruit softening, through an increase of moisture retention, enabling the hydrolytic enzymes of the cell wall component do act at better conditions (Al-Shahib and Marshall, 2003; Marondedze et al., 2014; Sassi et al., 2020; Hussain et al., 2020). The different response exhibited by the fruit texture as a result of ripeness stage demonstrated its non-homogenous texture. Decreases in the firmness values of date fruit was also reported by Amorós et al. (2009) for seven date palms from the Elche grove along the ripeness process. They found that a softening process started at different ripeness stage of date fruit from kimri stage to tamr stage.

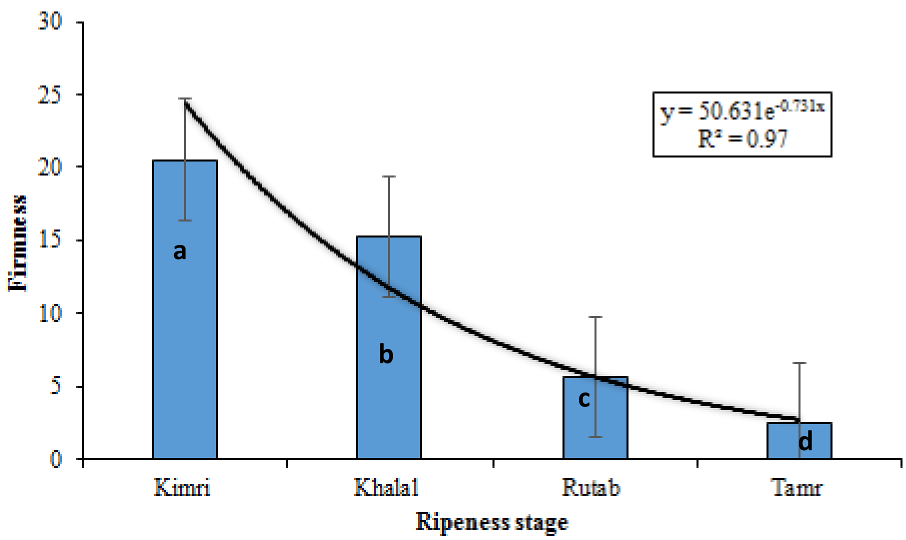

Figure 3 Mesocarp firmness of date fruit during ripening stages on-palm. Bars with different letters are significantly different ($p\leq0.05$)

3.3 Chemical changes during ripening

The change of some chemical properties of date juice and DW of date fruit during studied different stages of date fruit ripeness have been presented in Table 2. As shown in this table, the values of DW of fruit, TSS and pH of date juice increased during ripening while TA decreased. So, the highest pH value and TSS of date juice were 4.76% and 19.45 %, respectively at tamr stage. According to Amorós et al. (2009), these changes in TSS of date juice is due to increasing of sucrose, fructose, and glucose concentrations during ripening. Similar evolution in sucrose, fructose, and glucose concentrations have been found in other date varieties grown in the United Arab Emirates and Oman from khalal to tamr stages, depending on variety (Ahmed et al., 1995; Al-Hooti et al., 1997a; Myhara et al., 1999).

A comparison between the four growth stages showed that significantly higher amounts of TA existed at tamar stage (Table 2), however some extent reduction in TA was recorded when fruit turned from khalal into rutab and. So, the lowest level of acidity was recorded at rutab stage. The similar trend for TA of date fruit was found during ripeness of by Mortazavi et al. (2015). It was observed that maximum and minimum TA levels were obtained at tamar and rutab stage, respectively. As it was stated earlier, pH values showed significantly changes ($p≤0.05$) during ripening (Table 2). The pH values obtained in tamr stage were below the neutral value indicating acidic characteristics of fruit. The increase in pH was due to a decrease in the amount of hydrogen ions provided by organic acids during the ripening process. Similar increase in pH was observed during ripeness of nine Iranian date fruit cultivars (Mortazavi et al., 2015).

