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Physico-chemical changes during development and ripening of 'Helali' date palm fruit

Adel D. Al-Qurashi

Department of Arid Land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdul-Aziz University, P.O.Box. 80208, Jeddah 21589, Saudi Arabia. e-mail: aalqurashi@kau.edu.sa

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Abstract

Physical and biochemical changes in 'Helali' date palm fruit were studied during development and ripening. In two successive seasons, the results showed that fruit and flesh weight, diameter and length were gradually increased during development until week 17 (*Bisir* stage), slightly decreased during ripening at week 23 (*Rutab* stage), but sharply decreased during the *Tamer* stage at week 27 from pollination. The changes in these parameters showed a clear sigmoidal pattern for 'Helali' fruit growth. Seed weight gradually increased during development until week 17, but decreased during the *Tamer* stages at week 23 and 27 from pollination, respectively. Flesh/seed ratio sharply decreased from week 6 to week 10, fluctuated until week 14, gradually increased until week 23 from pollination and then decreased during the *Tamer* stage. TSS and flesh dry weight percentage remained constant or slightly fluctuated from week 6 to week 14 from pollination and then rapidly increased during maturation and ripening. Acidity percentage gradually decreased from week 6 to week 17 from pollination, and then increased during ripening (*Rutab* and *Tamer* stages). Vitamin C concentration sharply decreased from week 6 to week 10 from pollination, slightly decreased during maturation, but decreased at a faster rate during ripening. Total phenols concentration gradually increased during development until week 14 from pollination, but sharply decreased during maturation and ripening to a low level. The concentration of soluble tannins gradually increased from week 6 to week 17 from pollination, and then sharply decreased at a faster rate during ripening. However, on a fruit basis (mg/fruit), the soluble tannins content gradually increased during development until week 17 from pollination and then sharply decreased during ripening to a low level. The concentration of nutrient elements (nitrogen, potassium, phosphorus, magnesium, calcium, sodium, zinc, iron, copper and manganese) gradually decreased during development and more progressively during ripening.

Key words: Development, growth, quality, ripening, *Phoenix dactylifera* L., date palm.

Introduction

Date palm is the most successful and extremely important subsistence crop in most of the hot arid desert regions [1, 2]. Generally, whole dates are harvested and marketed at three stages of their development mainly mature firm (*Bisir* or *Khalal*), full ripe (*Rutab)* and dry (*Tamer*) [3]. The decision for harvesting at one or other stage depends on cultivar characteristics, especially soluble tannins level, climatological conditions and market demand [3, 4]. Most of the available literature information concentrates mainly on the chemical composition of dates at the maturity and ripening stages and/or changes during storage for some cultivars. However, relatively little consideration being given to the physico-chemical changes during development and ripening. Ragab *et al.* [5] characterized some of the chemical changes during development and ripening of six date palm cultivars growing in Egypt. In Iran, Rouhani and Bassiri [6] described some of the physical and chemical changes of 'Shahani' dates during development and ripening. Sawaya *et al.* [7] studied the growth and compositional changes at various developmental stages of some date cultivars, exclusive 'Helali', growing in Saudi Arabia. Ahmed *et al.* [8] reported some of the chemical changes during development, maturation and ripening of twelve date cultivars which are widely consumed in United Arab Emirates. Other reports from Saudi Arabia [9, 10], United Arab Emirates [11], Sudan [12] and Iraq [13] considered some of the changes in chemical composition that accompany only the maturation and ripening stages, and yet major alterations in the chemical composition of the fruits might be expected to run in parallel with the visible physical changes during development, maturation, and ripening. 'Helali' is one of late season date palm cultivars being extensively cultivated in the Gulf region. At the maturity (*Bisir)* stage, the fruit are astringent as a result of high contents of soluble tannins, and removal of tannins is necessary for the fruit to be edible [3]. The fruit do not ripen at one time, even in the same bunch, consequently several harvests (10-15) are required during the harvesting season (early September to late November). In some regions in Saudi Arabia and in some other countries in the Gulf region, only 30-40% of the total fruit might normally ripen on tree and the remaining fruit fail to ripe which cause a great economic loss [3]. To the best of my knowledge, no available literature information on the physico-chemical changes of 'Helali' dates during the entire growing season including development, maturation and ripening stages. Such information is necessary

for better understanding of the physical and biochemical events that accompany the development, maturation and ripening of such hard to ripen cultivar. Therefore, the aim of this study was to characterize the growth and compositional changes during development, maturation and ripening of 'Helali' dates growing under arid climate conditions.

