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# TEXTURE PROFILE ANALYSIS OF DATE FLESH FOR SOME SAUDI DATE CULTIVARS

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## ABSTRACT

Texture profile analysis (TPA) parameters (i.e., brittleness, hardness, cohesiveness, elasticity and adhesiveness) were determined for eight popular cultivars of Saudi dates, namely *Bari, Khudari, Khlass, Serri, Sukkari, Suffri, Saqie,* and *NubotSaif* at the Khalal, Rutab and Tamer stages of maturity. The effects of cultivar type and maturity stage on TPA characteristics were investigated. The hardness values at the Khalalstage varied from 72.83 N (*Khudari*) to 35.34 N (*Suffri*). The cohesiveness values ranged from 0.803 (*Suffri*) to 0.763 (*Khlass*). There was no adhesiveness on the surfaces of *Barhi, Serri, Sukkari, Saqie,* and *NubotSaif* cultivars at the Khalal stage, whereas the adhesiveness was very low for the other three cultivars. At the Rutab stage, a sharp decrease in hardness values was found relative to those at the Khalal stage, with values ranging from 4.632 N (*Saqie*) to 0.254 N (*Khalas*). The values for hardness, adhesiveness, gumminess, chewiness and resilience at the Khalal stage were significantly higher than the values at the other two maturity stages.

**KEYWORDS:** Texture Profile Analysis, Date Flesh, Date Cultivars, Maturity Stage, Brittleness

## INTRODUCTION

The date palm (*Phoenix dactylifera* L.) is one of the oldest fruit trees in the world and has been closely associated with the sustenance and culture of the people in the Middle East, including the Kingdom of Saudi Arabia, since ancient times. The date fruit is a good source of fiber, carbohydrates, minerals and vitamins, and it also has anti-mutagenic and anti-carcinogenic properties (Mohamed, 2000; Vayalill, 2002; Al-Farsi, 2005; Ishurd& Kennedy 2005; Baloch *et al*., 2006). Different varieties of dates vary considerably in their chemical and mechanical properties, which have a major influence on their structural, sensory and texture characteristics (Rahman & Al-Farsi, 2005).

Considering the increasing cultivation and surplus date production in the Kingdom, there is an emphasis on exportation, for which ascertaining the quality of date cultivars is crucial. Defining the fruit characteristics of major Saudi Arabian date cultivars will ensure that the cultivar is protected. International standards for the export of dates also demand homogeneity in color, size and texture (Al-Abdoulhadi *et al*., 2011).

The mechanical properties of agricultural materials and food in general play an important role in the harvesting, handling, trading, processing, quality control and development of new products. Mechanical properties are considered to be one of the four most important parameters that reflect the quality of the food material (Bourne, 2002). These parameters include texture, firmness and chew ability. Texture can be influenced by many factors, including the moisture content and water activity in addition to the chemical composition.

Texture in fruits depends on several anatomical features, such as tissue layers and cell size, resulting in a combination of different sub-phenotypes, such as firmness, mealiness, gumminess and juiciness. Firmness, far, is

determined mainly by the skin cell size and the shape of the underlying pericarp cell layers (Klima Johnson *et al*., 2011). Fruit texture is related to the cell wall structure and to the architectural changes occurring during the development and ripening phases (Costa *et al*., 2011; Giongo *et al*., 2011).

For dates, the absence of scientific information on fundamental mechanical properties has a significant impact on quality during manufacturing (e.g. distorted and injured tissues) and also during handling and treatment, which affects the stability and quality during storage and marketing. To ensure access to optimized conditions for the design and operation of handling, processing and manufacturing steps; the mechanical properties of dates must be identified (Messina and Jones, 1990).

Determination of the mechanical properties of dates, including textural profile analysis, has many benefits; standard specifications and quality control of dates based on their mechanical properties can be developed to enhance their marketing sector both locally and internationally. Direct applications of these mechanical properties include the design of systems and mechanisms for harvesting, handling, processing and manufacturing dates on well-established engineering bases, as well as the design of systems for compressing and stoning of dates. Additionally, by obtaining knowledge of textural properties, it is possible to design and select appropriate systems for the production of date paste at a continuous level and to identify the textural properties of date pastes, which in turn helps in the design of systems that use date paste in the bakery and food industries.

The mechanical properties of foods, which govern the appropriate selection of the method and device used for testing, can be divided into the basic properties of brittleness (fracturability), hardness (firmness), cohesiveness and elasticity (springiness) and adhesiveness, as well as the secondary (derivative) properties of chewiness and gumminess (Szczeniak, 1966).