Table 2 Chemical parameters of fate fruit during ripening stages on-palm.

Characteristics	Different ripeness stages			
	Kimri	Khalal	Rutab	Tamr
Moisture content (%)	84±1.5^{a}	52±2.25^{b}	43±2.5^{c}	20±3.5^{d}
TSS (%)	9.82±0.12^{a}	12.91±0.21^{b}	17.23±0.33^{c}	19.45±0.25^{d}
pH	3.15±0.02^{a}	3.85±0.03^{b}	4.02±0.02^{c}	4.76±0.05^{d}
TA (g citric acid/100 g fresh fruit)	0.69±0.003^{a}	0.76±0.004^{b}	0.65±0.004^{c}	0.82±0.005^{d}
Dry weight content of date fruit (g)	31±1.15^{a}	41±1.23^{b}	48±1.15^{c}	55±1.25^{d}

Note: Values of the columns with different superscripts indicate significant differences ($p≤0.05$).

3.4 Visual color changes of selected date fruits during ripening

Ripening on-palm allowed the identification of different studied ripeness stages based on days after anthesis (DAA) and fruit color (Figure 1). The color of date fruits was obviously discernable in each stage, mainly kimri and tamr. As it can be found from Figure 1, all the selected date fruit were green in color at the kimri stage; then at the khalal stage were red. As the date fruits ripened further to the next stage, their color and texture changed significantly. All of the date fruits at the rutab stage had developed a dull brown color, starting from the distal end. By the tamr stage, the fruits had turned dark brown-black in color. The red color of fruits is a desirable trait for their suitability for processing into pickles, chutney and dates-in-syrup. At the rutab stage, half of each fruit becomes soft and develops a dark brown color, while at the last stage, tamr, the fruit turns dark brown-black and becomes wrinkled. A similar pattern was reported by Al-Hooti et al. (1997b) for four maturity stages of date fruit and some processed date products. They found that all the cultivars were green in color at the kimri stage; but by the khalal stage, the cultivars had developed different colors, at the khalal stage, Shahla and Bushibal fruits were red, Gash Gaafar and Lulu fruits were yellow, and Gash Habash fruits were yellow-scarlet. As the date fruits matured further to the next stage, their color and texture changed significantly. All of the date fruits at the rutab stage had developed a dull brown color, starting from the distal end. By the tamr stage, the fruits had turned dark brown-black in color.

3.5 Fruit color changes during ripening

Color is the important parameter affecting the consumer acceptability. It is also an important quality parameter in commercial date fruits. On the other hand, fruit color was one of the main indexes to determine the ripeness of date fruit during ripening on-palm. The results of color measurement of fresh date fruits of selected cultivar 'Mazafati variety', in terms of Hunter $L*$, $a*$, $b*$, $C*$, and h^{o} values, are presented in Figures 4-5. As it can be seen from Figure 4, the date fruits at the kimri stage were light green in color with a slight yellowish tinge, which is indicated by the positive $b*$ values. In the khalal stage, fruits had showed a higher positive $a*$ values (a reddish color). At the rutab and tamr stages, the color of the date fruits was darker (lower $L*$ values), and had reached a neutral grey-black (the $a*$ and $b*$ values approached almost zero). Generally, at the kimri stage, date fruits from showed maximum lightness values, but at the rutab and tamr stages, the lightness values decreased. The $a*$ negative value in Table 2 showed that fruit were mostly green (at kimri stage of ripeness). The positive *a** value with lower lightness values in khalal fruits show these fruits to be of darker red color.

