



# Fruit Morphological and Biochemical Characterization of Three Saudi Arabian Date Palm (*Phoenix dactylifera* L.) Cultivars Grown in District Khairpur, Pakistan

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**Abstract:** In the present study fruit morphological and biochemical characterization of three Saudi Arabian date palm cultivars (Ajwa, Safawi and Ruthana) were carried out, which were cultivated in the district Khairpur, Pakistan. Fruits were collected at four different fruit growth stages (kimri, khalal, rutab and tamar) from fifteen years old trees for morphological (fruit colour, fruit length, fruit diameter, fruit weight, pulp ratio, seed length, seed diameter, seed weight) and biochemical analyses (moisture content, pH, total soluble solids, total sugars, reducing sugars, non-reducing sugars). Results of fruit physical characters showed that significantly highest fruit length (5.5 cm at rutab stage), fruit weight (20.2 g at khalal stage) was observed in cv. Safawi, whereas at khalal stage significantly lowest fruit length (3.4 cm) was observed in cv. Ajwa and fruit weight (13.2 g) was observed in cv. Ruthana. Fruit/pulp ratio (FPR) (90.7%) was higher in the fruits of cv. Ajwa at khalal stage, while at rutab stage FPR (92%) was higher in the fruits of cv. Safawi. Fruits showed significant variations in colour, size and weight from kimri to tamar stage. Biochemical analyses of fruits revealed that highest moisture content (86.2%) was observed in fruits of cv. Ruthana at kimri stage. Total soluble solids (TSS) increased from 8.7% (at kimri stage) to 20.5% (at tamar stage) in cv. Ruthana. pH of the fruits at kimri stage was 3.2 in cv. Ajwa, whereas pH increased to 5.2 in cv. Ruthana at tamar stage. Total sugars (reducing and non-reducing) increased from 7.56% in cv. Ajwa at kimri stage to 69.7% in cv. Safawi at tamar stage as significantly highest values. Findings obtained in the present study described morphological attributes and biochemical constituents of the fruits of three exotic cultivars introduced in climatic conditions of the district Khairpur, Pakistan will open the route and interest of the farmers to introduce other elite date cultivars grown in the world.

**Keywords:** Biochemical Analysis, Moisture Content, Total Soluble Solids, Morphological Attributes, Rutab, Tamar.

## 1. INTRODUCTION

Date palm (*Phoenix dactylifera* L.) belongs to family Arecaceae being diploid ( $2n = 36$ ), dioecious and having potential varietal collection cultivated in the tropical world [1]. According to Chao and Krueger [2] date palm remain full productive for 40–50 years under normal conditions but generally it may bear fruit up to 150 years in certain circumstances. Maryam *et al.* [3] described that date palm holds 4<sup>th</sup> position among commercial crops (mango, citrus and banana) playing a key role in the socio-economic development of the country. Pakistan holds 5<sup>th</sup> position in dates' production with established industrialization, shares 10.2% in world production [4]. Date fruits are enriched in

minerals, sugars, vitamins and various compounds used as traditional medicines [5, 6]. Agronomy of date palm play significant role for peoples' income in rural areas, major income source for farmers, important food source to the peoples in rural areas [7]. Date fruits are oblong, berry with thick mesocarp and thin fibrous endocarp, constitute 85-90% of total fruit weight [8]. Fruit developmental stages of dates are categorized into five stages (hababouk, kimri, khalal, rutab and tamar). Hussain *et al.* [9] described that fruits at hababouk and kimri stage remain green in colour and non-edible, while fruits at edible khalal stage acquire proper size, shape and colour, and next to khalal is rutab stage (half ripened) and tamar (full ripened) either on the tree in dry cultivars or manually dried