Much research has been published on the texture of many food products, such as meat and dairy products and most types of fruit and vegetables, but very few reports are available on the texture of dates. The firmness of dates as a function of maturity has been studied (My hara *et al.,* 2000). At 103 days after pollination, the force required to penetrate the dates was $186 \times 10^4$ Pa. As the dates matured, this firmness decreased to $53.6 \times 10^4$ Pa at 152 days after pollination (corresponding to the Rutab stage of maturity). Immediately after the Rutab stage, the firmness increased temporarily to $89.8 \times 10^4$ Pa before reaching a minimum of $28.2 \times 10^4$ Pa at 170 days after pollination. Instrumental texture profile analysis (TPA) for date flesh was performed as a function of moisture content (Rahman and Al-Farsi, 2005). Although various uses for dates have been realized, pertinent data on the design of systems and mechanisms for harvesting, handling, processing and manufacturing dates are lacking. Thus far, there seems to be limited research on the mechanical properties of dates, including textural profile. Therefore, the present study was undertaken to determine some of the basic properties of the textural profile (brittleness, hardness, cohesiveness, elasticity and adhesiveness) beside with the secondary (derivative) properties (chewiness and gumminess) for eight popular Saudi date cultivars and to study the effects of the various cultivar types on the textural profile in addition to test the effects of various maturity stages (Khalal, Rutab and Tamer) on the textural profile.

## MATERIALS AND METHODS

### Sample Preparation

Eight popular Saudi date cultivars at the Khalal, Rutab and Tamer stages of maturity, *viz. Barhi, Khudari, Khlass,*

*Serrie, Sukkari, Suffri, Saqie and NubotSaif*, were used in all experiments. The dates were obtained from the educational farm of King Saud University. Dates were sorted to discard the damaged fruits, and immediately kept for less than 24 h in a cold store at 5 ºC. The moisture content in the flesh of dates was determined using AOAC procedures (AOAC, 1995), where the samples were dried at 70 ºC for 48 h under a vacuum of 200 mmHg (Vacutherm model VT 6025, Heraeus Instrument, D-63450, Hanauer, Germany).

### Instrumentation

A texture analyzer (TA-HDi, Model HD3128, Stable Micro systems, Surrey, England), together with a 75-mm-diameter disk plunger (# P 75), was used to conduct stress relaxation tests. The texture analyzer was interfaced with an IBM-compatible PC and a software package called Texture Expert Exceed, version 2.05, that was supplied by the same company. This package enabled the acquisition of data in Excel format. The software can determine the gradient of the curve between any two specified locations and the area under the curve. All experiments were conducted at room temperature (23°C). The instrument was calibrated with 50-100 kN force with a linearity better than 1%.The contact area between the plunger disk surface and each tested fruit surface was determined experimentally.

### Textural Profile Analysis Test

The experiments were conducted using the whole fruits of the eight cultivars, which were placed horizontally at the three stages of maturity. The force was measured by Compacting the sample with a rod velocity of 1.5 mm/s to a depth of 5 mm. The compression process included two bites to obtain the TPA properties, which included basic properties (hardness, cohesiveness, elasticity and adhesiveness) and secondary properties (chewiness, gumminess and resilience).

### Statistical Analysis

All needed statistical analyses were performed using the IBM SPSS software package (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0 Armonk, NY: IBM Corp.).

## RESULTS AND DISCUSSIONS

### Khalal Stage

The data obtained on the texture profile analysis properties, i.e, firmness, cohesiveness, elasticity, adhesiveness, chewiness, gumminess and resilience, for the eight date cultivars at the Khalalstage of maturity are plotted and shown in Figure 1. Similarities in the characteristics of all cultivars were observed at the Khalal stage, in addition toan absence of adhesiveness for most of them. The average firmness values ranged from 72.83 N for *Khudari* to 35.34 N for *Suffri.* For cohesiveness, the values ranged from 0.763 for *Khlass*to 0.803 for *Suffri.* No surface adhesiveness was observed for *Barhi, Seri, Sukkari, Saqie* and *NubotSaif* at the Khalalstage. Very low values of adhesiveness were obtained for the other three cultivars: 0.082, 0.064 and 0.091 (N.S) for *Khudari, Khlass,* and *Suffri*, receptively. Chewiness ranged from 50.35 N for *NubotSaif* to 25.82 N for *Suffri*. Elasticity refers to the rate thata distorted sample returns to its original state after removal of the force causing distortion. All obtained values of elasticity were high and ranged from 0.927 (92.27%) for *Seri* to 0.888 (88.8%) for *Khlass*, which indicates high elasticity for all tested cultivars at the Khalal stage. Resilience describes the way that a sample returns to its original state after distortion as a function of speed and applied force. The values or resilience ranged from 0.623 for *Sukkari*to 0.556 for *Khlass*. Brittleness was not observed forany cultivar at the Khalal stage, which indicates high elasticity at this stage of maturity under the test conditions applied.

