

## Effect of Gamma Irradiation on Anatomical Structure and Quality Attributes of Some Semi Dry Date Palm Fruits During Storage

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**Abstract:** Three semi dry cultivars of Arabian dates (Siwi from Egypt, Sukkary from Saudi Arabia and Zahidi from Iraq) were irradiated by gamma irradiation (0, 3 and 5 kGy doses) then stored for 8 months at 25±2°C. The experiment was conducted to investigate the effect of gamma irradiation on the anatomical characters, tannins contents and sensory evaluation during storage. For the three cultivars, a significant decrease was observed in flesh and dry weight during storage period. Irradiation especially at 5 kGy had a superior effect on reducing the attrition of these concern speculiarly in "Sukkary" cultivar. The rate of losing weight in unirradiated control fruits is faster than irradiated fruits. Siwi date fruit irradiated at 5 kGy showed the least significant value of weight loss percentage when compared to any treatments else. It was significantly more preferred from the panelists than the other cultivars for its freshness, color and tastes regardless the effect of irradiation. The reserve was true for irradiated Zahidi date fruits, which showed the highest significant degrees of shrink appearance. Tannins degradation was extended with advanced storage durations in the tested cultivars. These degradations were commonly induced by irradiation especially 5 kGy particularly in Siwi and Sukkary cultivars. The histological examinations revealed that no significant changes were noted in epidermis, exocarp, outer mesocarp, tannin layers, inner mesocarp and mesocarp thickness of the pericarp to the immediate effect of the irradiation dose of 5 kGy. After 8 months of storage, there was a significant decrease in the thickness of tannin layers in the three tested cultivars. This decrement was observed by cracking of tannin contents and shrinkage in cell walls of tannin layers and obviously in the irradiated fruits. Regarding to the inner mesocarp and mesocarp thickness which form the most part of the fleshy date fruits, observations showed that both of Zahidi and Sukkary cultivars recorded significant decrease in the thickness of these layers by marked obliterated and collapsed cells. The decrement was obviously recorded in the unirradiated fruits. While no significant differences were observed in Siwi cultivar. As for the irradiation treatment with 5kGy improved and reduced the amount of loss in mesocarp thickness in the tested cultivars. Siwi cultivar was less sensitive to the irradiation dose and much storable than the Sukkary and Zahidi cultivars.

**Key words:** *Phoenix dactylifera* • Semi dry fruits • Gamma irradiation • Anatomical characters • Sensory attributes

### INTRODUCTION

Date palm (*Phoenix dactylifera* L.) is marketed worldwide as an excellent source of sugars, mineral salts and vitamins fruit crop [1]. Many studies have revealed that dates have strong antioxidants, anticancer and antiviral activities [2-4]. The Arab countries produce about 73% of global production. 7.54 million Metric tons of date were produced in 2012, with the main tonnage coming from Egypt (19.47%), followed by Saudi Arabia, Iran, United Arab Emirates, Pakistan, Algeria, Iraq [5].

High losses in dates due to infestation and contamination with microorganisms either during handling or storage under unsuitable conditions were recorded by Emam *et al.* [6]. Fumigation with methyl bromide used widely with dates preservation, but it will be phased out by 2015. The need for alternative safe tool for food preservation to prolong, minimize food losses during storage has therefore become urgent. Irradiation has gained attention as an effective and safe alternative tool for assuring food safety [7]. It delays ripening, inhibits growth and sprouting, senescence, reduces spoilage and

disinfects fresh produce and extend the shelf life of many fruits [8-10]. The use of irradiation to control insects and its effects on nutrients sensory and microbial of dates has been investigated [11-13]. However, energy is imparted into metabolically alive tissues of the commodities, so undesirable damage can occur [14]. A textural change induced by irradiation is still one of the main limiting factors for its use.

Plant tissues soften with increasing doses of irradiation over critical thresholds was observed [15]. Radiation induced softening has been attributed to breakdown of cell wall constituents such as pectin, cellulose and hemicellulose and alteration of semipermeable membranes, which resulted in structural weakening and loss of turgor, respectively, in tissues [16]. The extent of the softening depends on dose levels, cultivar and storage period.

