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Changes in Soluble Sugar Content During the Development of Fruits in Some Varieties of Omani Date Palm (*Phoenix dactylifera*)

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Abstract

The abundance of soluble sugars in six varieties of Date Palm *Phoenix dactylifera*, as well as the pattern of soluble sugar accumulation in relation to the specific stage of development, have been studied. The monosaccharide fructose was found to be the major sugar in all varieties. Total soluble sugar levels were found to increase steadily as the fruits developed. The Nighal variety had the highest sugar levels. There was a decrease in fresh weight with an increase in sugar concentration, while the absolute sugar levels were found to remain constant.

Introduction

The Date palm *Phoenix dactylifera* is a member of the family palmae and grows between latitude 10° and 35° North from the River Indies to the Canary Islands. Major production areas include Saudi Arabia, Iraq, Iran, Algeria, Egypt, Morocco, Tunisia, Libya, United Arab Emirates, Oman, and Sudan. Good quality dates are also produced in Arizona and California (USA).

Dates are a major fruit crop in the Middle East and contribute 75-80 percent of the world production. Dates are an excellent source of readily available energy, supplying around 160-230 kcal/100 g. For nomads of this region dates are staple food. Dates are usually consumed fresh after picking, especially at the khalal, and particularly ripe rutab, stages. However most dates are dried (stored) and used later during the off-season.

In Oman there are about 8 million date palm trees, occupying about 74 percent (25000 ha) of the total area of fruit trees (33772 ha) and 45 percent of the total cropped land. Trees are planted in mixed blocks of different varieties and age (Anonymous, 1989). In Oman more than 30 varieties are cultivated e.g. Barny, Bonarinja, Fardh, Hanthal, Halawy, Khalas, Khunaizi, Muznag, Nighal, Omsilla etc.

According to the stage of development the fruits can be classified into five main categories viz., Hababook or Jadal, Jamry, Bisir, Rutab and Tamr (El-Mardi *et al*., 1995).

The sugar levels are known to change during the development of the fruit and the process is generalised as maturation and ripening. Vinson and Freeman (1911) reported that the total sugars and sucrose increase with ripening and noted the rapid accumulation of total sugars and the inversion of sucrose at the later stages of development. Depending upon the type of sugars, dates can be classified into two types Sawaya *et al*. (1983).

1) Dates containing sucrose
2) Dates containing reducing sugars.

Depending on the moisture content dates can be classified into i) Dry with less than 20 percent moisture and high sucrose level, ii) Semi dry with 20-30 percent moisture and an equal quantity of sucrose and Soft with high moisture content and almost no sucrose (Hussein *et al*., 1976). Biochemically dry and semi-dry dates are considered to be immature due to the absence of the enzyme invertase, which converts sucrose into its constituent monosaccharides. Dry dates lack the enzyme invertase whereas semi-dry dates contain only small amounts of this enzyme. Soft dates contain very high levels of invertase (Mougheith *et al*., 1976; Rouhani and Bassiri, 1976).

Materials and Methods

Fruits from six varieties of date palm trees *Phoenix dactylifera* at different stages of development were collected from the college farm at Sultan Qaboos University. These varieties are Bonarinja, Fardh, Hanthal, Khalas, Khunaizi and Nighal. The stages of development are classified according to Cook and Furr (1953), Sawaya *et al*. (1983) and El-Mardi *et al*. (1995).

To extract, purify and quantify the soluble sugars in the fruit of the date palm tree, a modified procedure of McCready *et al*. (1950) and of Harborne (1991) was used. The extraction was done in 80 percent ethanol in a blender, vacuum filtered and centrifuged at 5000 g for 15 minutes. Samples of the extract were placed onto a silica gel TLC plate to separate and identify the sugars in the extract. Soluble sugars were detected after spraying with aniline: diphenylamine reagent and heating at 100°C for 5-10 minutes to obtain specific colours at fixed R, values (Harborne, 1991).

0.1 ml of extract is evaporated to dryness at 100°C and the residue was taken up in 3 ml of distilled water, layered in a boiling tube containing 6 ml of the enthrone solution in an ice bath. The tube was immediately transferred to a boiling water bath. Rapidly cooled after 10 minutes and the absorbance measured in a Spectronic 21 spectrophotometer at 600 nm. A calibration graph was constructed for soluble sugars using glucose and fructose.