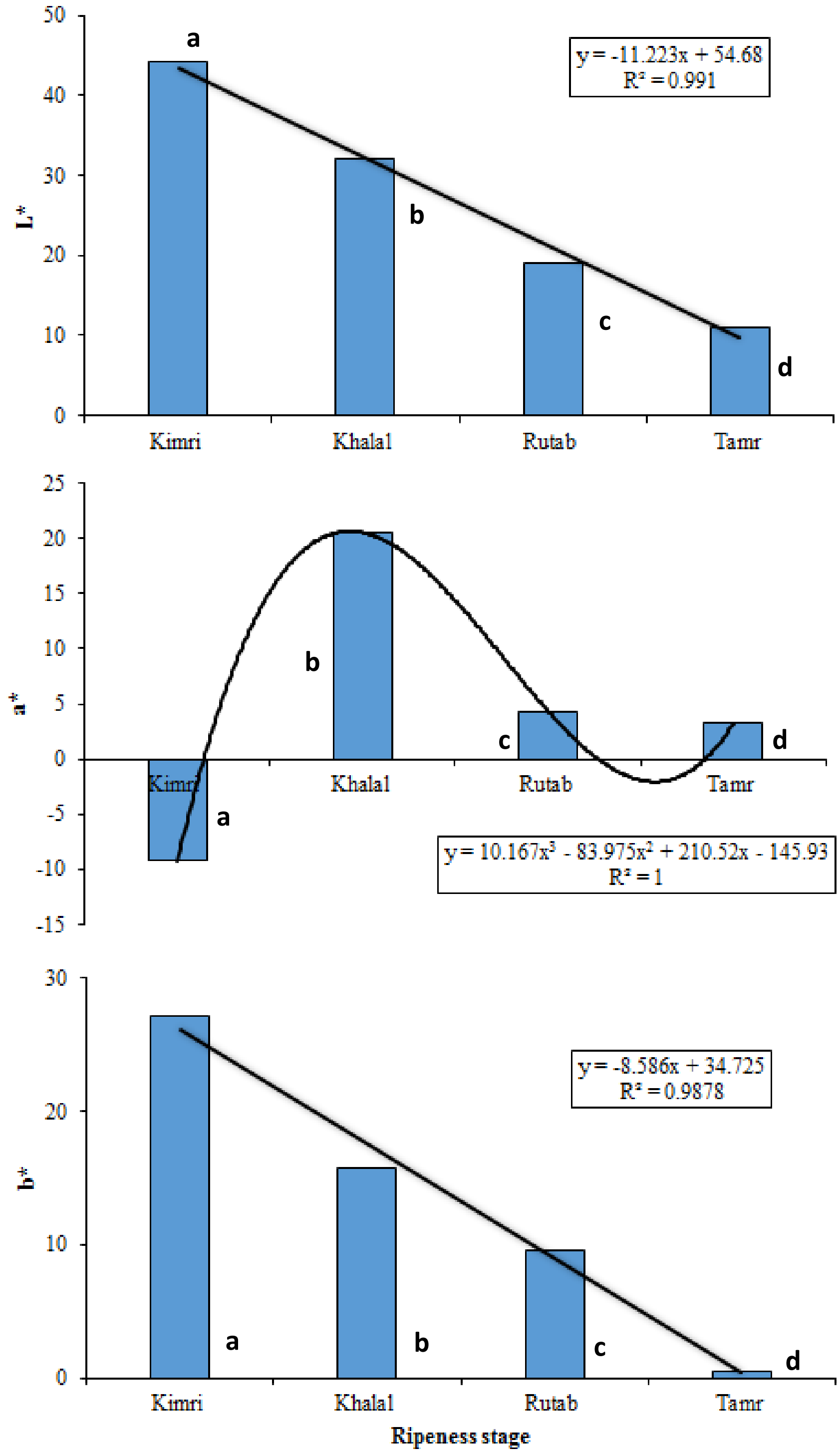

Figure 4 Color parameters of date fruit during ripening stages on-palm. Bars with different letters are significantly different ($p \leq 0.05$)

The fruit color can be described during date ripening on-palm (green to black) by hue angle progress within a specific interval. Therefore, hue angle permit to separate the date fruits according to physiological maturity and ripeness. In this study, the hue angle ($h°$) significantly reduced during ripening steps as linearly (Figure 4). Decreased hue angle (h values), lightness ($L*$), $a*$ and $b*$ values for tamr fruits of selected variety reflect the presence of darker grey-black color at this stage of ripeness. The highest value of chroma (C^*) was obtained in kimri stage due to the intensity or purity of slight yellowish color.