No data are available for anatomical tissues changes of semi dry date after irradiation process. Therefore, the present work introduce the histological and tannins content changes associated with some physical, sensorial attributes of three Arabic date fruits after irradiation and storage period at room temperature.

## MATERIALS AND METHODS

**Plant Material:** Three semi-dry date cultivars were selected as Siwi (Egyptian), Sukkary (Saudi Arabia and Zahidi (Iraqi). Fruit samples were getting after harvest directly from New Valley Governorate, (Egypt) whereas Saudi Arabia mature dates (Sukkary) were obtained from orchard directly near Al -Ahssa and Jaada. Whereas, Zahidi samples were imported from Iraq near Degla valley. All samples were not fumigated, collected after harvesting and sun dried completely for semi dry samples. Ten kilo gram per each cultivar were packaged in polypropylene bags and then transferred to National Centre for Radiation Research and Technology, Nasr City, Cairo for irradiation process.

**Irradiation:** The irradiation process was carried out at National Centre for Radiation Research & Technology (NCRRT). Samples were irradiated with  $\gamma$ - rays at different doses (0.0, 3.0 and 5.0 kGy) which applied for each date cultivar. The irradiation process was performed at room temperature using Gamma source, (Cobalt-60, Russian Model at dose rate  $10 \text{ kGy hr}^{-1}$ ). Each treatment represented by four replicates, each replicate was divided into two groups; the first one for the histological changes, the second for the tannins analysis and sensory evaluation (250 g/each) [9 treatments  $\times$  4 replicates  $\times$  2 groups  $\times$  250g].

**Anatomical Study:** Specimens of untreated and treated with 5.0 kGy of date palm fruits were collected to observe the histological changes by the instantaneous effect of irradiation dose (0, 5 kGy) for 0 and 8 months of storage at room temperature. Samples of pericarp were killed and fixed in FAA solution (Formalin, acetic acid and 50% ethyl alcohol, 5:5:90 by volume) for 24 h. The schedule of the paraffin method as described by Johansen [17] was followed. Serial transverse sections ( $10 \mu\text{m}$ ) in thickness were made by LEICA rotary microtome model RM 2125 RTS and fixed on slides by means of Haupt's adhesive [18]. The sections were stained with a Safranin–Fastgreen combination and then mounted in Canada balsam [18]. Observations and photomicrographs were obtained with LEICA light research microscope model DM 2500 supplied with a digital camera.

**Physical Characters:** Flesh weight/100 g: Subtraction of weighting dates before and after eliminations of seeds were calculated and considered as flesh/100g.

Dry weight: Samples were dried in an oven at  $70^\circ\text{C}$ , to a final constant weight was recorded as the dry weight [19].

Weight loss%: Fruits were weighed periodically and the loss in fruits weight was recorded for each replicate.

**Tannins Analysis:** Total tannins were determined in fruit flesh by using Folon Denes colorimetric method at 760 wave length, the concentration was calculated from a standard curve of pyrogalllic acid as mg/100g dry weight according to A.O.A.C. [19].

**Sensory Evaluation:** At the end of the storage period Larmond [20] method was used to assess the sensory characteristics of semi dried date cultivars. The following attributes: freshness, color, taste and skin shrinkage on a 5- point scale were selected to evaluate the taste and the visual appearance of the tested cultivars by 5 well trend members of National Center for Radiation Research and Technology.

**Statistical Analysis:** Data were analyzed statistically using analysis of variance (ANOVA) and differences among the means were determined for significance at 0.05 using LSD test [21].

## RESULTS AND DISCUSSION

**Anatomical Changes:** The date palm fruit is a simple, oblong, one-seeded berry with a fleshy pericarp divided into the exocarp, mesocarp and the endocarp (Fig. 1 A, B & C). The exocarp consists of 3 different types of layers;