The average values and the results of the statistical analysis of TPA properties for the eight date cultivars at the Khalal stage are shown in Table 1. There were no significant differences in firmness among all the tested date cultivars except for *Barhi* and *Suffri*, which had values of 45.41 and 35.74 N, respectively. These values were lower than those of the other six cultivars, which indicate the relative weakness of their structure at this stage of maturity. Cohesiveness was not significantly different among *Barhi*, *Khudari*, *Khlass*, *Sukkari* and *NubotSaif*, whereas a significant difference was found among *Serie*, *Suffri* and *Saqie*. Adhesiveness was low in*Khudari*, *Khlass* and *Suffri*, without significant differences among them. Elasticity values were high for all cultivars. Resilience was not significantly different between *Barhi* and *Khudari*, *Seri* and *Sukarri*, *Saqie* and *NubotSaif* and *Khlass* and *Suffri*

It should be noted that the *Barhi*cultivar at the Khalal stage is the most consumed and widespread variety because of its acceptable texture. This cultivar at this particular stage of maturity requires extensive investigation of its TPA objective characteristics and comparison with its sensory properties as a function of storage temperature (cold storage, freezing and under controlled atmospheric conditions such as different concentrations and combinations of oxygen and carbon dioxide) and conditions such as relative humidity as well as different packaging materials.

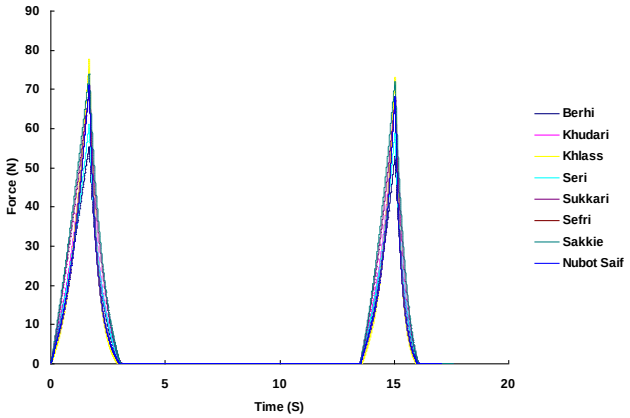


**Figure 1: Texture Profile Analysis for the Eight Date Cultivars at the Khalal Stage**

**Rutab Stage**

The textural profile analysis data of the eight date cultivars at the Rutab stage are plotted and presented in Figure 2. The obtained curves display a considerable reduction in the maximum force (firmness) for the eight date cultivars relative to that at the Khalal stage. The results also indicate variability of the firmness values, which ranged from 4.623 N for *Saqie* to 0.254 N for *Khlass* at the Rutab stage and 72.83 N for *Khudari* to 35.34 N for *Suffri* at the Khalal stage. This considerable decline in firmness is the result of major changes that occur in structural tissues during the ongoing maturation process and progression from the Khalal to the Rutab stage of maturity. The most notable changes involve the type of sugar, which changes from sucrose to fructose and glucose as a result of enzymatic activity during the maturation process. These changes soften the fruits and allow them to retain a higher percentage of water (approximately 45% of the wet weight). The changes in pectin induced by the pectinase enzyme lead to softening of the date structure at the Rutab stage relative to the Khalal stage. The soft and supple structure of many date cultivars during the Rutab stage make the fruit susceptible to distortions that result from imposed mechanical stresses.

Table (2) shows a comparison of the mean values of TPA properties for the eight date cultivars at the Rutab stage, where significant differences ($P<0.05$) were found. For firmness, the average values ranged from 4.62 N for *Saqie* to 0.254 N for *Khlass*. There were no significant differences in firmness for the *Barhi*, Seri and *Saqie*cultivars and for the *Sukkari*,

*Suffri*, and *NubotSaif* cultivars, whereas there were significant differences between these six cultivars and the *Khudari* and *Khlass* cultivars. The firmest cultivars at the Rutab stage were *Saqie*, *Seri* and *Barhi*, and the least firm cultivar was *Khlass*.

Cohesiveness was lower at the Rutab stage than the Khalal stage because of the softness of the fruits at the Rutab stage. Cohesiveness values ranged from 0.748 for Seri to 0.51 for the *Barhi* cultivar. There were no significant differences in cohesiveness values for *Khudari*, *Sukkari* and *Saqie* cultivars, whereas there were significant differences between these three cultivars and the remaining five cultivars. Adhesiveness was higher for all cultivars at the Rutab stage than at the Khalal stage. Three of the cultivars that did not exhibit any adhesiveness at the Khalal stage showed low values of adhesiveness at the Rutab stage. These cultivars are *Sukkari* (0.063 N.s), *Saqie* (0.023 N.s) and *NubotSaif* (0.037 N.s).