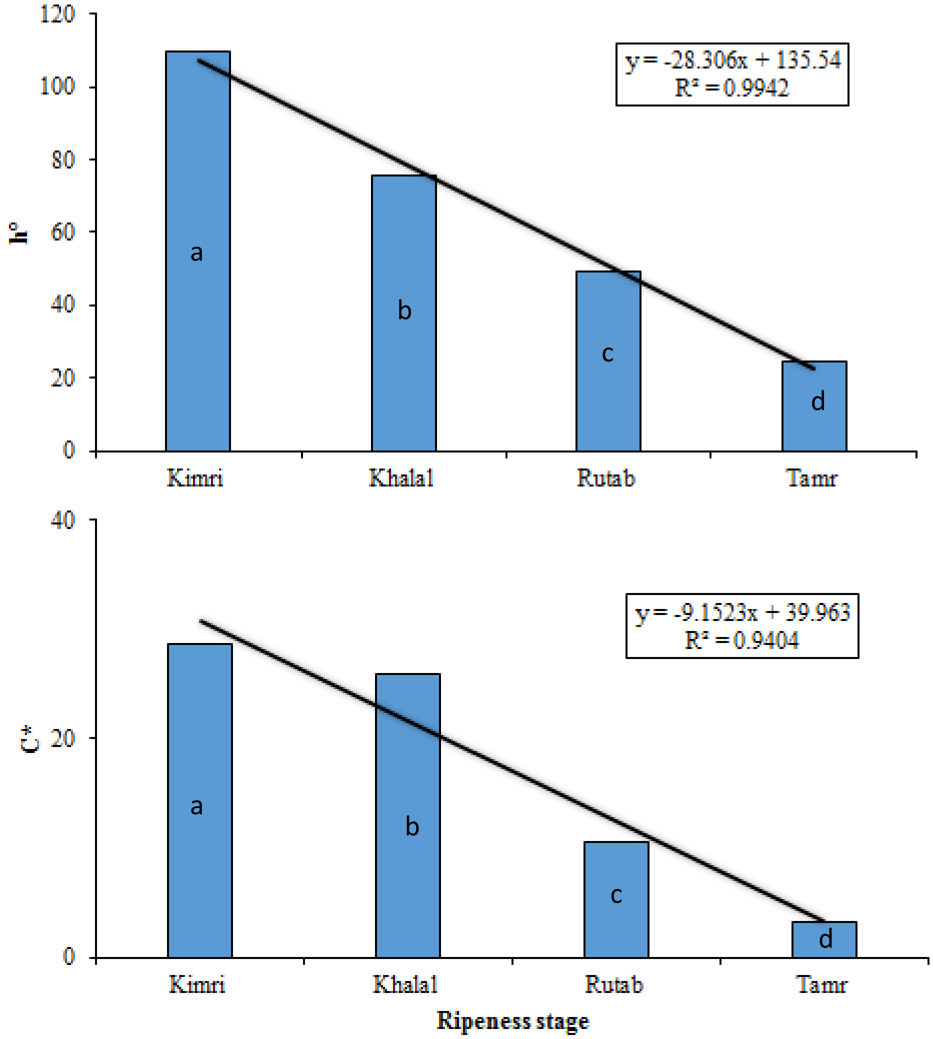

Figure 5 Color parameters calculated of date fruit during ripening stages on-palm fruits. Bars with different letters are significantly different ($p≤0.05$)