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under sun). Markhand *et al.* [10] mentioned that dates belong to soft type are consumed at khalal stage contain low tannins and sweet taste whereas semi-dry and dry varieties are mostly consumed at tamar stage. Ismail *et al.* [11] reported that dates are consumed frequently at rutab and tamar stages. Baliga *et al.* [12] mentioned that shape and organoleptic characteristics of dates categorize different date varieties. According to Al-Jasass *et al.* [13] colour of dates is important feature, which helps the consumers in selection of dates quality. Additionally, physical properties of dates are key aspects in determination of dates quality based on colour, shape, size and texture, while nutrient content analyses can be assessed with biochemical analyses and assessment of organoleptic characteristics are one of the key factors. Previous studies reported significant variations in fruit colour occur throughout different fruit growth stages in different kinds of date varieties [14]. Physical evaluation (flesh weight and seed weight, length and diameter) of fruits vary significantly from one variety to another often used as criteria helping the suppliers in sorting and grading of dates [15]. The intake of dates in the daily diet may reduce the risk of several chronic diseases like diabetes, cancer and cardiovascular diseases [16]. Al-Mamary *et al.* [17] described that dates retain some biological activities including anticarcinogenic, anti-inflammatory, and antioxidant. In food industries immediate analysis is generally carried out, with regard to food grading to identify biochemical constituents in each category of fruits [18]. Likewise, the concentration analysis of total soluble solids can be identified in fruit juices, which can help to know total soluble sugars (glucose, fructose and sucrose) with other soluble compounds, i.e., minerals and pectin. Identification of biochemical compounds in the dates is of great importance for food industries, ultimately enhance demand of foods in the markets. Carbohydrates are the major components of dates at tamar stage, therefore are the major source of calories, generally in the form of simple sugars, while proteins present in dates provide a little amount of calories. Currently, in fulfilling the demands and preferences of consumers in selecting food and food products that possess health protecting effects, knowledge regarding the type and concentration of health protective compounds available in food is crucial. Present study described the fruit morphology and biochemical constituents of three

elite exotic cultivars (Ajwa, Safawi and Ruthana) originally belongs to Saudi Arabia cultivated in district Khairpur, Pakistan. Study confirmed that exotic cultivars of date palm showed acceptable fruit size and food grade compounds beneficial for human health as a source of daily diet, hence the date cultivars can be introduced in the area for commercial cultivation and production.

## 2. MATERIALS AND METHODS

### 2.1. Morphological Attributes of Fruits

Fruits were collected at four different fruit growth stages (kimri, khalal, rutab and tamar) from the fifteen years old trees cultivated at Shah Abdul Latif University, Khairpur (latitude 27.490418° N, longitude 68.761593° E). Vernier Caliper was used to measure length and diameter of whole fruits and seeds according to procedures of Moustafa *et al.* [19] at four different growth stages (kimri, khalal, rutab and tamar) as fruit colour, fruit length, fruit diameter, fruit weight, pulp ratio, seed length, seed diameter, seed weight. Fruits were weighed using an analytical balance. All measurements were taken as an average of 10 randomly picked fruits and their seeds.

Pulp/fruit ratio (PFR) was recorded using formula:

$$PFR = \frac{PW}{FW} \times 100$$

Seed weight (*SW*) was taken using formula:

$$SW = FW - PW$$

Where *FW* and *PW* are fruit and pulp weights, respectively.

### 2.2. Chemical Analysis of Fruits

Chemical characteristics of fruits, i.e., moisture percentage, total soluble solids, pH and total sugars (reducing and non-reducing) were identified at four different fruit growth stages as per method suggested by Association of Official Analytical Chemists (AOAC) [20]. A Spectrophotometer was used to identify biochemical constituents in the fruit samples. Fresh fruits were chopped into small pieces and put in hot air oven at 60 °C for 48 hours until it reached to a constant weight. Dried fruit samples were further divided into small pieces and grinded with mortar and pestle. A solution of fruit sample

was prepared by adding 800 ml of water and 300 g of dates' paste, filtered and subjected to analysis of pH, TSS, TS, RS and NRS. Moisture content was identified according to following formula:

$$\text{Moisture \%} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Total weight}} \times 100$$

### 2.3. Statistical Analysis

Three varieties were used in this study. Fruits were collected at four different growth stages (kimri, khalal, rutab and tamar). Data were analyzed using Completely Randomized Design (CRD) and two-way analysis of variance (ANOVA) was performed. Each treatment contained three replicates and each replicate was consisted of 10 randomly picked fruits for each replicate of each fruit growth stage. Comparison of mean values in columns was obtained with LSD at 5% using Statistix software.

## 3. RESULTS AND DISCUSSION

### 3.1. Morphological Attributes of Fruits at Different Growth Stages

#### 3.1.1. Kimri stage

Kimri is the second fruit growth stage after hababouk which lasts for longest period during fruit growth. Ajwa, Safawi and Ruthana were green at kimri stage (Figure 1a, 1b, 1c), however colour