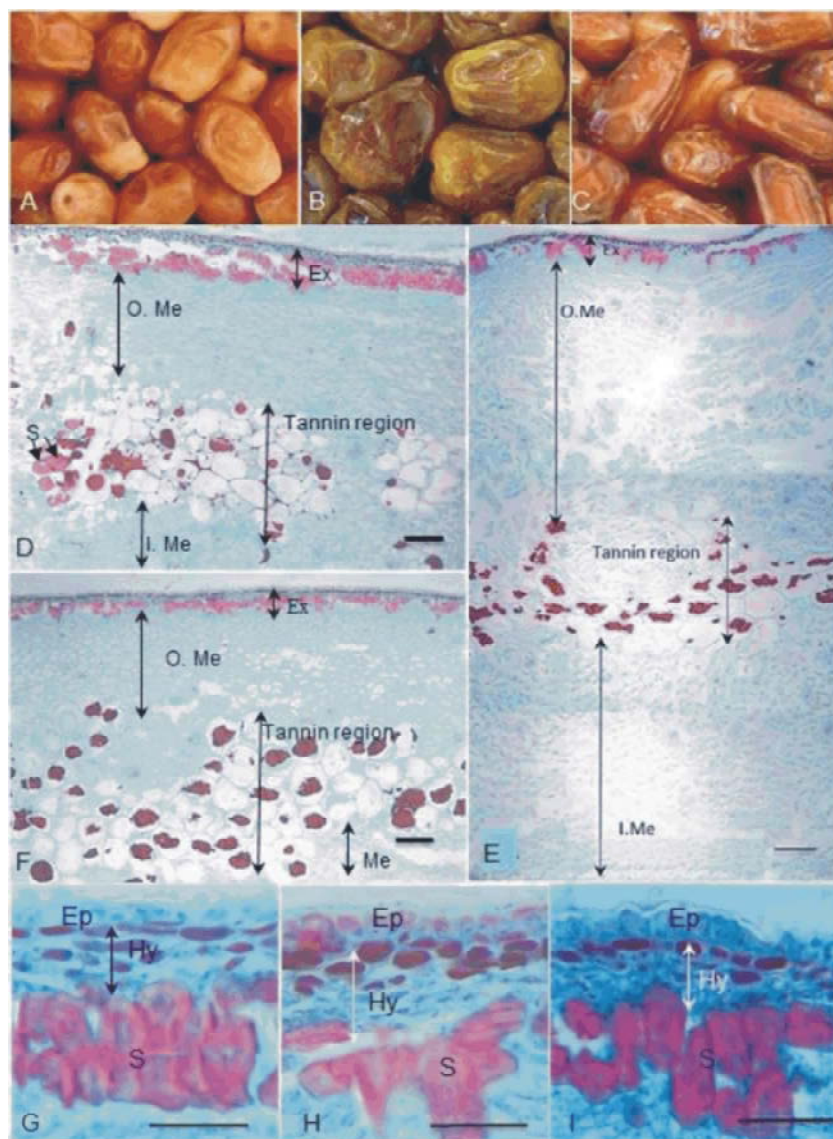


Fig. 1: A, B&C. Morphology of Arabic date fruit cultivars for marketing at tamr stage Fig. 1 A. "Zahidi" the Iraqi cultivar, Fig. 1B. "Sukkary" Saudi Arabia, Fig. 1C "Siwi" the Egyptian cultivar at zero time of storage. Figs. 1D to 1F. Light microscope micrographs of cross-sections of the pericarp of tested date fruits. Fig.1D. Zahidi cultivar, Fig.1E. Sukkary cultivar, Fig.1F. Siwi cultivar (Bar=100µm), Figures G,H &I magnified area from Figures D, E &F showed the exocarp layers in the three tested fruits (Bar=25µm). Figure abbreviations: Ex, Exocarp; O. Me, Outer-mesocarp; I. Me, Inner-mesocarp; Ep, Epidermis; Hy, Hypodermis; S, Stone cells.

the first layer is the epidermis which consists of uniseriate cells covered with cuticle. The second layer is the hypodermis and consists of 4-6 layers of parenchymatous cells some of these filled with tannins. The third and last part of the exocarp is occupied by stone cells in radial or tangential orientation. Mesocarp which consists of the most part of fruit size consists of enlarged parenchymatous cells. The mesocarp divided into outer-mesocarp and inner-mesocarp, between them there are 2-8

layers of tanniferous cells distributed around the inside surface of the outer-mesocarp in red to brown colored. Moreover, some tannin cells were shown scattered in the outer-mesocarp zone (according to the tested cultivar). The vascular system of the pericarp consisted of several collateral bundles distributed in all zones of the mesocarp. The endocarp consists of one layer of small cells which could be seen around seed cavity in early stage of fruit development (Fig. 1D, E & F).