3.6 Correlation between the colorimetric ripeness parameters and the chemical ripeness indices

Table 3 shows Pearson's correlation among colorimetric ripeness parameters, pH, TA, TSS and mesocarp firmness of date fruit for studied ripeness stages. Significant and strong correlations ($p<0.05$ and $p<0.01$) can be noticed. These include significantly strong correlation that color parameters showed with TSS followed by the mesocarp firmness. The linear correlation of TSS with a* value indicated a gradual increase of TSS when green color in kimri stage was changing to dark color during ripening on-palm. Also, the increasing of TSS was linearly correlated with the intensity of date fruits epicarp, to higher intensity, TSS content will be higher. Though, the color changes in the epicarp are well described by the h° values. At the same time that the h° values decreases and the epicarp becomes dark, the TSS content increases to adequate values of ripeness for consumption, its allowed better results of TSS content due to the higher linear correlation. Mesocarp firmness decrease when the red and dark tones appear in the epicarp, therefore the firmness also can be calculated from the color parameters. In addition, as the ripening was reached and h° decreased, mesocarp firmness decreases linearly. If the simpler and economically parameters need to be determined or measured, linearity is important in estimating any unknown and dependent parameters.

Table 3 Pearson's correlation coefficients (r) among colorimetric ripeness parameters TA, TSS and mesocarp firmness of 'Mazafati' date fruit ripening.

Variables	Chroma	Hue	*L**	*a**	*b**	pH	TA	TSS	Mesocarp firmness
Chroma	1								
Hue	-0.91*	1							
*L**	0.91*	-0.88*	1						
*a**	0.87*	-0.91*	0.81	1					
*b**	0.93**	-0.89*	0.92*	0.93*	1				
pH	0.82*	0.81*	-0.93*	-0.84*	-0.81*	1			
TA	-0.82*	-0.81*	0.83*	0.84*	-0.85*	0.84	1		
TSS	0.93**	-0.92**	0.91*	0.92*	0.91**	0.90*	0.91*	1	
Mesocarp firmness	-0.91**	0.91**	-0.89*	-0.88*	-0.89*	0.88*	0.88*	0.89*	1

Note: **. Correlation is significant at the 0.01 level (2-tailed).

4 Discussion

In the studied areas, the date fruits in kimiri and tamr stages are called "ripe physiologically" and "suitable for tasting", respectively. Rutab are considered suitable for export and also khalal as processed form for juice, jams, etc. Further, due to subsequent color and ripeness changes for consumption, the date fruits in rutab stage needs minimum processing and suitable for local markets. In this research, Mazafati date fruits had a specific color distribution during ripening on-palm. This color distribution is similar to previous studies in date fruits for five cultivars of date fruits at different stages of maturity showed by Al-Hooti et al. (1997b), or Aseel variety from rutab stage to ripe dehydrated dates (Haider et al., 2012).

The amount of chlorophylls, carotenoids and anthocyanin of date fruit in kimri and khalal stage were acceptable for green and red colors (Al-Farsi et al., 2005; Mortazavi et al., 2015; Marondedze et al., 2014; Sassi et al., 2020; Hussain et al., 2020). In this study, the green color as chlorophyll content was disappeared at khalal stage as it has been reported by other researchers that the considerable degradation of chlorophylls during fruit development for early stages of development (Bacha et al., 1987; Mortazavi et al., 2010). The concentration and composition of carotenoids in some date fruits have been determined as major role in green color at kimri stage by Mortazavi et al. (2010) and Boudries et al. (2007). Ripening on-palm of fruits can be defined with the color parameters of a fully developed dark epicarp. L* value of rutab and tamr (ripeness for consumption) was similar to five studied varieties of date fruit in the tree completely mature that reported by Al-Hooti et al. (1997b). Also, Mazafati date fruits in stages rutab and tamr reach similar L* value reported by Haider et al. (2012) for Aseel variety of date fruit. The value of L*, the most important indicative of dark color appearance, was lower during ripening on tree in Mazafati date fruit and a* and b* values reached to almost zero in rutab and tamr similar to the results of Al-Hooti et al. (1997b) for five selected varieties.