of the fruits slowly turned into a characteristic fruit colour at khalal and tamar stages. Results obtained with two-way-ANOVA showed significant effect of growth stage ( $< 0.0001$ ), variety ( $< 0.0001$ ), whereas combined effect of growth stage and variety was non-significant for seed length (0.9972 cm) and seed weight (0.6461 g). Data in Table 1 show that at kimri stage significantly highest fruit length (4.5 cm) was observed in cv. Safawi followed by Ruthana (4.0 cm) and Ajwa (3.2 cm). Ajwa dates exhibited significantly highest fruit diameter (2.4 cm) followed by Safawi (2.3 cm) and Ruthana (2.2 cm). Fruit weight (15.8 g) was noted as significantly highest in cv. Safawi followed by Ruthana (10.2 g) and Ajwa (8.2 g). Comparing the seed length, seeds of cvs. Safawi and Ruthana were equal in length however vary in diameter. Fruits at kimri stage remain green, hard and generally inedible for all date varieties studied; however, fruits in this stage exhibited rapid growth. Al Udhaib [21] noted average fruit length (27.5 mm) and average weight (5.8 g) at kimri stage. Tafti and Fooladi [22] observed rapid fruit growth at kimri stage (90% weekly growth) gradually decreased to 20% at late kimri stage. Abdul-Hamid *et al.* [23] reported significant differences among dates with regard to dimensions particularly for cv. Ajwa which is among elite cultivars, had smallest fruit size (14.6 mm diameter and 26.4 mm length respectively). Dimensions (length, width, thickness) of date fruit were 34.45 mm, 17.52 mm and 16.80 mm, respectively at kimri stage [24].

**Table 1.** Morphological Characterization of fruits of Ajwa, Safawi and Ruthana at different growth stages (kimri, khalal, rutab and tamar).

Growth Stage	Cultivar	FL (cm)	FD (cm)	FW (g)	F/PR (%)	SL (cm)	SD (cm)	SW (g)
Kimri	Ajwa	3.2 ± 0.11 <sup>d</sup>	2.4 ± 0.1 <sup>bc</sup>	8.2 ± 0.18 <sup>g</sup>	87.8 ± 0.2 <sup>g</sup>	1.9 ± 0.1 <sup>c</sup>	0.7 ± 0.08 <sup>abc</sup>	1 ± 0.08 <sup>a</sup>
	Safawi	4.5 ± 0.11 <sup>b</sup>	2.3 ± 0.1 <sup>bc</sup>	15.8 ± 0.18 <sup>b</sup>	93 ± 0.2 <sup>a</sup>	2 ± 0.1 <sup>bc</sup>	0.9 ± 0.08 <sup>ab</sup>	1.2 ± 0.08 <sup>de</sup>
	Ruthana	4.0 ± 0.11 <sup>c</sup>	2.2 ± 0.1 <sup>cd</sup>	10.2 ± 0.18 <sup>f</sup>	87.2 ± 0.2 <sup>h</sup>	2 ± 0.1 <sup>bc</sup>	1 ± 0.08 <sup>a</sup>	1.3 ± 0.08 <sup>d</sup>
Khalal	Ajwa	3.4 ± 0.11 <sup>d</sup>	3.0 ± 0.1 <sup>a</sup>	15.2 ± 0.18 <sup>c</sup>	90.7 ± 0.2 <sup>d</sup>	2 ± 0.1 <sup>bc</sup>	0.9 ± 0.08 <sup>ab</sup>	1.4 ± 0.08 <sup>cd</sup>
	Safawi	5.4 ± 0.11 <sup>a</sup>	2.4 ± 0.1 <sup>bc</sup>	20.2 ± 0.18 <sup>a</sup>	90.2 ± 0.2 <sup>e</sup>	2.2 ± 0.1 <sup>bc</sup>	0.8 ± 0.08 <sup>abc</sup>	1.6 ± 0.08 <sup>cd</sup>
	Ruthana	4.1 ± 0.11 <sup>c</sup>	2.3 ± 0.1 <sup>bc</sup>	13.2 ± 0.18 <sup>d</sup>	85.6 ± 0.2 <sup>i</sup>	2.1 ± 0.1 <sup>abc</sup>	0.8 ± 0.08 <sup>abc</sup>	1.9 ± 0.08 <sup>a</sup>
Rutab	Ajwa	3.5 ± 0.11 <sup>d</sup>	3.0 ± 0.1 <sup>a</sup>	15 ± 0.18 <sup>c</sup>	91.3 ± 0.2 <sup>c</sup>	2.1 ± 0.1 <sup>abc</sup>	0.8 ± 0.08 <sup>abc</sup>	1.3 ± 0.08 <sup>d</sup>
	Safawi	5.5 ± 0.11 <sup>a</sup>	2.5 ± 0.1 <sup>b</sup>	20 ± 0.18 <sup>a</sup>	92 ± 0.2 <sup>b</sup>	2.3 ± 0.1 <sup>a</sup>	0.5 ± 0.08 <sup>d</sup>	1.6 ± 0.08 <sup>bc</sup>
	Ruthana	4.1 ± 0.11 <sup>c</sup>	2.4 ± 0.1 <sup>bc</sup>	13 ± 0.18 <sup>d</sup>	85.3 ± 0.2 <sup>i</sup>	2.2 ± 0.1 <sup>bc</sup>	0.8 ± 0.08 <sup>abc</sup>	1.9 ± 0.08 <sup>a</sup>
Tamar	Ajwa	3.4 ± 0.11 <sup>d</sup>	2.8 ± 0.1 <sup>a</sup>	13 ± 0.18 <sup>d</sup>	90 ± 0.2 <sup>e</sup>	2.1 ± 0.1 <sup>abc</sup>	0.7 ± 0.08 <sup>abc</sup>	1.3 ± 0.08 <sup>d</sup>
	Safawi	5.4 ± 0.11 <sup>a</sup>	2.0 ± 0.1 <sup>d</sup>	14.8 ± 0.18 <sup>c</sup>	89.1 ± 0.2 <sup>f</sup>	2.3 ± 0.1 <sup>a</sup>	0.5 ± 0.08 <sup>d</sup>	1.6 ± 0.08 <sup>bc</sup>
	Ruthana	4.0 ± 0.11 <sup>c</sup>	2.2 ± 0.1 <sup>cd</sup>	11.3 ± 0.18 <sup>e</sup>	84 ± 0.2 <sup>j</sup>	2.2 ± 0.1 <sup>bc</sup>	0.6 ± 0.08 <sup>cd</sup>	1.8 ± 0.08 <sup>ab</sup>
Variability		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
GS		< 0.0001	0.0005	< 0.0001	< 0.0001	0.0238	0.0017	< 0.0001
V		< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0600	0.0931	< 0.0001
GS × V		0.0023	0.0372	< 0.0001	< 0.0001	0.9972	0.0537	0.6461