Table 1: Anatomical characters of the studied date palm fruits

Cultivar characters	Zahidi	Sukkary	Siwi
Average thickness of epidermis and cuticle layer (μm)	15.33	18.96	22.87
No. of hypodermis layers	4-5	5-6	4-5
No. of tannin layers in hypodermis	3-4	1-3	1-2
Average thickness of stone cell layers(μm)	97-110	67-72	55-90
Maximum thickness of stone cell layers (μm)	103.05	69.43	76.39
Description of stone cell layers	Continuous	Nearly continuous	Nearly continuous
Average thickness of exocarp (μm)	146.5	166.91	115.32
Average thickness of outer-mesocarp (μm)	728.21	1596.49	504.24
Average thickness of tannins region between outer and inner-mesocarp (μm)	344.20	457.40	724.23
Average No. of tannins layers between outer and inner-mesocarp	3-6	2-8	3-6
Density and description of tannins layers between outer and inner-mesocarp	Few in each group, discontinuous	Few continuous	Medium, continuous
Average thickness of inner-mesocarp (μm)	2131.68	2686.11	1799.4
Average thickness of mesocarp (mm)	3.20	4.74	3.02

Data presented in Table (1) were obtained from cross sections of fruits of date palm cultivars. Average thickness of epidermis and cuticle layer was ranged from 15.33 μm in Zahidi cultivar to 18.96 μm in Sukkary and 22.87 μm in Siwi cultivar (Fig. 1G, H & I). Number of hypodermis layers was 4-5 layers in Zahidi, Siwi cultivars and relatively increased in Sukkary where ranged from 5- 6 layers. Number of tannin layers in hypodermis is varying from one layer to 4 layers and also in distribution sometimes appear as continuous layers, or discontinues and/or in separated cells embedding in hypodermis layers (Fig. 1 G, H & I). The highest value for maximum thickness of stone cell layers was 103.05 μm in Zahidi cultivar. The stone cells are found in continuous layers, where it appears as nearly continuous in the Sukkary and Siwi cultivars. The highest average in thickness of exocarp was recorded in the Sukkary cultivar 166.91 μm while the lowest was recorded in Siwi cultivar 115.32 μm. The highest average in thickness of outer mesocarp was recorded in Sukkary followed by Zahidi and Siwi cultivars (1596.49, 728.21 and 504.24 respectively). Average thickness of tannins region ranged between 344.20 to 457.40 and 724.23 μm in Zahidi, Sukkary and Siwi cultivars respectively.

#### **Distribution of the Tannin Region Between Outer and Innermesocarp**

**The Iraqi cultivar "Zahidi":** Tannin-containing cells spread in groups of parenchymatous cells reached 200 to 400 μm and 200 to 350 μm for tangential and radial dimension respectively. These parenchymatous groups are separate from each other by few normal parenchyma cells. Occasionally some individual tannin cells or rarely two or three were observed in the outer and inner mesocarp. Also, there were few stone cells occur on the periphery of the tannin parenchymatous groups (Fig. 1 D).

**The Saudi cultivar "Sukkary":** Tannin cells constitute a continuous zone of parenchymatous cells. This parenchymatous zone consists of 5-8 cell layers, reached about 300to 600 μm in thickness with several ridges oriented toward the outer surface. The tannin cells spread either individually or in clusters of 2 to 8 cells (Fig. 1 E)

**The Egyptian Cultivar "Siwi":** Tannin-containing cells developed in nearly continuous zone of parenchymatous cells. This parenchymatous zone consists of 3-6 layers reached about 600 to 800μm in thickness. Tannin-cells distributed in high densities to be either in individual cells or groups of 2 or 3 cells (rarely up to 5). Also, there were few individual tannin cells or in groups of 2-3 cells embedded in the outer mesocarp (Fig. 1 F)

The lowest average number of tannin layers between outer and inner mesocarp was recorded in Zahidi cultivar and the tannin cells distributed in few cells. The highest average thickness of inner mesocarp was recorded in Sukkary cultivar 2686.11μm, followed by Zahidi 2131.68μm while the lowest average was in Siwi by 1799.41μm.