Data have been statistically analysed using analysis of

variance, while linear regression was used for the construction of the calibration graph.

Results

The following is the phenotypic description of different stages in the development of date palm fruits:

Hababook or Jadal: This stage appears shortly after pollination, the 'fruit' assumes round shape, cream colour with green stripes. Relatively this is a slow stage and continues for 4-5 weeks after pollination.

Jamry: This stage is characterized by the elongation of the fruit and corresponding increase in its weight. The fruit develops green colour and has high concentration of tannin. This stage continues for about 9 weeks.

Bisir: The colour changes to yellow, red or pink. The flesh and skin are firm. There is a slow increase in the weight by the accumulation of sugars. This stage continues for 3-5 weeks or even more in some varieties.

Rutab: The fruit begins to soften at the apex and continues downwards. The fruit develops honey colour and sweet taste. Fruits of some varieties remain smooth during this stage and in others they become wrinkled due to loss of water. The stage continues for about 2-4 weeks.

Tamr: This is the final stage of maturity. In case of dry cultivars fruits become light coloured and have a hard dry skin, while in the soft cultivars the flesh remains soft and intact with a dark colour. Accordingly Tamr can be classified into three types.

Soft dates: Contain reducing sugars with very few cultivars containing sucrose.

Semi-dry dates: Contain more sucrose than reducing sugars, These consist of two parts; the part near the perianth is dry while the upper part is soft.

Dry dates: The whole flesh is solid and dry, contain relatively more sucrose than reducing sugars. Sucrose levels here are higher than semi-dry dates.
It should be mentioned at this stage that no soluble sugars were detected at the Hababook or jadal stage.

The Jamry stage: This is an early stage of development and all varieties contained only fructose. The Nighal variety contains the highest fructose levels expressed as mg g^{-1} fresh weight, which is more than five times the levels in the Bonarinja variety and nearly three times as high as the levels in the second best variety, the Khunaizi (Table 1). The differences in the levels of the other varieties were not significant.
The highest increase in weight at this stage was found in the Khalas variety, however the fructose content was low. The lowest mean fruit weight was in the Bonarinja variety so was the case with fructose. Fardh variety follows the Khalas in fruit weight while the other four varieties show a more or less similar mean fruit weight.

The Bisir stage: At the Bisir stage the only sugar present was again the ketohexoses fructose. The highest fructose levels were in Nighal variety followed by Khalas variety where as the Khunaizi which was in second place in the earlier stage displaced to fifth place (Table 1). Bonarinja variety, which contained the lowest levels in the Jamry stage, has overtaken the Fardh variety, which contained the lowest levels at this stage.
The fruit weight was highest in the Khunaizi variety followed by the Khalas variety. The variety with the smallest fruit at this stage was the Fardh. It is interesting to know that this variety also has the lowest fructose content at this stage.

The Rutab stage: The fructose levels increased sharply between the Bisir and the rutab stages (Table 1) with the highest levels in the Nighal variety, while the lowest being the Khunaizi and the Bonarinja varieties.
The Khunaizi variety had the highest mean fruit weight at this stage. Fardh and Bonarinja varieties showed the lowest fresh weight where as the other three varieties had similar fruit weight (Table 2).

The Tamr stage: Fructose was the only sugar detected in fruits of the Tamr stage of development. The fruits of the Nighal variety show the highest sugar levels, with the Khalas following very closely, but the fruits of the Fardh variety had the lowest sugar content. It is worth mentioning that at this stage there was a considerable increase in soluble sugars in all varieties, an increase of 18 to 23.50 percent over the rutab stage was detected.
At this stage fruits of the Khunaizi variety show the highest mean fruit weight, however among the other varieties there was no significant difference.

Stored Tamr: To study the effect of storage on the sugar content of the fruits, stored fruits from the previous season were used for extraction and their sugar levels determined. The Khunaizi variety has the highest sugar content. The mean fruit weight decreased significantly.