GS = Growth Stage, V = Variety

### 3.1.2. Khalal stage

Khalal is the third fruit growth stage after hababouk and kimri, this is distinguished with appearance of a particular fruit colour (yellow or red) based on variety types (Figure 1d, 1e, 1f). Data presented in Table 1 show that fruits of Ajwa and Safawi at khalal stage were red coloured while fruits of cv. Ruthana were yellow. Fruit length significantly increased at khalal stage compared to kimri stage in cvs. Safawi (5.4 cm) followed by Ruthana (4.1 cm) and Ajwa (3.4 cm). Comparing the fruit diameter among studied cultivars at khalal stage, cv. Ajwa revealed with significantly larger fruit diameter (3.0 cm) followed by cvs. Safawi (2.4 cm) and Ruthana (2.3 cm). Fruit weight increased significantly at khalal stage in cv. Safawi (20.2 g) followed by Ajwa (15.2 g) and Ruthana (13.2 g). Seed length, seed diameter and seed weight of studied cultivars similarly increased at khalal stage. Most of the growth of fruits is completed at khalal stage, and after khalal stage fruit dimensions are also increased significantly compared to kimri stage. Different reports [25, 26] mentioned that kimri stage is followed by khalal stage, at which a significant change in fruit colour occurs from green to yellow or red depending on date varieties, and simultaneously length and width of fruits were also increased and average weekly growth was reduced slowly at late khalal stage while average fruit weight was increased due to increase in sugar content. Al-Jasass *et al.* [13] observed the several colours of different Moroccan dates at edible khalal stage. Biglari *et al.* [27] observed that the difference in colours of the dates is mainly due to genetic variations resulting in the development of characteristic colour pigments. Several pigments (chlorophylls, carotenoids, and anthocyanins) are responsible for green, yellow, and red colours in date fruits at khalal stage, respectively [28]. Usually, at khalal stage the fruit dimensions were significantly highest [29]. Several studies done on dates in Tunisia [30] and Iran [31] observed significant increase in fruit dimensions at khalal stage.