Materials and Methods

Plant materials and experimental procedure: During 2008 and 2009 growing seasons, six uniform 'Helali' date palm trees of 22-years-old growing in a sandy-loamy calcareous soil, drip irrigated and receiving normal cultural practices at the experimental orchard of the Faculty of Meteorology, Environment and Arid Land Agriculture at Hada Al-Sham, Saudi Arabia, were selected for this experiment. The experiment was designed as a completely randomized design with three replicates (two trees for each replicate). All trees were pollinated from one male tree during the flowering period (3-7 March in 2008 and 8-12 March in 2009 season). Following fruit set, the crop load was adjusted to 8 bunches per palm. In both seasons, three fruit samples of 20 fruits each were collected at 6, 8, 10, 12, 14, 17, 23 and 27 weeks from pollination for physical and chemical determinations.

Physical characteristics, TSS, acidity and vitamin C determinations: Fruit, flesh and seed weight, flesh/seed ratio, fruit length and diameter were recorded independently in each of the 20 fruits per replicate at each sampling date. A homogeneous sample was prepared from these 20 fruits per replicate for measuring total soluble solids (TSS), acidity, vitamin C, total phenols, soluble tannins and nutrient elements. Total soluble solids (TSS) were measured as Brix % in fruit juice with a digital refractometer. Titratable acidity was determined in juice by titrating with 0.1 N sodium hydroxide in the presence of phenolphthalein as indicator [14], and the results were expressed as a percentage of malic acid. Ascorbic acid (vitamin C) was measured, according to Ranganna [14], by the oxidation of ascorbic acid with 2,6-dichlorophenol endophenol dye and the results were expressed as mg/100 g fresh weight.

Total phenols determination: Total phenols were measured according to Velioglu *et al.* [15] using Folin-Ciocalteu reagent. Two hundred milligrams of fruit tissue (including skin and flesh) were extracted with 2 ml of 50% methanol for 2 h with shaking at ambient temperature. The mixture was centrifuged for 10 min, and the supernatant was decanted into 4 ml vials. Then, 200 µl of the extract was well mixed with 1.5 ml Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water) and allowed to stand for 5 min at ambient temperature. A 1.5 ml of 20% sodium carbonate was added. After 90 min, absorbance was measured at 750 nm using a UV-Vis spectrophotometer. The blank contains only water and the reagents. Total phenols were quantified from a calibration curve obtained by measuring the absorbance of known concentrations of gallic acid.

Soluble tannins determination: Soluble tannins were measured according to Taira [16]. Five g of fruit tissue (including skin and flesh) was homogenised with 25 ml of 80% methanol in a blender and then centrifuged. The supernatant was collected and the precipitant was re-extracted with 80% methanol and centrifuged. The combined supernatant was brought to 100 ml with distilled water. Then 1 ml sample solution was mixed with 6 ml distilled water and 0.5 ml Folin-Ciocalteu reagent (previously diluted 10-fold with distilled water) and shaken well. After exactly 3 min, 1 ml of saturated sodium carbonate was added and mixed well. Then 1.5 ml distilled water was added and mixed well (total, 10 ml) and left for 1 h at ambient temperature before measuring absorbance at 750 nm using a UV-Vis spectrophotometer. The blank contains only water and the reagents. Soluble tannins were quantified from a calibration curve obtained by measuring the absorbance of known concentrations of gallic acid.

Nutrient analysis: The collected fruit samples were washed with distilled water, and oven dried for 48 h at 65°C in paper bags. Samples were ground and wet digested as described by Chapman and Pratt [17]. Nitrogen was analyzed by micro-Kjeldahl procedure. Phosphorus was measured by spectrophotometer. Potassium and sodium concentrations were determined by emission flame photometer. Iron, zinc, magnesium, calcium, manganese and copper concentrations were measured by atomic absorption.

Statistical analysis of data: The obtained data were statistically analyzed as a completely randomized design with three replicates by analysis of variance (ANOVA) using the statistical package software SAS (Statistical Software, SAS Institute Inc., Cary, NC., USA, 2000). Comparisons between means were made by *F*-test and the least significant differences (LSD) at $P = 5\%$.