Discussion

Fruit ripening is a complex process consisting of respiratory climacteric, chlorophyll degradation, carotenoid synthesis, cell wall degradation and conversion of starch to sugars. Unlike dates from Saudi Arabia, Omani dates are of the soft type. The softening is an integral part of ripening and has a direct effect on post harvest life of fruit and its commercial value. Increase in the concentration of soluble pectic polysaccharides affects the softening. Increase in the

Table 1: Soluble sugars in fruits of different stages of development

	Jamry	Bisir	Rutab	Tamr	Stored Tamr
	9.61a	28.29	96.94	324.68	357.89
Bonarinja	27.00b	148.24	590.36	2493.54	2612.60
	0.96c	2.83	9.69	32.47	35.79
	10.54	18.32	112.05	296.75	331.86
Fardh	49.27	90.68	683.50	2196.00	2386.05
	1.05	1.83	11.21	29.68	33.19
	12.66	21.51	135.20	312.85	360.47
Hanthal	42.62	129.21	973.44	2415.20	2685.50
	1.27	2.15	13.52	31.29	36.05
	11.17	29.83	207.56	400.96	415.38
Khalas	63.70	191.51	1515.19	2947.00	2970.00
	1.12	3.00	20.76	40.10	41.54
	17.68	19.73	124.51	359.33	385.78
Khunaizi	56.75	133.18	972.42	2874.64	2912.65
	1.77	2.00	12.45	35.93	38.58
	28.36	60.75	275.00	488.53	544.40
Nighal	91.89	378.00	1988.25	3678.63	3810.80
	2.84	6.08	27.50	48.85	54.30

a = Concentration (mg g^{-1}), b = Absolute amount (mg $fruit^{-1}$), c = Content (%)

Table 2: Changes in fresh weight (g) of fruits at different stages of development

	Jamry	Bisir	Rutab	Tamr	Stored Tamr
Bonarinja	2.81	5.24	6.09	7.68	7.30
Fardh	4.68	4.95	6.10	7.40	7.19
Hanthal	3.37	6.30	7.20	7.72	7.45
Khalas	5.70	6.42	7.30	7.35	7.15
Khunaizi	3.21	6.75	7.81	8.00	7.55
Nighal	3.24	6.23	7.23	7.53	7.00

activity of polyuronide hydrolysing enzymes such as endopolygalacturonase, degradation of hemicellulose and pectin are associated with softening (Brady 1987; Huber, 1983; Paull *et al*., 1983). Nevertheless, ripening incorporates a series of independent events coordinated by system 2 ethylene, which initiates the synthesis of wall hydrolysing enzymes, which soften the wall.

Omani dates are generally smaller than dates from elsewhere in the Arabian Peninsula and contain the reducing sugar fructose as their major detectable component, while Saudi dates contained high levels of the non-reducing sugar sucrose. The absence of sucrose in Omani dates can be attributed to the high, and usually continuous, activity of the enzyme invertase, which splits the disaccharide sucrose to its constituent monosaccharides (Rygg, 1975; Al-Bakir and Whitaker, 1978). Our findings are in agreement with these results.

Fructose levels were found to increase with the increase in the fruit weight indicating that probably there was active synthesis and accumulation. However the fructose concentration appears to increase with the storage of fruits. This is probably due to the decrease in the fruit weight owing to the loss of moisture content, leading to an increase in the concentration of the sugar. Active biosynthesis of more fructose under such conditions of dryness is not expected. The decrease in the weight of the fruit accounts for the increase in the sugar concentration after the storage, nevertheless absolute sugar levels remain almost constant. Similar trends in fructose accumulation during developmental stages were reported by Vinson and Freeman (1911), Sakri *et al*. (1975), Sawaya *et al*. (1983) and Bashah *et al*. (1988).

When the comparison is made between different stages of the development. varieties responded differently. At the Jamry stage the Nighal variety had the highest fructose levels with the other varieties not significantly different from each other. The results are similar at the Bisir, rutab and Tamr stage. Tamr fruits from various varieties are usually stored for off-season consumption. But the fruits of the Nighal variety are not usually stored as Tamr. This could be due to the fact that the Nighal fruits at the rutab and Tamr stages are very rich in sugars and are therefore consumed as rutab or Tamr with little left for storing.

In all varieties the period of highest sugar accumulation occurred between the rutab and the Tamr stages, indicating perhaps high photosynthetic activity, high rate of photosynthate translocation as well as high invertase activity.

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