Chewiness property was also much lower at the Rutab stage than at the Khalal stage, as it ranged from 13.8 N for *Sukkari* to 0.395 N for *Khlass*, which clearly proves the softness of the *Khlass* variety relative to the other cultivars. This softness may add to the sweetness of *Khlass*, which characterizes this variety at the Rutab stage for most consumers in the Kingdom. The elasticity of all varieties at the Rutab stage was lower than that at the Khalal stage, except for the Seri and *Saqie*cultivars where it ranged from 0.95 for *Seri* to 0.732 for *Barhi*. The resilience of all cultivars at the Rutab stage was lower than that at the Khalal stage, where it ranged from 0.305 for *Saqie* to 0.097 for the *Barhi* cultivar.

**Table 1: Average Values of the TPA Properties of the Eight Date Cultivars at the Khalal Stage**

| Cultivar | Firmness (N) | Cohesiveness | Adhesiveness (N.s) | Chewiness (N) | Elasticity | Resilience |
|---|---|---|---|---|---|---|
| *Barhi* | $45.41^{b}\pm8.77$ | $0.773^{b}\pm0.03$ | - | $32.45^{b}\pm7.39$ | $0.913^{a}\pm0.02$ | $0.572^{bc}\pm0.04$ |
| *Khudari* | $64.69^{a}\pm8.33$ | $0.766^{b}\pm0.03$ | $0.082^{a}\pm0.008$ | $46.22^{a}\pm6.07$ | $0.918^{a}\pm0.01$ | $0.572^{bc}\pm0.03$ |
| *Khlass* | $72.83^{a}\pm6.37$ | $0.763^{b}\pm0.02$ | $0.064^{a}\pm0.008$ | $50.64^{a}\pm4.63$ | $0.888^{b}\pm0.02$ | $0.556^{c}\pm0.04$ |
| *Seri* | $69.67^{a}\pm8.80$ | $0.799^{b}\pm0.02$ | - | $50.01^{a}\pm5.61$ | $0.927^{a}\pm0.01$ | $0.613^{a}\pm0.03$ |
| *Sukkari* | $72.18^{a}\pm2.99$ | $0.778^{a}\pm0.007$ | - | $50.09^{a}\pm1.52$ | $0.926^{a}\pm0.01$ | $0.623^{a}\pm0.008$ |
| *Suffri* | $35.74^{c}\pm11.77$ | $0.803^{b}\pm0.046$ | $0.091^{a}\pm0.007$ | $25.82^{c}\pm10.24$ | $0.918^{a}\pm0.01$ | $0.557^{c}\pm0.029$ |
| *Saqie* | $67.32^{a}\pm8.62$ | $0.782^{ab}\pm0.01$ | - | $47.01^{a}\pm5.23$ | $0.913^{a}\pm0.01$ | $0.588^{abc}\pm0.04$ |
| *NubotSaif* | $65.34^{a}\pm8.41$ | $0.765^{b}\pm0.03$ | - | $50.35^{a}\pm8.49$ | $0.916^{a}\pm0.03$ | $0.601^{ab}\pm0.03$ |

*Different characters associated with the mean values for each property in each column indicate a significant difference at the 5% level (P <0.05)