### 3.1.3. Rutab stage

Rutab stage of dates is obtained before harvesting and is distinguished by gradual conversion of khalal into tamar while the dates are attached in bunch on

the tree (Figure 1d, 1e, 1f). Physical observations of fruits showed that colour of one half of the fruits of cvs. Ajwa and Safawi remained red and of Ruthana remained yellow at edible rutab stage while another half of the fruits acquired characteristic colour of tamar stage (brown, black or dark brown). Measurement of fruit dimensions presented in Table 1 at rutab stage revealed that significantly larger fruit length (5.5 cm) was observed in cv. Safawi followed by Ruthana (4.1 cm) and Ajwa (3.5 cm). Fruit weight declined at rutab stage was observed due to a significant decline in moisture content in cv. Safawi (20.0 g) followed by cv. Ajwa (15.0 g) and Ruthana (13.0 g). Seed length enhanced in all cvs whereas seed diameter of cv. Safawi decreased at rutab stage. Highest seed weight (1.9 g) was noted in cv. Ruthana at rutab stage followed by Safawi (1.7 g) and Ajwa (1.4 g). Dates at rutab stage turn brown or black slowly from one side, becomes soft, and severe fruit taste due to high concentration of tannins is changed to sweet taste due to increase in sugar content in the fruits [21]. Al-Shahib and Marshall [26] reported that fruits at khalal stage can be harvested and stored in low temperatures to avoid spoilage. According to Ahmed *et al.* [32] the appropriate fruit harvesting stage is rutab compared to khalal stage to avoid fruit ripening failure; however, if the fruit is harvested at khalal stage, consume more time to dry, simultaneously major quantity of dates turns into inferior quality during drying process. At khalal stage significantly highest fruit weight was due to high moisture content, which decreases slowly till tamar stage and results in low fruit weight [33]. Fruit size (except width) is reduced at rutab and tamar stages [24]. Similarly, Tafti and Fooladi [22] observed differences in fruit weight and dimensions during ripening stage in cv. Shamsaei.

### 3.1.4. Tamar stage

Final stage of fruit growth is tamar stage obtained either on the tree (in dry date varieties) or through drying the dates under sun or in artificial dehydrators. Data in Table 1 show that colour of the fruits of Ajwa and Safawi was black whereas colour of fruits of cv. Ruthana was brown at edible tamar stage. Results showed that fruit dimensions significantly decreased at tamar stage in all date varieties due to a significant decrease in moisture content. The largest fruit length (5.4 cm) was noted



in cv. Safawi followed by Ruthana (4.0 cm) and Ajwa (3.4 cm). Fruit diameter of cv. Safawi (2.0 cm) decreased significantly followed by Ajwa (2.8 cm) and Ruthana (2.2 cm). Similarly, there was a significant decrease in fruit weight compared to rutab stage, it was observed in cv. Safawi (14.8 g) followed by cvs. Ajwa (13.0 g) and Ruthana (11.3 g). Seed length measured in cvs. Safawi (2.3 cm) as largest value, Ruthana (2.2 cm), Ajwa (2.1 cm). Seed diameter and seed weight similarly decreased in all studied cultivars compared to previous rutab stage. Asif *et al.* [34] described measurements of Saudi Arabian date cultivars Ajwa and Safawi without indicating fruit growth stage as fruit length (2.89 cm and 4.02 cm) width (2.17 cm and 2.17 cm), weight 10.39 g and 9.76 g, pulp weight (9.25 g and 8.86 g), seed weight (1.14 g and 0.90 g), respectively. Gasim [35] recorded fruit dimensions at tamar stage in cvs. Ajwa and Safawi as fruit length (3.07 cm and 4.07 cm), width (2.21 cm and 2.45 cm), weight (8.24 g and 9.46 g), seed weight (0.97 g and 1.0 g), respectively. Haider *et al.* [29] described that fruit and pulp weight (5.01 g – 13.40 g) and (4.18 g – 12.33 g), respectively, decrease significantly from khalal to tamar stage was observed in certain cultivars of date palm and in addition, dimensions of dates were also reduced from 1.73 cm – 1.20 cm length, 0.63 cm – 0.38 cm

width. Phenological characters are supporting in the studies of different fruit maturation stages and fruit shelf life and useful in sorting, grading, and processing [36]. Dates become brown at tamar (if fruit colour was yellow at khalal stage) or black or dark brown (if fruit colour was red at khalal stage) and the skin is soft in moist dates and hard in dry dates obtained from the trees growing in different soil types and climatic conditions. Similarly, fruit weight continues to reduce if the harvesting is delayed.