Data presented in Table (2) indicated that, there are no significant differences recorded to the immediate effect of the irradiation dose 5 kGy on the following characters epidermis & cuticle, exocarp, outer mesocarp, tannin layers, inner mesocarp, mesocarp thickness of the pericarp for the Zahidi, Sukkary and Siwi date palm fruits.

Concerning the effect of the storage time (8 months) on the anatomical character of the un-irradiated and irradiated date fruits, data were shown in Table (3). There is significant decrease in the thickness of tannin layers in the three tested cultivars after 8 months at room temperature. This decrement was illustrated in (Figs. 2D & 2E) by cracking in tannin contents and shrinkage in cell walls of tannin layers and obviously in the irradiated fruits. This result matched well with the

Table 2: Immediate effect of irradiation on anatomical characters of tested semi dry dates at zero time of storage at room temperature

Layer thickness	0.0 kGy			5.0 kGy		
	I	S	E	I	S	E
Epidermis & cuticle (μm)	15.33 c	18.96b	22.87a	15.17 c	18.91b	21.21a
Exocarp (μm)	146.41ab	166.21a	115.32b	141.54ab	163.38a	118.64b
Outer mesocarp(μm)	728.22b	1596.5a	504.24c	729.75b	1512.02a	488.12c
Tannin layers (μm)	334.21c	457.41bc	724.24a	344.01c	470.81bc	628.4ab
Inner mesocarp(μm)	2131.63b	2686.11a	1791.52c	2156.24b	2550.9a	1839.4c
Mesocarp (mm)	3.20b	4.70a	3.03b	3.19b	4.53a	3.016b

Means having the same letter(s) in each row are insignificantly different at 5% level.

I= The Iraqi cultivar "Zahidi", S= the Saudi cultivar "Sukkary", E= the Egyptian cultivar "Siwi"

Table 3: Effect of irradiation on anatomical characters of tested semi dry dates after 8 months of storage at room temperature

Layer thickness	0.0 kGy			5.0 kGy		
	I	S	E	I	S	E
Epidermis & cuticle (μm)	14.59c	13.26c	18.65a	12.96c	12.79c	16.86ab
Exocarp (μm)	127.78abc	158.98a	120.06bc	118.44c	144.69ab	103.78c
Outer mesocarp(μm)	573.81b	959.73a	305.54c	616.85b	1103.32a	383.46c
Tannin layers (μm)	250.0c	380.33b	461.5a	208.2d	251.6c	390.4b
Inner mesocarp(μm)	1086.19c	1359.44b	1432.96b	1502.3b	2445.08a	1876.7b
Mesocarp (mm)	1.90c	2.70b	2.20b	3.32b	3.80a	2.75b

Means having the same letter(s) in each row are insignificantly different at 5% level.

I= The Iraqi cultivar "Zahidi", S= the Saudi cultivar "Sukkary", E= the Egyptian cultivar "Siwi"