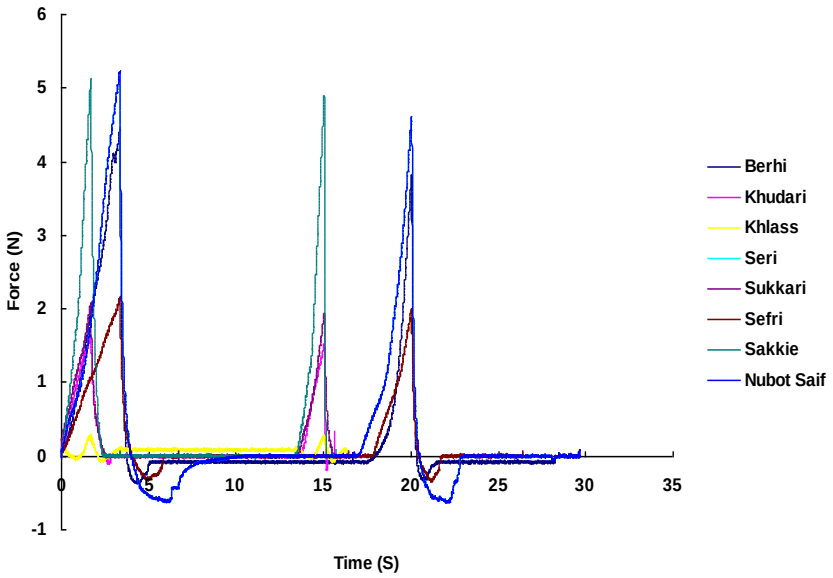


**Figure 2: Textural Profile Analysis for the Eight Date Cultivars at the Rutab Stage**

**Tamer Stage**

The textural profile analysis for the eight date cultivars at the Tamer stage is shown in Figure 3. The curves indicate the clear difference between the Tamer stage and the other two stages (Khalal and Rutab), especially for *Khudari, Sukkari, Suffri* and *Saqie* cultivars. The results obtained for this stage are more similar to those of the Rutab stage than to those of the Khalal stage. Most Saudi dates are classified as semidried at the Tamer stage; these dates pass through the Rutab stage and enter the relatively dry stage without hardening. They are characterized by a higher content of converted sugars (glucose and fructose) relative to binary sugars (sucrose), expect for the *Sukkari* cultivar, which is characterized by its higher sucrose content relative to the converted sugars. At the Tamer stage, the moisture content decreases to less than 24% (on wet basis) and the flesh becomes cohesive and wrinkled in some varieties. There is also a tendency for the fruit to be elastic, especially for cultivars with a higher converted sugar content. The outer crust may adhere to the flesh part and wrinkle and harden slightly. The mean values of TPA properties for the eight date cultivars at the Tamer stage are presented in Table 3. The firmness for five cultivars (*Khudari, Khlass, Sukkari, Suffri*and*Saqie*) was higher at the Tamer stage than at the Rutab stage.

The firmness of the remaining three cultivars, i.e., *Barhi*, *Serri* and *NubotSaif*, was lower than that at the Rutab stage. At the Tamer stage, the firmness varied from 26.44 N for *Saqie*to 2.10 N for the *Barhi* cultivar, with a coefficient of variance ranging from 26.77% for *Barhi* to 6.25% for the *Khudari* cultivar. Cohesiveness values ranged from 0.94 for *Khlass* to 0.77 for the *Suffri* cultivar, with a coefficient of variance varying from 13.1% for *Barhi* to 3.25% for the *NubotSaif* cultivar. There were no significant differences in cohesiveness values at the Tamer stage for all cultivars. Table 3 shows the absence of adhesiveness for *Khudari*, *Khalss* and *Saqie* cultivars as well as variation of adhesiveness from 2.0 N.s for *Sukkari* to 0.29 for *Suffri* for among remaining five cultivars. There were no significant differences in adhesiveness for *Barhi*, *Serri*, *Suffri* and *NubotSaif*, but significant differences in adhesiveness values were observed between these four cultivars and the *Sukkari* cultivar. The Brittleness was not present in any cultivar except *Sukkari*, in which it had a value of 0.131 N as a result of the unique structural texture at the Tamer stage arising from the high content of binary sugars (sucrose) relative to the other cultivars.

The highest chewiness was observed for *Sukkari* (28.16 N) and *Saqie* (20.40 N), whereas the chewiness of other cultivars varied from 4.568 N for *Khudari* to 1.578 N for the *Barhi* cultivar. Significant differences in chewiness values were not observed for the *Sukkari* and *Saqie* cultivars, although significant differences in chewiness were present between these two cultivars and the other six cultivars.

The results in Table 3 indicate the uniqueness of the *Sukkari* cultivar at the Tamer stage, with lower elasticity (0.689) than the other seven cultivars, i.e., 0.939 for *Seri* to 0.866 for the *Barhi* cultivar. A significant difference was present between the *Sukkari* cultivar and the other seven cultivars, thus indicating the brittle structural texture of the *Sukkari* cultivar, which also explains its lower elasticity. The resilience at the Tamer stage was similar to that at the Khalal stage and varied within the limits of 0.35 for Saqie to 0.209 for the *Khlass* cultivar. The results of the analysis of variance indicated a lack of significant differences in the resilience of *Barhi*, *Khudar*i, Khlass and *NabotSaif* cultivars and the presence of significant differences between these four cultivars and the *Seri*, *Sukkari*, *Suffri* and *Saqie* cultivars.