Results

Fruit growth and changes in physical parameters: Because of similarity between the results of the two seasons (no significant interactions between seasons), data were presented as the means of both seasons. In order to relate the changes in the physical and chemical properties to fruit growth, the fruit and flesh weight, diameter and length were measured during development and ripening. Fruit and flesh weight, diameter and length were gradually increased during development until week 17 (maturity or *Bisir* stage), slightly decreased during ripening at week 23, but sharply decreased during the *Tamer* stage at week 27 from pollination (Figs 1 and 2). The changes in these parameters show a clear sigmoidal pattern for 'Helali' fruit growth (Figs 1 and 2). Seed weight gradually increased during development until week 17 (maturity or *Bisir* stage), but decreased during the *Bisir* and the *Tamer* stages at week 23 and 27 from pollination, respectively (Fig. 1). Flesh/seed ratio sharply decreased from week 6 to week 10, fluctuated until week 14, gradually increased until week 23 from pollination and then decreased during the *Tamer* stage (Fig. 1).

Changes in chemical parameters: TSS concentration was 11.87% at week 6 and slightly fluctuated until week 12, but then rapidly increased during maturation and ripening to reach a maximum level (60.02%) at the *Tamer* stage at week 27 from pollination (Fig. 3). Flesh dry weight percentage followed a similar pattern as for TSS concentration (Fig. 2). Acidity concentration slightly increased from week 6 to week 8 to reach a maximum level (4.86%), and then gradually decreased from week 8 to week 17 followed by an increase during ripening (3.35 and 4.55% for the *Rutab* and the *Tamer* stage, respectively) at week 23 and 27 from pollination (Fig. 3). Vitamin C concentration was at highest early in the season

(14.82 mg/100 g fw) and then sharply decreased until week 10 (7.74 mg/100 g fw), with a further slight decrease during maturation and ripening to reach a level of 6.10 mg/100 g fw at the *Tamer* stage (Fig. 3). Total phenols concentration gradually increased during development until week 14 from pollination to a maximum level (2.18 mg/g fw), but then sharply decreased thereafter to a relatively very low level (0.14 mg/g fw) at the *Tamer* stage (Fig. 4). The concentration of soluble tannins was at highest concentration in early season (16.0 mg/g fw) and then gradually decreased until week 17 (the *Bisir* stage) followed by a further decrease at a faster rate during ripening to reach low level (3.70 and 2.59 mg/g fw for the *Rutab* and the *Tamer* stage, respectively). However, as amount per fruit, the soluble tannins content gradually increased during development until week 17 from pollination (the *Bisir* stage) to reach a maximum level (113.0 mg/g fw) and then sharply decreased during ripening to reach low level (51.53 and 22.62 for the *Rutab* and the *Tamer* stage, respectively) (Fig. 4).

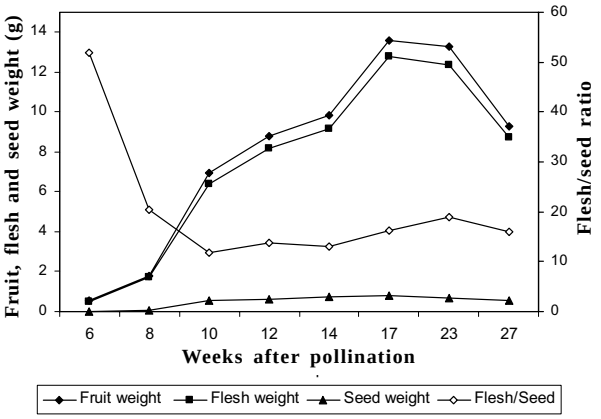

Figure 1. Changes in fruit, flesh and seed weight and flesh/seed ratio of 'Helali' date palm during development and ripening. LSD at 5% for time effect are 0.54, 0.54, 0.066 and 2.37 for fruit, flesh and seed weight and flesh/seed ratio, respectively.

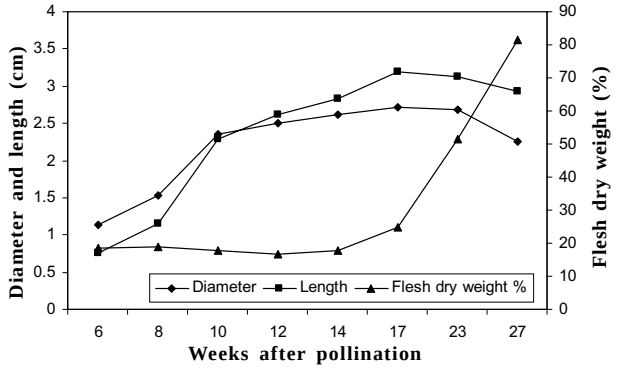

Figure 2. Changes in diameter, length and flesh dry weight percentage of 'Helali' date palm fruit during development and ripening. LSD at 5% for time effect are 0.096, 0.094 and 1.64 for diameter, length and flesh dry weight percentage, respectively.