The dark color pigments produced during fruit development on tree may require some environmental factors such as sunlight (Shahidi and Naczk, 2004; Al-Farsi et al., 2005; Biglari et al., 2008). Since the consumers like to buy date fruits dark gray-black, those factors can be considered an attractive characteristic. These changes in composition, color, texture or other sensory attributes of date fruits during ripening stages have been identified due to accumulation of phytochemicals such as carotenoids, the phenolics, flavonoid glycosides, flavones, flavonols, flavoxanthin in the fruit (Barreveld, 1993; Al-Farsi et al., 2005). The concentration of these phytochemicals decreases with advancing stage of fruit ripeness.

Fruit quality and shelf life in advanced stages are affected by loss firmness. This occur because firmness of fruit declined during ripening, which were consistent with loss in crude fiber (Barragán-Iglesias et al., 2018). As it was states earlier, Mazafati date fruits ripening on-palm produces drastic changes on firmness between each ripeness stage. Amorós et al. (2009) have reported also similar results for seven date palms from the Elche grove along the ripeness process. They found that a softening process started at different ripeness stage of date fruit from kimri stage to tamr stage. In this study, minimum values of firmness were maintained in both rutab and tamr.

Similar to firmness, the sugars content is changed during ripening too. Therefore, the sufficient carbon source for high sucrose content may not been guaranteed in dates harvested in pre-ripeness stage and consequently post-harvest sweetening (Gomez et al., 1999). TSS and TA are the main factors affecting fruit taste. TSS showed an increasing trend during fruit development. High TSS values represent the high percentage of sugars. Fruit sweetening in the final stages of fruit ripeness is common and it can be related to the hydrolytic conversion of insoluble carbohydrate polymers into low density soluble sugars (Saleem et al., 2005). However, losing substantial portion of water raises the concentration of soluble solids in date fruit. This issue affects the taste and texture of date, and makes it much sweeter (Mortazavi et al., 2015).The TSS values for Mazafati date fruit in studied ripeness stages were similar to nine Iranian date fruit cultivars reported by Mortazavi et al. (2015). Data analysis of TA showed that the maximum acidity of 0.1% as a low acidity fruit and has a minor effect on date taste. Reduction of acidity level at rutab stage may be related to the conversion of organic part of acids into sugars. Further, the fruit had very low metabolic activity at tamar stage, so increasing TA level may be due to the considerable water loss and juice concentration at the last stage of fruit development. The same results were reported by Mortazavi et al. (2015) for nine Iranian date fruit cultivars. High relationships were found between color index with TSS content and mesocarp firmness in this study.

5 Conclusion

Noticeable variations in ripeness indexes and physicochemical properties of Mazafati date fruit were found at four ripening stages on-palm (kimri, khalal, rutab and tamr). Results obtained showed that major compositional changes in the fruit are developmental regulated. Significant decrease in geometrical properties (except width) and gravimetrical properties (fruit mass, true volume of fruit) was observed along days after anthesis (DAA). The results also showed that mesocarp firmness, pH, TSS and TA values increased when ripening was developed. Differences at a 5% level of significance were found among the developmental stages in the color of fruit. The CIE a^* non-linearly decreased significantly from kimri to tamr, it was higher at khalal stage while CIE L^* and b^* value decreased as the fruit advanced in ripeness. Also, the h^o and C^* showed a decreasing trend with advancing ripeness as the epicarp changed from green to dark color. Furthermore, Pearson correlation was used to investigate the relationship between selected colorimetric ripeness parameters, pH, TA, TSS and mesocarp firmness of date fruit for studied ripeness stages. Interesting significantly strong correlations were observed. The fruit ripening on-palm from physiological maturity to ripeness can be described by ripeness indexes as the nondestructive and destructive indexes as presented in this research. However, more investigation needs to be done to ensure the inclusion of fruit biochemical attributes when assessing fruit readiness to harvest.

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