**Table 2: Average Values of the TPA Properties of the Eight Date Cultivars at the Rutab Stage**

| Cultivar | Firmness (N) | Cohesiveness | Adhesiveness (N.s) | Chewiness (N) | Elasticity | Resilience |
|---|---|---|---|---|---|---|
| *Barhi* | $4.131^{a}\pm1.51$ | $0.510^{c}\pm0.16$ | $0.791^{d}\pm0.22$ | $1.749^{bc}\pm0.43$ | $0.732^{d}\pm0.19$ | $0.097^{d}\pm0.02$ |
| *Khudari* | $1.526^{bc}\pm0.18$ | $0.640^{ab}\pm0.05$ | $0.643^{d}\pm0.078$ | $0.863^{bc}\pm0.15$ | $0.890^{ab}\pm0.08$ | $0.260^{ab}\pm0.044$ |
| *Khlass* | $0.254^{c}\pm0.05$ | $0.615^{bc}\pm0.17$ | $0.447^{c}\pm0.13$ | $0.395^{c}\pm0.10$ | $0.875^{abc}\pm0.10$ | $0.189^{d}\pm0.18$ |
| *Seri* | $4.456^{a}\pm1.23$ | $0.748^{a}\pm0.09$ | $0.199^{ab}\pm0.06$ | $3.03^{b}\pm0.84$ | $0.950^{a}\pm0.23$ | $0.220^{bcd}\pm0.02$ |
| *Sukkari* | $1.770^{b}\pm0.37$ | $0.674^{ab}\pm0.11$ | $0.063^{a}\pm0.01$ | $13.80^{a}\pm3.78$ | $0.875^{abc}\pm0.15$ | $0.221^{bcd}\pm0.02$ |
| *Suffri* | $1.613^{b}\pm0.30$ | $0.605^{bc}\pm0.11$ | $0.262^{b}\pm0.01$ | $0.729^{bc}\pm0.13$ | $0.770^{cd}\pm0.10$ | $0.238^{bc}\pm0.04$ |
| *Saqie* | $4.623^{a}\pm1.302$ | $0.674^{ab}\pm0.111$ | $0.023^{a}\pm0.01$ | $2.567^{bc}\pm0.82$ | $0.941^{a}\pm0.12$ | $0.305^{a}\pm0.05$ |
| *NubotSaif* | $2.686^{b}\pm1.01$ | $0.629^{abc}\pm0.09$ | $0.037^{a}\pm0.01$ | $1.183^{bc}\pm0.38$ | $0.835^{bc}\pm0.09$ | $0.194^{cd}\pm0.06$ |

*Different characters associated with the mean values for each property in each column indicate a significant difference at the 5% level (P <0.05)

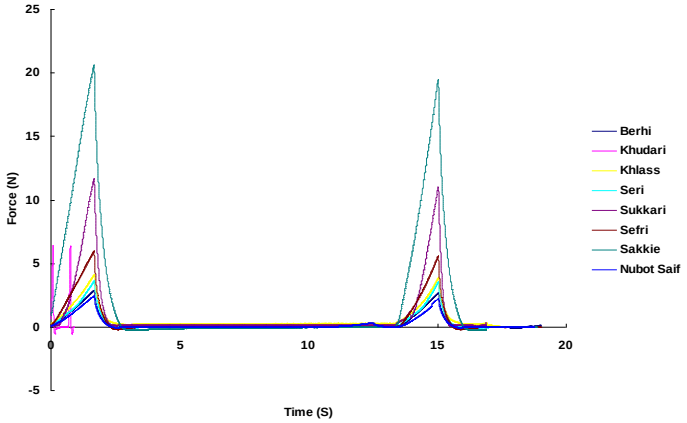


**Figure 3: Texture Profile Analysis for the Eight Date Varieties at the Tamer Stage**

**Effect of Maturity Stage on TPA Properties**

Table 4 shows a comparison of the effect of maturity stage on the TPA properties for the eight date cultivars. Significant differences (P <0.05) were observed in the firmness at the Khalal stage for all cultivars relative to the Rutab and Tamer stages. There were no significant differences in firmness between the Rutab and Tamer stage for *Barhi*, *Khlass*, *Seri*, *Sefri* and *NubotSaif* cultivars relative to the Khalal stage, whereas the Khudari, Sukkari and Saqie cultivars showed significant differences in firmness at the three stages. Cohesiveness was higher at the Tamer stage than at Khalal and Rutab stages for all cultivars expect *Sefri*. The lowest cohesiveness was observed at the Rutab stage. Only the *Khlass* cultivar did not show any significant changes in firmness values over the three stages of maturity.