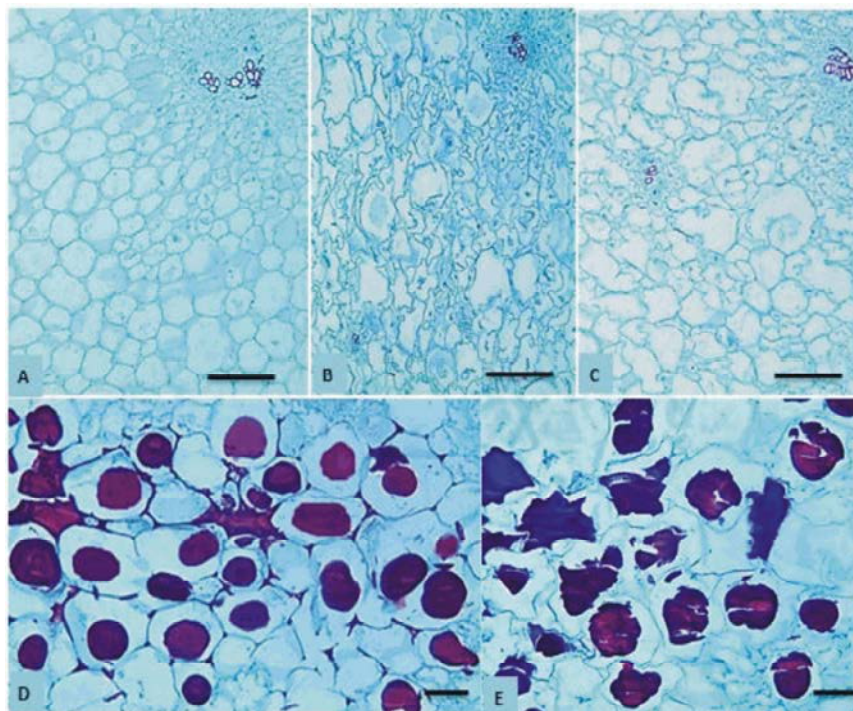


Fig. 2: Transverse section in the pericarp of the Zahidi fruits. Figs.2A&2D. Before storage, Figs. 2B,2C&2E after 8 month of storage. Fig. 2Aillustrated the regular distribution of the parenchymatous cells of the mesocarp. Fig.2B. Note the high shrinkage in mesocarplayers due to the storage time. Fig. 2C. Slight shrinkage was found inmesocarp region due the treatment with 5KGy(Bar=100μm in A, B, C).Fig. 2D. One group of parenchymatous tannin containing cells in the tannin region between the outer and the inner mesocarp layers. Fig. 2E. Note the cracking occurred in the tannin cells. (Bar=50μm in D&E)

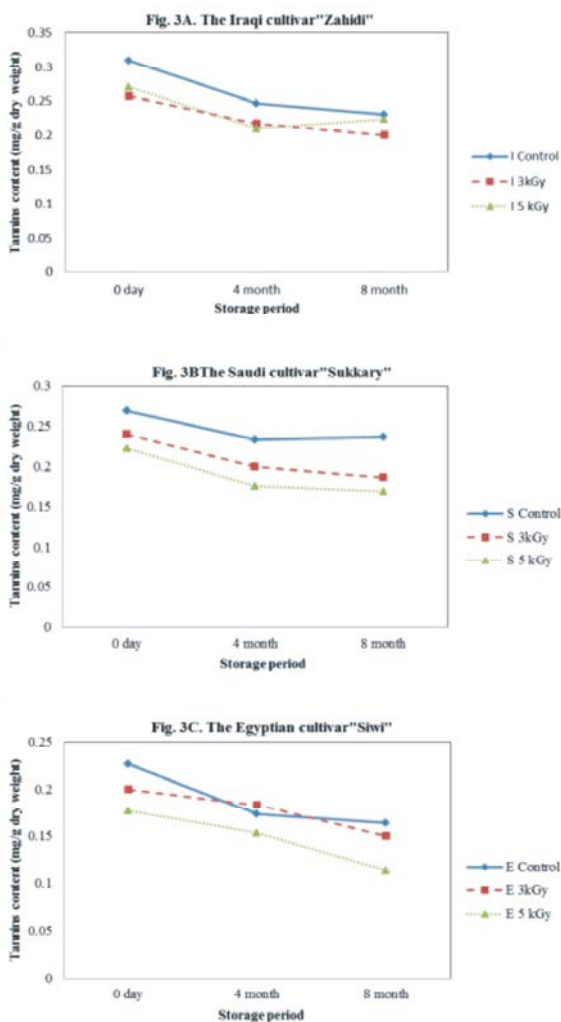


Fig. 3: Effect of irradiation on tannin content (mg/g dry weight) of date fruits during storage periods.

determination of tannins content as shown in Fig. 3 (A, B&C) and confirms the findings by Aleid *et al.* [22].

Regarding to the inner mesocarp and mesocarp thickness which form the most part of the fleshy date fruits, data showed that both of Zahidi and Sukkary cultivars recorded significant decrease (lost about 40%) in the thickness of these layers during 8 months. These results could be explained due to the enlarged, thin wall parenchyma cells of these layers and it can easily collapse, obliterated due to loss moisture with storage time (Figs. 2A, 2B&2C). The decrement was obviously recorded in the unirradiated fruits. While no significant differences observed in Siwi cultivar. It was less sensitive to the irradiation dose and much storable than the Sukkary and Zahidi cultivars.