## 3.2. Biochemical Analysis of Fruits at Different Growth Stages

### 3.2.1. Kimri stage

Kimri stage is characterized by green colour of the dates (Figure 1a, 1b, 1c), occurrence of high tannins, high moisture and decreased sugar content, acidic pH, therefore fruit remain inedible during kimri stage. Results obtained with two-way-ANOVA showed significant effect of growth stage ( $<0.0001$ ), variety ( $<0.0001$ ), whereas combined effect of growth stage and variety was non-significant for pH (0.4094). Data presented in Table 2 show that significantly highest moisture content was noted in cv. Ruthana (86.2%) followed by Ajwa (80.2%)



**Fig. 1.** Fruits of cvs. (a) Ajwa (b) Safawi (c) Ruthana at kimri stage, (d) khalal, rutab and tamar stage of cv. Ajwa, (e) khalal and rutab stage of cv. Safawi, (f) khalal and rutab stage of cv. Ruthana.

and Safawi (78.1%). Highest pH value at kimri stage was observed in cv. Ruthana (3.5) followed by Safawi (3.4) and Ajwa (3.2). Total soluble solids were higher in the fruits of cv. Safawi (9.7%) followed by Ajwa (9.2%) and Ruthana (8.2%). Total sugars (reducing and non-reducing) were higher in Ruthana (9.0%) followed by Safawi (8.9%) and Ajwa (7.8%). Khodabakhshian and Khojastehpour [24] observed 84% moisture content, 9.82% TSS, 3.15 pH of dates at kimri stage. Myhara *et al.* [37] described that severe flavor of date fruit at kimri stage is due to the presence of tannins, which decreases at ripening stage (khalal) and almost vanishes at tamar stage.

### 3.2.2. Khalal stage

The percentage moisture content of fruits of all studied cultivars decreased gradually while the fruits reached at khalal stage and acquired a particular fruit colour (yellow or red) (Fig. 1d, 1e, 1f). Soft type date varieties are edible at khalal stage due to occurrence of high sugar content and low tannins which make the fruit edible. Results showed that significantly highest moisture content percentage was noted in cv. Ruthana (56.7%) followed by cvs. Ajwa (55.6%) and Safawi (51.2%). Comparing the percentage of moisture content at khalal stage with kimri stage, the moisture content was decreased to 30% – 36% once the fruit acquired yellow or red colour depending on the type of date variety. Highest pH value was noted in cv. Safawi (3.8) followed by Ruthana (3.7) and Ajwa (3.6). Total soluble solids increased at khalal stage in the fruits of all cultivars compared to kimri stage. Results showed that highest total soluble solids were observed in cv. Ruthana (14.2%) followed by cv. Ajwa (13.2%) and Safawi (12.2%). Total sugars (reducing and non-reducing sugars) also increased at khalal stage compared to kimri stage were significantly highest in cv. Ajwa (22.5%) followed by cv. Ruthana (17.6%) and Safawi (14.5%). Conversion of khalal stage just into rutab stage in a bunch indicates full maturation of khalal stage containing proper sugar content and ready for harvesting to make tamar or Chuhara (boiled/dried dates). Dates belong to dry category are not harvested at khalal stage due to high tannins, however dates are left on the tree until reach to tamar stage on the tree. Full ripening of dates was obtained at tamar stage containing health promoting compounds. Total soluble solids (glucose, fructose and sucrose) increase at khalal

and tamar [38]. Several reports [39, 40] described that Ajwa dates are a good energy source due to high amount of glucose and fructose (reducing sugars) and low amount of sucrose (non-reducing sugars) making the dates suitable for diabetic patients. Khodabakhshian and Khojastehpour [24] observed 52% moisture content, 12.9% TSS, 3.85 pH in dates at khalal stage.

### 3.2.3. Rutab stage

Rutab stage is distinguished from khalal by gradual conversion of one side of fruits into tamar which continues until fruits convert into complete tamar if the harvesting is delayed (Figure 1d, 1e, 1f). At rutab stage, further decrease in moisture content compared to khalal was observed; however, a significant increase in sugar content, pH, total soluble solids were noted in fruits at rutab stage. Data presented in Table 2 show that significantly highest moisture content was noted in cv. Ajwa (43.5%) followed by cv. Safawi (40.4%) and Ruthana (38.7%). Highest pH value was observed in cv. Ruthana (4.2) followed by Ajwa (4.1) and Safawi (4.2). Similarly, percentage of total soluble solids increased at rutab stage compared to khalal stage was higher in cv. Ajwa (18.2%) followed by Safawi (17.1%) and Ruthana (17.0%). Significantly highest percentage of total sugars (reducing and non-reducing) was noted in cv. Ajwa (40.6%) followed by cv. Ruthana (38.5%) and cv. Safawi (36.7%). Weight of Ajwa flesh and seed increase at rutab stage and decrease during tamar stage; therefore, Ajwa dates contain 77% sugars (0.5% sucrose, 34.5% glucose and 25.6% fructose) at tamar stage compared to other date varieties [35]. Khodabakhshian and Khojastehpour [24] described the moisture content (43%), TSS (17.23%), pH (4.02) in dates at rutab stage.