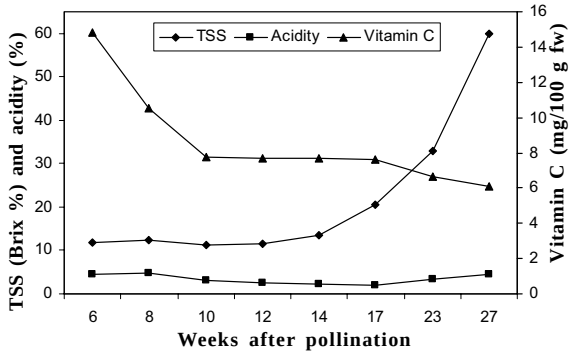

Figure 3. Changes in TSS, acidity and vitamin C concentration of 'Helali' date palm fruit during development and ripening. LSD at 5% for time effect are 1.44, 0.41 and 0.48 for TSS, acidity and vitamin C concentration, respectively.

Changes in nutrient concentration: Nitrogen concentration gradually decreased during development, maturation and ripening to reach a low level of 235 mg/100 g dw (Fig. 5). Phosphorus was at highest concentration at early stage (91.9 mg/100 g) but gradually decreased during development, maturation and ripening reaching a low level (57.8 mg/100 g). Potassium was at high concentration at early stage (1725 mg/100 g), progressively decreased during development and ripening to reach a lower level (877 mg/100 g). Magnesium concentration was 132.5 mg/100 g but gradually decreased during development and ripening reaching a low level of 82.6 mg/100 g. Calcium concentration was 197.7 mg/100 g at early stage but sharply decreased until week 10, slightly decreased until week 17 from pollination, then sharply decreased during ripening (*Rutab* and *Tamer* stages) to a low level (95 mg/100 g). The concentration of sodium gradually decreased during development, maturation and ripening to reach a low level (36.7 mg/100 g) (Fig. 5). The concentration of iron was 8.97 mg/100 g at early stage, gradually decreased during development and ripening reaching a low level of 4.32 mg/100 g (Fig. 6). Manganese was at highest concentration at early stage (2.32 mg/100 g), sharply decreased during development until week 12 then gradually decreased at a slower rate during maturation and ripening to reach a lower level (0.85 mg/100 g) (Fig. 6). The concentration of zinc was 3.87 mg/100 g at early stage, sharply decreased from week 6 to 10, then gradually decreased at a slower rate during development and ripening to reach a low level (1.89

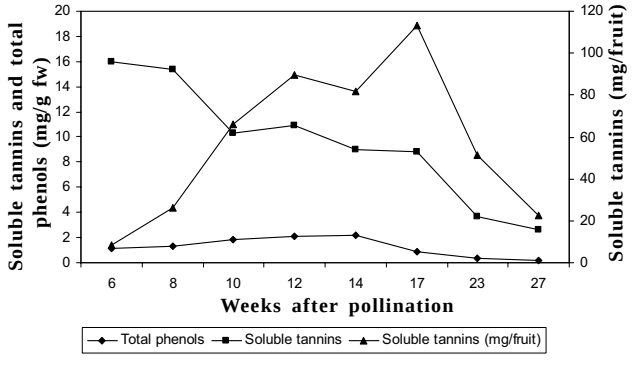

Figure 4. Changes in total phenols concentration and soluble tannins concentration and amount of 'Helali' date palm fruit during development and ripening. LSD at 5% for time effect are 0.15, 1.03 and 8.93 for total phenols concentration and soluble tannins concentration and amount, respectively.

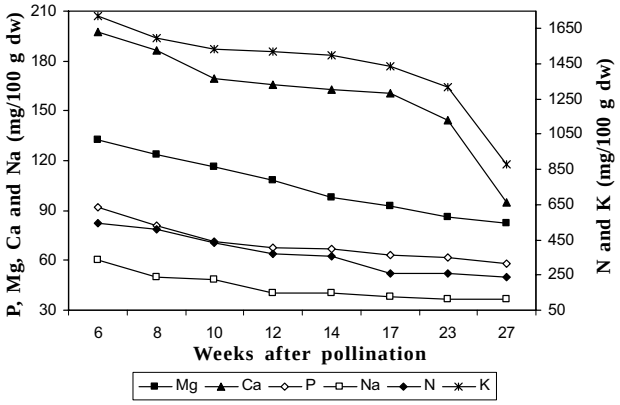

Figure 5. Changes in nitrogen, phosphorus, potassium, magnesium, calcium and sodium concentration of 'Helali' date palm fruit during development and ripening. LSD at 5% for time effect are 18.69, 5.05, 70.55, 3.67, 3.68 and 3.53 for nitrogen, phosphorus, potassium, magnesium, calcium and sodium concentration, respectively.