**Table 3: Average Values of the TPA Properties of the Eight Date Cultivars at the Tamer Stage**

| Cultivar | Firmness (N) | Cohesiveness | Adhesiveness (N.s) | Chewiness (N) | Elasticity | Resilience |
|---|---|---|---|---|---|---|
| *Barhi* | $2.10^{d}\pm0.56$ | $0.82^{a}\pm0.105$ | - | $1.58^{b}\pm0.57$ | $0.87^{a}\pm0.07$ | $0.23^{d}\pm0.03$ |
| *Khudari* | $7.50^{c}\pm0.49$ | $0.83^{a}\pm0.07$ | - | $4.57^{b}\pm1.40$ | $0.80^{a}\pm0.09$ | $0.23^{d}\pm0.03$ |
| *Khlass* | $3.68^{cd}\pm0.78$ | $0.94^{a}\pm0.06$ | - | $2.57^{b}\pm0.74$ | $0.88^{a}\pm0.065$ | $0.21^{d}\pm0.04$ |
| *Seri* | $3.20^{d}\pm0.58$ | $0.85^{a}\pm0.031$ | $0.83^{a}\pm0.13$ | $3.55^{b}\pm1.00$ | $0.94^{a}\pm0.05$ | $0.28^{bc}\pm0.032$ |
| *Sukkari* | $15.72^{b}\pm3.90$ | $0.89^{a}\pm0.09$ | $2.00^{b}\pm0.33$ | $28.16^{a}\pm4.01$ | $0.69^{b}\pm0.06$ | $0.30^{b}\pm0.05$ |
| *Suffri* | $5.12^{cd}\pm0.92$ | $0.77^{a}\pm0.03$ | $0.29^{a}\pm0.032$ | $3.77^{b}\pm0.98$ | $0.91^{a}\pm0.02$ | $0.24^{cd}\pm0.03$ |
| *Saqie* | $26.44^{a}\pm6.29$ | $0.83^{a}\pm0.03$ | - | $20.04^{a}\pm4.37$ | $0.94^{a}\pm0.03$ | $0.35^{a}\pm0.036$ |
| *NubotSaif* | $2.36^{d}\pm0.41$ | $0.85^{a}\pm0.03$ | $0.72^{a}\pm0.10$ | $1.79^{b}\pm0.34$ | $0.93^{a}\pm0.03$ | $0.23^{d}\pm0.03$ |

*Different characters associated with the mean values for each property in each column indicate a significant difference at the 5% level (P <0.05)

There were no significant differences in adhesiveness for *Barhi* and *Suffri* cultivars at the Rutab and Tamer stages of maturity. The *Khudari*, *Sukkari* and *Saqie* cultivars exhibited significant differences inchewiness at all stages of maturity, whereas *Barhi*, *Khlass*, *Seri*, *Sefri* and *NubotSaif* showed significant differences only at the Khalal stage of maturity.

Elasticity was similar and high for the eight cultivars at all stages of maturity. There were no significant differences in elasticity at the three stages of maturity for *Khudari*, *Khlass*, *Seri* and *NabotSaifbut*. However, significant differences in elasticity existed at the Rutab stage for *Barhi* and *Suffri* cultivars, at the Tamer stage for *Sukkari* and at the Khalal stage for the *Saqie* cultivar.

There were significant differences in resilience among the three stages of maturity for *Barhi*, *Seri* and *Sukkari*. It should be noted that significant differences in resilience were present for all cultivars at the Khalal stage relative to both the Rutab and Tamer stages.

The results for each cultivar at the three stages of maturity demonstrate an obvious difference in the values of firmness, cohesiveness, adhesiveness, chewiness and resilience at the Khalal stage relative to the Rutab and Tamer stages for all eight date cultivars. This difference can be attributed to the chemical, enzymatic and structural tissue changes within the fruit during the process of maturation and the progression from the Khalal to Rutab stage, with its resultant conversions of sugars, pectin and