### 3.2.4. Tamar stage

Tamar is the final stage of fruit growth either acquired on the tree or through drying the khalal or rutab stage dates under sun or using solar dehydrators. Tamar stage dates contain significantly lowest moisture content percentage compared to rest of the earlier fruit growth stages (kimri, khalal and rutab); however, sugar content, pH and TSS are significantly increased. Data in Table 2 show that moisture content of fruits of cv. Ruthana (24.6%) was noted as highest value among three cultivars at tamar stage followed by Safawi

(23.2%) and Ajwa (20.6%). Maximum pH value was observed in cv. Ruthana (5.2) followed by Safawi (5.0) and Ajwa (4.9). Percentage of total soluble solids were higher in cv. Ruthana (20.5%) followed by cv. Safawi (20.1%) and Ajwa (19.6%). Total sugars (reducing and non-reducing) were significantly highest in the fruits at tamar stage as noted in cv. Safawi (69.7%) followed by cv. Ajwa (68.9%) and Ruthana (63.0%). AlShwyeh and Almahasheer [41] conducted a detailed study on biochemical analysis of thirty-five Saudi Arabian date varieties at tamar stage observed highest moisture content (29.2%) per 100 g sample in cv. Safawi, whereas highest glucose content was observed in cv. Rawthanat Alqasim (83.09%). Abdul-Hamid *et al.* [23] described that at tamar stage highest moisture content (28.6%) was observed in Ajwa dates while lowest moisture content (12.6%) was observed in dates of cv. Berni. Moisture level in dates of Ajwa at tamar stage maintains fruit flesh and results in high preference of consumers [23]. Moisture content of dates at tamar stage is generally 20% or less depending on the variety. Dates with moisture content (10% to 30%) belong to semi-soft, while dates with moisture content less than 10% are included in dry category [42]. Studies done on majority of date varieties holds optimal moisture content level range from 10 – 30% [43]. Ajwa dates can be isolated from other varieties due to occurrence of higher nutritional compounds and also being preferred dates of Holy Prophet (PBUH) [44]. El-Sohaimy and Hafez [45] in a study on biochemical analysis of dates

observed 13.8% moisture and 73% carbohydrates. Khodabakhshian and Khojastehpour [24] described the moisture content (20%), TSS (19.45%), pH (4.76) in dates at tamar stage, since increase in pH was due to a decrease in hydrogen ions during ripening process. pH was increased during ripening of nine Iranian date varieties [46]. Carbohydrates content (69.7%) was observed in Safawi as highest level whereas in Ajwa amount of carbohydrates was 63.0% at tamar stage. Jamil *et al.* [47] identified similar carbohydrate levels in dates at tamar stage. Glucose level in different date varieties was observed in Rawthanat Alqasim (83.0 mg/dL), Sukari Alriyad (80.4 mg/dL), Alkhanizi (51.0 mg/dL) had maximum glucose content while, Khadri (19.7 mg/dL), Majdul Almadina (24.1 mg/dL), Shuqara (24.7 mg/dL) had the lowest [41]. Studies suggest that the dates are a good source of soluble sugars required for different metabolic reactions in the body.

#### 4. CONCLUSIONS

Morphological attributes of dates studied at different growth stages revealed that fruits of cv. Ajwa were smallest in length however fruits of cv. Safawi were the longest at rutab stage among the fruits studied. Fruit colour of all date varieties at kimri stage was green, slowly developing into red (Ajwa and Safawi) and yellow (Ruthana) at khalal stage. Fruit length, diameter and weight increased significantly from kimri to rutab stage, while at tamar stage there

**Table 2.** Biochemical analysis of fruits of Ajwa, Safawi and Ruthana at different growth stages (kimri, khalal, rutab and tamar).