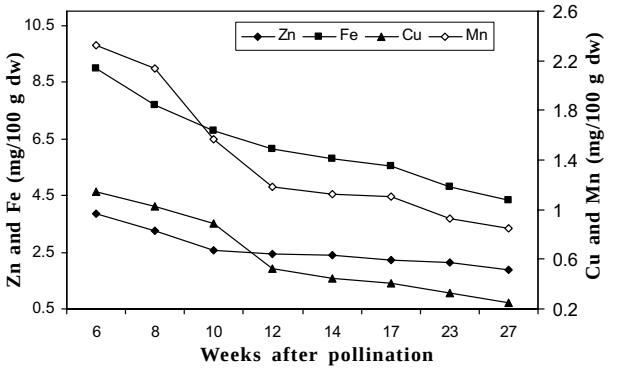

Figure 6. Changes in zinc, iron, copper and manganese concentration of 'Helali' date palm fruit during development and ripening. LSD at 5% for time effect are 0.24, 0.38, 0.054, and 0.13 for zinc, iron, copper and manganese concentration, respectively.

mg/100 g) (Fig. 6). Copper was at highest concentration (1.14 mg/100 g) at early stage, sharply decreased from week 6 to week 12 from pollination, then gradually decreased during development and ripening to reach a low level of (0.25 mg/100 g) (Fig. 6).

Discussion

In order to relate the changes in the physical and chemical properties to fruit growth, the fruit, flesh and seed weight, diameter and length were measured during development and ripening. Fruit growth based on fruit, flesh and seed weight, diameter and length followed a smooth sigmoidal type of curve for 'Helali' dates (Figs 1 and 2). These results confirm those of Rouhani and Bassiri [6] and Shabana *et al.* [18] for other date palm cultivars. From the growth curve of fruit weight, three phases in the growth rate can be distinguished: an initial rapid increase in fruit weight from week 6 to week 10 (the *Kimri* stage), slow increase in fruit weight from week 10 to week 17 (the *Bisir* stage) and a declining rate of growth from week 17 until harvest at week 23 (the *Rutab* stage) and at week 27 (the *Tamer* stage) from pollination. The fruit reached the maximum size at the maturity stage (17 week from pollination) with a growth rate of 0.114 g fresh weight per day. The increment in seed weight increases was higher than that of flesh weight from week 6 to week 14 from pollination but thereafter the opposite was true. This may explain the sharp decrease in flesh/seed ratio from week 6 to week 10 followed by the gradual increase until ripening (Fig. 1). It can be concluded that seeds reached complete maturity at week 14 from pollination before entering the *Bisir* stage. These results confirm those of Rouhani and Bassiri [6] for 'Shahani' date palm cultivar. In apples, it was also reported that the seeds appear to reach their maximum weight before the other parts of the fruit [19]. The accumulation of TSS and dry weight in fruit flesh (Fig. 3) increased during development with a vast increase during ripening mainly due to gain in sugars and loss of water. These results confirm those of Rouhani and Bassiri [6], Shabana *et al.* [18] and Sawaya *et al.* [10]. The sharp decrease in acidity during development with an increase during ripening was also reported for other date palm cultivars [6, 10]. The vitamin C concentration was considerably lower at the *Rutab* and the *Tamer* stages (6.63 and 6.10 mg/100 g, respectively) compared to earlier stages of fruit development (14.82 mg/100 g) (Fig. 3). Such sharp decrease in vitamin C concentration during development and ripening has also been observed by Sawaya *et al.* [10] in some other date palm cultivars. The fruit weight continued to increase until week 17 from pollination (the *Bisir* stage) (Fig. 1). A net increase in the amount of soluble tannins with fruit growth until maturation in combination with a decrease in concentration strongly suggests that the rate of accumulation in these compounds is highest in early season (Fig. 4). However, the sharp decrease thereafter in both amount and concentration during ripening showed a possible cease of accumulation together with breakdown and/or a conversion into insoluble form. It is known that most soluble tannins are converted into insoluble form during development and ripening in many other fruits such as persimmon[16]. Generally, the concentration of all nutrient elements gradually decreased during development and more progressively during ripening (Figs 5 and 6). These results confirm those of earlier works reported by Sawaya *et al.* [7, 9], Aljuburi *et al.* [20] and Ahmed *et al.* [8] for other date palm cultivars.

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