As for the irradiation treatment with 5kGy improved and reduced the amount of loss in mesocarp thickness and record 27%, 19% and 9% for Zahidi, Sukkary and Siwi cultivars, respectively. These results matched well with the observations of Kertesz *et al.* [16], that radiation induced softening has been attributed to breakdown of cell wall constituents such as pectin, cellulose and hemicellulose and alteration of semipermeable membranes, that resulted in structural weakening and loss of turgor, respectively, in tissues. The extent of the softening depends on dose level, cultivar and storage period.

The aforementioned results are true for the tested cultivars with the data of weight loss, shrinkage degree and some sensory attributes at the end of storage period will be shown below.

Both of epidermis and outer exocarp thickness were reduced with the storage time in the tested cultivars but these decrements were not significant. This result due to the structure of these layers. The epidermis was covered with a cuticle layer, the stone cells with much thicker walls. These features can control and organize water loss through these parts of the pericarp.

**Physical Characters:** The effects of irradiation on dates Flesh weight / 100g, Dry weigh/100g and weight loss% are shown in Table (4). For the three cultivars, a significant decrease in dry weigh/100g and flesh weigh/ 100g was observed during storage period. This result is in agreement with the finding by Ismail *et al.* [23] on Bahraini date varieties and Al-Farsi *et al.* [24] on three native sun-dried date varieties from Oman. These values are in good agreement with those found by Tafti and Fooladi [25] and Amoros *et al.* [26]. Also, Amira *et al.* [27] noticed significant differences between five Tunisian varieties exist for the weights of the whole date, pulp and seed. Irradiation especially at 5 kGy had a superior effect on reducing the attrition of these concerns peculiarly in "Sukkary" cultivar. However, Fruit weight loss was increased with advanced in storage durations regardless of the cultivars and irradiation effects. This reduction was due to transpiration and water loses from fruit skin. When the fruit is harvested, it no longer depends on its root system. Therefore, water loss in fruit cannot be replaced from the root and moisture content will be reduced [28]. Furthermore, the rate of losing weight in untreated (control) fruits is faster than irradiated ones. Siwi date fruit irradiated at 5 kGy showed the least significant value of WL% when compared to any treatments else. The same result was concluded by Al-Yahyai and Al-Kharus [29] for working on date palm

Table 4: Effect of irradiation treatments on Flesh weight/ 100g, Dry weight/100g and weight loss% of the tested semi dry date fruits during storage at ambient temperature (25±2°)

Treatments	0day		4month			8 month		
	Flesh weight/ 100g	Dry weight/ 100g	Flesh weight/ 100g	Dry weight/ 100g	WL%	Flesh weight/ 100g	Dry weight/ 100g	WL%
I Control	88.6 bc	47.8 bc	83.1 cd	42.4 bc	5.7b	76.2 d	39.8 c	12.6a
I 3kGy	88.9 bc	46.2 cd	84.3 bc	42.9 bc	4.5c	80.6 c	41.1 bc	8.2b
I 5 kGy	88.2 c	44.9 d	85.6 b	44.5 ab	2.6d	82.1 bc	40.6 bc	5.1c
S Control	93.6 a	51.9 a	86.5 b	43.3 bc	7.2a	83.7 b	41.9 ac	10.0b
S 3kGy	88.4 c	47.7 bc	85.9 a	44.8 ab	2.5d	83.8 b	42.7 ab	6.6c
S 5 kGy	90.3 b	48.8 b	88.7 a	46.2 a	1.6de	86.7 a	43.4 a	3.6d
E Control	86.2 d	45.8 cd	80.5 e	41.0 cd	5.8 b	79.8 b	42.2 ab	6.5c
E 3 kGy	86.2 d	46.1 cd	83.9 c	43.6 b	2.3d	82.9 b	40.3 c	3.3d
E 5 kGy	84.2 d	50.2 cd	82.3 d	42.8 bc	1.9e	83.1 b	40.1c	2.9d

Means within the same column followed by the same letters are not significantly different at 0.05

I= The Iraqi cultivar "Zahidi", S= the Saudi cultivar "Sukkary", E= the Egyptian cultivar "Siwi"