G. Stage	Cultivar	MC (%)	pH	TSS (%)	TS (%)	RS (%)	NRS (%)
Kimri	Ajwa	80.2 ± 0.18 <sup>b</sup>	3.2 ± 0.19 <sup>h</sup>	9.19 ± 0.11 <sup>j</sup>	7.56 ± 0.36 <sup>j</sup>	5.29 ± 0.94 <sup>g</sup>	2.4 ± 0.13 <sup>j</sup>
	Safawi	78.1 ± 0.18 <sup>c</sup>	3.4 ± 0.19 <sup>gh</sup>	9.7 ± 0.11 <sup>i</sup>	8.89 ± 0.36 <sup>i</sup>	6.29 ± 0.94 <sup>g</sup>	2.6 ± 0.13 <sup>j</sup>
	Ruthana	86.2 ± 0.18 <sup>a</sup>	3.5 ± 0.19 <sup>fg</sup>	8.7 ± 0.11 <sup>k</sup>	8.99 ± 0.36 <sup>i</sup>	7.09 ± 0.94 <sup>g</sup>	1.9 ± 0.13 <sup>k</sup>
Khalal	Ajwa	55.6 ± 0.18 <sup>e</sup>	3.6 ± 0.19 <sup>efg</sup>	13.2 ± 0.11 <sup>g</sup>	22.5 ± 0.36 <sup>f</sup>	16.4 ± 0.94 <sup>e</sup>	6.0 ± 0.13 <sup>h</sup>
	Safawi	51.2 ± 0.18 <sup>f</sup>	3.8 ± 0.19 <sup>ef</sup>	12.2 ± 0.11 <sup>h</sup>	14.5 ± 0.36 <sup>h</sup>	14.1 ± 0.94 <sup>ef</sup>	7.4 ± 0.13 <sup>g</sup>
	Ruthana	56.7 ± 0.18 <sup>d</sup>	3.7 ± 0.19 <sup>ef</sup>	14.2 ± 0.11 <sup>f</sup>	17.6 ± 0.36 <sup>g</sup>	12.4 ± 0.94 <sup>f</sup>	5.1 ± 0.13 <sup>i</sup>
Rutab	Ajwa	43.5 ± 0.18 <sup>g</sup>	4.1 ± 0.19 <sup>c</sup>	18.2 ± 0.11 <sup>d</sup>	40.6 ± 0.36 <sup>c</sup>	29.2 ± 0.94 <sup>c</sup>	11.4 ± 0.13 <sup>e</sup>
	Safawi	40.4 ± 0.18 <sup>h</sup>	4 ± 0.19 <sup>cd</sup>	17.1 ± 0.11 <sup>e</sup>	36.7 ± 0.36 <sup>c</sup>	29.83 ± 0.94 <sup>c</sup>	10.2 ± 0.13 <sup>f</sup>
	Ruthana	38.8 ± 0.18 <sup>i</sup>	4.2 ± 0.19 <sup>c</sup>	17.0 ± 0.11 <sup>e</sup>	38.5 ± 0.36 <sup>d</sup>	26.2 ± 0.94 <sup>d</sup>	12.3 ± 0.13 <sup>d</sup>
Tamar	Ajwa	20.6 ± 0.18 <sup>l</sup>	4.9 ± 0.19 <sup>b</sup>	19.6 ± 0.11 <sup>c</sup>	68.9 ± 0.36 <sup>a</sup>	54.2 ± 0.94 <sup>a</sup>	14.7 ± 0.13 <sup>a</sup>
	Safawi	23.2 ± 0.18 <sup>k</sup>	5 ± 0.19 <sup>ab</sup>	20.1 ± 0.11 <sup>b</sup>	69.7 ± 0.36 <sup>a</sup>	56.1 ± 0.94 <sup>a</sup>	13.6 ± 0.13 <sup>b</sup>
	Ruthana	24.93 ± 0.18 <sup>j</sup>	5.2 ± 0.19 <sup>a</sup>	20.5 ± 0.11 <sup>a</sup>	63 ± 0.36 <sup>b</sup>	50.1 ± 0.94 <sup>b</sup>	12.9 ± 0.13 <sup>c</sup>
Variability		Pr > F	Pr > F	Pr > F	Pr > F	Pr > F	Pr > F
GS		< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
V		< 0.0001	0.0176	0.0009	< 0.0001	0.0010	< 0.0001
GS × V		< 0.0001	0.4094	< 0.0001	< 0.0001	0.0098	< 0.0001

GS = Growth Stage, V = Variety



was slight decrease in fruit weight and diameter due to loss of moisture content at tamar stage. Fruits of all date varieties developed acceptable size which can be utilized for commercialization by making edible tamar dates. Chemical characterization of fruits at different growth stages (kimri, khalal, rutab and tamar) showed that sugar content, pH and TSS level increased gradually from kimri to tamar stage showed acceptable food grade constituents. TS of the fruits increased significantly from khalal to tamar stage. Highest sugar content was observed at tamar stage can be utilized as a good source of human nutrition. Fruits' physical and chemical characterization studied would help the farmers to prefer the cultivation of exotic cultivars in addition to cvs. Ajwa, Safawi and Ruthana in the agro-climatic conditions of the district Khairpur, Pakistan.

## 5. CONFLICT OF INTEREST

The authors declare no conflict of interest.

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