**Table 4: Comparison of the Mean Values of TPA Properties of the Eight Date Cultivars at Three Stages of Maturity**

| Cultivar | Maturity Stage | Textural Profile Analysis Properties | | | | | |
|---|---|---|---|---|---|---|---|
| | | Firmness (N) | Cohesiveness | Adhesiveness (N.s) | Chewiness (N) | Elasticity | Resilience |
| *Barhi* | Khalal | 45.41$^{a}$ | 0.772$^{a}$ | - | 32.452$^{a}$ | 0.913$^{a}$ | 0.572$^{a}$ |
| | Rutab | 4.131$^{b}$ | 0.510$^{b}$ | 0.791$^{a}$ | 1.749$^{b}$ | 0.732$^{b}$ | 0.097$^{c}$ |
| | Tamer | 2.097$^{b}$ | 0.817$^{a}$ | 0.848$^{a}$ | 1.580$^{b}$ | 0.866$^{a}$ | 0.226$^{b}$ |
| *Khudari* | Khalal | 64.69$^{a}$ | 0.766$^{b}$ | 0.082 | 46.22$^{a}$ | 0.918$^{a}$ | 0.572$^{a}$ |
| | Rutab | 1.526$^{c}$ | 0.640$^{c}$ | 0.643$^{b}$ | 0.863$^{b}$ | 0.889$^{a}$ | 0.260$^{b}$ |
| | Tamer | 7.504$^{b}$ | 0.830$^{a}$ | - | 4.568$^{b}$ | 0.897$^{a}$ | 0.231$^{b}$ |
| *Khlass* | Khalal | 72.83$^{a}$ | 0.763$^{a}$ | 0.064 | 50.64$^{a}$ | 0.888$^{a}$ | 0.556$^{a}$ |
| | Rutab | 0.254$^{b}$ | 0.615$^{a}$ | 0.447 | 0.395$^{b}$ | 0.875$^{a}$ | 0.189$^{b}$ |
| | Tamer | 3.678$^{b}$ | 0.935$^{a}$ | - | 2.573$^{b}$ | 0.876$^{a}$ | 0.209$^{b}$ |
| *Seri* | Khalal | 69.67$^{a}$ | 0.799$^{b}$ | - | 50.01$^{a}$ | 0.927$^{a}$ | 0.613$^{a}$ |
| | Rutab | 4.456$^{b}$ | 0.748$^{b}$ | 0.119 | 3.030$^{b}$ | 0.950$^{a}$ | 0.220$^{c}$ |
| | Tamer | 3.198$^{b}$ | 0.851$^{a}$ | 0.830$^{a}$ | 3.548$^{b}$ | 0.939$^{a}$ | 0.277$^{b}$ |
| *Sukkari* | Khalal | 72.18$^{a}$ | 0.778$^{b}$ | - | 50.09$^{a}$ | 0.926$^{a}$ | 0.623$^{a}$ |
| | Rutab | 1.770$^{c}$ | 0.673$^{c}$ | 0.063 | 13.80$^{b}$ | 0.875$^{a}$ | 0.221$^{c}$ |
| | Tamer | 15.72$^{b}$ | 0.891$^{a}$ | 2.00 | 28.16$^{b}$ | 0.689$^{b}$ | 0.297$^{b}$ |
| *Suffri* | Khalal | 35.744$^{a}$ | 0.803$^{a}$ | 0.091 | 25.82$^{a}$ | 0.918$^{a}$ | 0.557$^{a}$ |
| | Rutab | 1.613$^{b}$ | 0.605$^{b}$ | 0.262 | 0.729$^{b}$ | 0.770$^{b}$ | 0.241$^{b}$ |
| | Tamer | 5.119b$^{b}$ | 0.774$^{a}$ | 0.290 | 3.773$^{b}$ | 0.907$^{a}$ | 0.238$^{b}$ |
| *Saqie* | Khalal | 67.32$^{a}$ | 0.782$^{b}$ | - | 47.01$^{a}$ | 0.914$^{b}$ | 0.588$^{a}$ |
| | Rutab | 4.623$^{c}$ | 0.674$^{c}$ | 0.023 | 2.567$^{c}$ | 0.941$^{a}$ | 0.305$^{b}$ |
| | Tamer | 26.44$^{b}$ | 0.832$^{a}$ | - | 20.04$^{b}$ | 0.943$^{a}$ | 0.35o$^{b}$ |
| *NubotSaif* | Khalal | 65.34$^{a}$ | 0.765$^{b}$ | - | 50.35$^{a}$ | 0.916$^{a}$ | 0.601$^{a}$ |
| | Rutab | 2.686$^{b}$ | 0.629$^{c}$ | 0.037 | 1.183$^{b}$ | 0.835$^{a}$ | 0.194$^{b}$ |
| | Tamer | 2.356$^{b}$ | 0.850$^{a}$ | 0.720$^{a}$ | 1.788$^{b}$ | 0.931$^{a}$ | 0.232$^{b}$ |

Cellulose materials inside the fruit the changes that occur during the maturation of fruits from the Rutab stage to the Tamer stage are essentially linked to the change in the moisture content of the fruit, which clearly decreased over time, leading to increased elasticity of the fruit. This outcome was particularly the case for the *Khudari*, *Khlass*, *Sefri*, and *Saqie* cultivars, and the *Sukkari* cultivar had a tendency to harden and become brittle because of its higher levels of binary sugars (sucrose) compared to all of the other cultivars. This difference is reflected in the consumer acceptance of these dates, which confirms the importance of texture profile analysis as an important quality standard.

## CONCLUSIONS

The results obtained indicate higher values of firmness for five cultivars, i.e, *Khudari*, *Khlass*, *Sukkari*, *Sefri*and *Saqie*, at the Tamer stage compared relative to the Rutab stage, whereas values for the other three cultivars, i.e., *Barh*i, *Seri*, and *NubotSaif*, were lower than those at the Rutab stage. Significant differences were present in the firmness values at the Khalal stage for all cultivars relative to both the Rutab and Tamer stages. For cohesiveness, higher values were present at the Tamer stage than atthe Khalal and Rutab stages for all cultivars except *Suffri*. Significant differences in firmness, adhesiveness, resilience, chewiness and gumminess were present at the Khalal stage relative to both the Rutab and Tamer stages for all cultivars. There were also significant differences for each cultivar with regard to firmness, adhesiveness, gumminess, chewiness and resilience at the Khalal stage relative to both the Rutab and Tamer stages.

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