Table 5: Effect of irradiation treatments on sensory quality of the tested semi dry date fruits at the end of storage time at ambient temperature (25±2°)

Treatments	Freshness	Color	Taste	Shrinkage
I Control	2.0 d	2.5 cd	2.8 cd	3.9 a
I 3kGy	1.8 d	2.2 d	2.7 d	3.7 a
I 5 kGy	2.1 d	2.6 c	3.1 c	3.7 a
S Control	2.6 bc	3.4 ab	3.5 b	3.3 b
S 3kGy	3.2 b	3.5 ab	3.9 b	3.0 b
S 5 kGy	3.0 bc	3.3 b	3.6 b	3.0 b
E Control	4.1 a	4.3 a	4.2 ab	2.8 b
E 3 kGy	4.0 a	3.8 a	4.4 a	2.7 b
E 5 kGy	3.6 ab	4.2 a	4.6 a	2.2 c

Means within the same column followed by the same letters are not significantly different at 0.05

I= The Iraqi cultivar Zahidi, S= the Saudi cultivar Sukkary, E= the Egyptian cultivar Siwi

storage (during 10 months). However, minimum level of the end of storage was significantly higher in unirradiated samples compared to the irradiated ones. Results of analysis of variance showed that the storage duration had a significant effect on the moisture content. A significant change with reduction from in moisture content was observed due to prolonged storage for 6 months [30].

**Tannin Analysis:** The astringency found in green date is commonly attributed to tannins. Different groups of tannins can found in fruits, two predominant ones are phenolic acids and condensed tannins [31]. In general, tannins decrease as the fruits matures, resulting in corresponding decrease astringency [32].

As shown in Fig.3 (A, B & C), in the three tested cultivars, tannins degradation were extended with advanced storage durations.

These degradations were commonly induced by irradiation especially at 5 kGy particularly in Siwi and Sukkary cultivars. Aleid *et al.* [22] treated date fruits "Khalas" cultivar with X- ray irradiation at 3, 5 and 7 kGy

and found some physical and chemical properties were significantly different between treatments (fruit hardness, crud protein and tannins). However, El Salhy [33] observed that tannins percentages were slightly affected by irradiation at 0.25, 0.50, 0.75 and 1.0 kGy on Amry (semi dry date fruits) without any significance between them. In general, the tannins present in green dates are primarily of phenolic acids and phenols or flavonoids were more affected by irradiation [25]. The enhancement or inducing percentage of major of these compounds was clear in semi dry date fruits. It is interesting to mention that structure of flavonoids or phenols are related each other especially under producing free radicals in presence of low moisture content of semi dry dates [6, 34, 35].

**Sensory Evaluation:** Sensory analysis is concerned an important technique to determine product quality. Because of genetic differences variable and growth conditions, date show a wide variation in their final appearance and quality. With respect to consumers, important quality criteria of the product and appearances including color, taste, flavor ....etc. [36].

Siwi date fruits were significantly more preferred from the panelists than other treatments for its freshness, color and taste regardless the effect of irradiation doses. Results of panel evaluation showed a significant variation between the six Tunisian date fruit cultivars on color, appearance, mouth texture (soft, sticky and astringent), taste (sweet and bitter), Ismail *et al.* [37]. The reserve was true for irradiated Zahidi date fruits. The possibility of changes (during storage) in quality value caused by irradiation depends on irradiation dose [10].

Considering the evaluation of shrink appearance, Zahidi date fruit with or without irradiation showed the high degree of shrink. Decreasing moisture content and

therefore, slight shrinkage was found to be the main reason for the change in most of these physical properties. The measured physical properties of Stamaran date changed linear with time of storage in room conventional condition [30].

The structure of the exocarp region in Zahidi cultivar characterized with a continuous distribution of stone cells (Fig. 1 A) explain the highly skin separation of fruit at the end of storage period. The outer mesocarp with thin walled cells could easily loss moisture during storage period and this causes cell shrinkage. While the stone cells have very thick walls, they distributed as continuous layers and neighbored to the shrinkage parenchyma of the outer mesocarp. In this case, high tension will produce between the two neighbored layers causing exocarp separation from the flesh part of Zahidi fruits. This result confirms the finding of Puchalski and Brusewitz [38] and Jha *et al.* [39].

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